Bennelongia Environmental Consultants

Mining Area C Southern Flank: Stygofauna Assessment

Prepared for:

BHP Billiton Iron Ore

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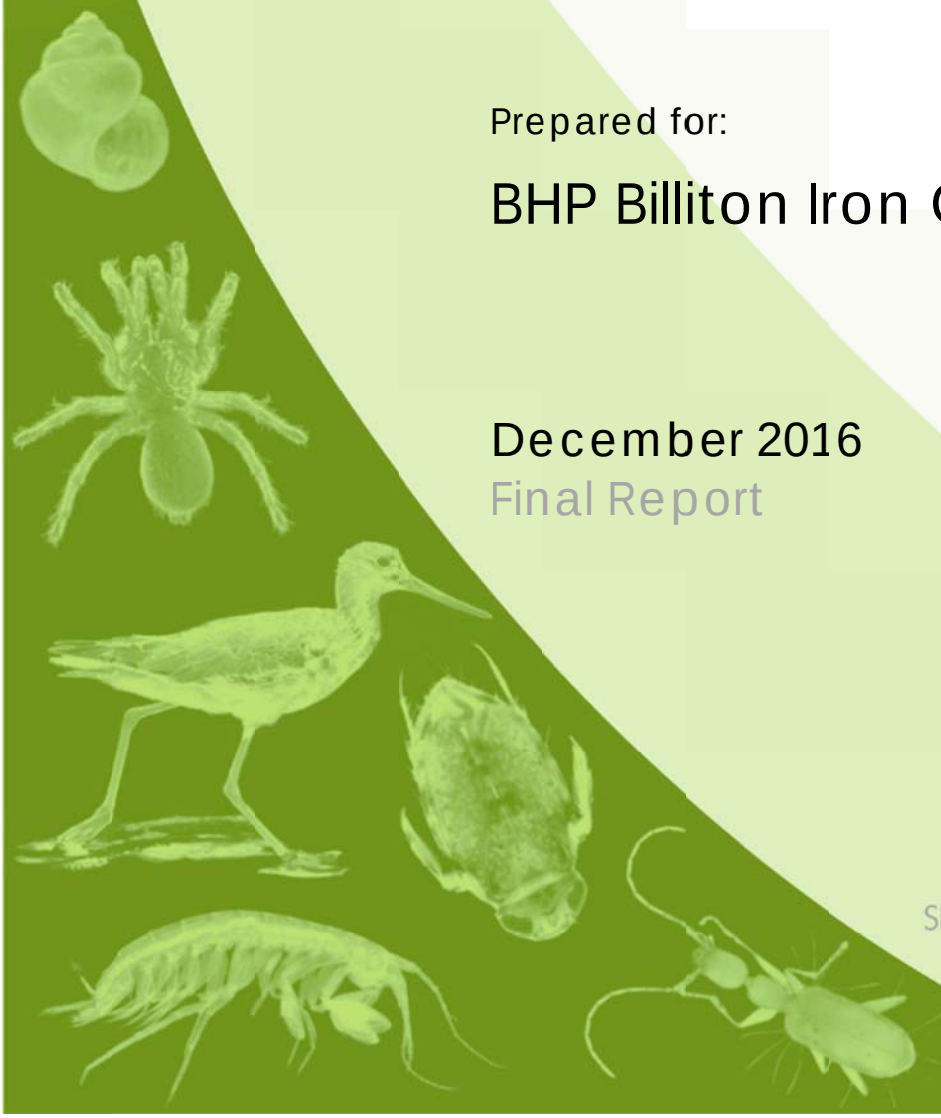
Final Report



Short-Range Endemics | Subterranean Fauna

Waterbirds | Wetlands

Mining Area C Southern Flank: Stygofauna Assessment

Bennelongia Pty Ltd
5 Bishop Street
Jolimont WA 6913

P: (08) 9285 8722
F: (08) 9285 8811
E: info@bennelongia.com.au

ACN: 124 110 167

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EXECUTIVE SUMMARY

BHP Billiton Iron Ore Pty Ltd (BHP Billiton Iron Ore) proposes to develop and operate a new satellite iron ore deposit located immediately south of the existing Mining Area C Mine at Southern Flank which will become part of the Mining Area C Mine (the Proposal). The Proposal is located approximately 90 kilometres (km) north east of Newman in the Pilbara Region of Western Australia. The Proposal will construct and utilise ore processing facilities, including ore handling plant, stockpiles and train load out facilities located at the existing Mining Area C mine. Primary crushing and open pit mining activities will take place in the Southern Flank locality. This approach reflects BHP Billiton Iron Ore's current approach of developing new orebodies which are able to utilise infrastructure around established mining hubs. This approach will also minimise the amount of clearing required for development of the new deposit.

For the purpose of assessment three areas have been described to categorise stygofauna habitat within the groundwater of the Mining Area C Southern Flank Project. These are:

- Groundwater Assessment Area – the proposed additional area of reduction in groundwater levels of ≥2 m associated with implementation of the Proposal and considering cumulative impacts of all mining operations within the catchment;
- Approved Drawdown Area - the area previously approved under Ministerial Statement 491 for groundwater drawdown of ≥2 m, noting that this area has been reduced where it falls outside the Groundwater Assessment Area ;
- Reference Area - areas of no groundwater drawdown within the regional catchments.

This report provides an assessment of the potential impacts of the Proposal on stygofauna within the Groundwater Assessment Area, and considers cumulative impacts for all species within the Groundwater Assessment Area and Approved Drawdown Area.

Stygofauna surveys in the Groundwater Assessment Area, Approved Drawdown Area and Reference Area were conducted in accordance with the recommendations of EPA Environmental Assessment Guideline 12 and Guidance Statement 54A. In total, 1170 stygofauna samples relevant to this assessment have been collected, with 224 samples from the Groundwater Assessment Area, 724 samples from the Approved Drawdown Area and 222 samples from the Reference Area. Sampling effort and survey methods at Mining Area C meet the EPA's expectations for stygofauna survey.

Of the 60 stygofauna species collected during sampling, 27 species were recorded in the Groundwater Assessment Area. Of these 27 species, six (the worm *Ainudrilus* sp. WA26 PSS), mite Halacaridae sp. B1, copepod *Schizopera* sp. B02, syncarids *Bathynella* sp. 1 and *Notobathynella* sp., and amphipod Paramelitidae sp. S04 (BR South)) are currently known only from the Groundwater Assessment Area. However, it is considered likely that the distributions of all six species extend outside the Groundwater Assessment Area and there is little conservation threat to these species from dewatering.

Weeli Wolli Spring PEC and its buffer contains 36.1 km^2 of calcrete, of which 34.4 km^2 is within the Approved Drawdown Area and may potentially experience drawdown of ≥2 m, mostly associated with dewatering activities at Hope Downs. A further 1.6 km^2 is within the Groundwater Assessment Area and is also predicted to experience ≥2 m drawdown as a result of the Proposal and operations at Hope Downs and Mining Area C. It is considered that the conservation values of individual stygofauna species occurring in the Weeli Wolli Spring PEC are unlikely to be threatened because of the existence of abundant stygofauna habitat downstream in the Lower Weeli Wolli and Marillana subcatchments.

As a result, it is considered that the Proposal meets the EPA's objective for stygofauna to maintain representation, diversity, viability and ecological function across the Groundwater Assessment Area at the species level. Given what is known of the distribution of stygofauna in the Pilbara generally, and the pattern of distributions in the vicinity of the Proposal, it is unlikely that the Groundwater Assessment Area contains outlying, genetically or ecologically unique populations of stygofauna

species (geographically separated from the main ranges of the species) that may be threatened by the Proposal. Therefore, the Proposal is also considered to meet the EPA's objectives at the population level.

While it is unlikely any species or unique populations will be threatened by the proposal, the predicted occurrence of groundwater drawdown within the calcrete area inside the Groundwater Assessment Area suggests the EPA's objective to maintain representation, diversity, viability and ecological function at the assemblage level may possibly not be maintained without mitigation measures. However, any impact on the stygofauna assemblage of the Weeli Wolli Spring PEC as a result of drawdown in the Groundwater Assessment Area is likely to be small compared with the effects of drawdown in the Approved Drawdown Area. In both areas, the primary cause of impact is the operation of Hope Downs, which will result in 14 m of (mitigated) drawdown many years in advance of the smaller drawdown caused primarily by the Proposal. This smaller drawdown has a likely maximum extent (80^{th} percentile of model predictions) of 2.5 m. It is considered that a drawdown of this magnitude is unlikely to cause any further alteration in the stygofauna assemblage and ecological character of the PEC.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Overview of Operation

BHP Billiton Iron Ore Pty Ltd (BHP Billiton Iron Ore) proposes to develop and operate a new satellite iron ore deposit located immediately south of the existing Mining Area C Mine at Southern Flank which will become part of the Mining Area C Mine (the Proposal). The Proposal is located approximately 90 kilometres (km) north east of Newman in the Pilbara Region of Western Australia (Figure 1). The Yandi deposit is reaching the end of its economic life, with available ore reserves expected to be depleted by approximately 2020. Additional ore sources are required to provide sufficient feed in order to sustain the current level of iron ore production from the BHP Billiton Iron Ore Pilbara mines. The Proposal will construct and utilise ore processing facilities, including ore handling plant, stockpiles and train load out facilities located at the existing Mining Area C mine. Primary crushing and open pit mining activities will take place in the Southern Flank locality. This approach reflects BHP Billiton Iron Ore's current approach of developing new orebodies which are able to utilise infrastructure around established mining hubs. This approach will also minimise the amount of clearing required for development of the new deposit.

1.2. Approvals History

An environmental impact assessment (EIA) for Mining Area C was conducted in 1997 via the Public Environmental Review (PER) process. The PER presented BHP Billiton Iron Ore's proposal to mine 14 iron ore deposits in the Northern Flank Valley at Mining Area C (i.e. deposits A, B, C, D, E, F, R, P1, P2, P3, P4, P5, P6, and the Brockman Detrital Deposit), referred to as the Current Approved Development Envelope.

The PER was assessed by the Environmental Protection Authority (EPA) and its recommendations were published in Bulletin No. 913 in 1998. A Ministerial Statement of Approval (MS) No. 491 was issued by the Minister for the Environment in December 1998 under Part IV of the *Environmental Protection Act 1986* (EP Act). Only two deposits were specifically assessed in the PER – C Deposit and the Brockman Detrital Deposit. In addition to the specific assessment of these two deposits, MS 491 provided an on-going mechanism for the development of the remaining 12 deposits. This involves the Mining Area C Environmental Management Plan (EMP) being reviewed and updated to the requirements of the EPA as the other deposits came on line. MS 491 also required that each new version of the EMP be made available for public review to the requirements of the EPA. Deposits A, B, C, D, E, F, R, P1, P2, P3, P4, P5, P6 and the Brockman Detrital have been described and assessed in previous versions of the EMP. EMP Revisions 1 through to 6 describe the current extent of mining below the water table (A, C, E, F, R, P1, P2, P3, P5 and P6 deposits) and above the water table (B, D, P4 and Brockman Detrital deposits) at Mining Area C. The Mining Area C EMP Revision 6 assessed the impact of all 14 deposits approved under the original MS 491.

1.3. Current Proposal

BHP Billiton Iron Ore is seeking to add the satellite ore bodies at Southern Flank to Mining Area C (Figure 2), as well as formalising the disturbance that was assessed as part of the approved EMP revision 6 assessment. New processing facilities will be constructed to support incremental increases in mining activity as follows:

- Primary Crushing facilities located south of existing infrastructure;
- Run of Mine pads and topsoil storage areas;;
- Overland conveyors;
- Coarse Ore Stockpile;
- Ore Handling Plant within existing Mining Area C lease area;

- Upgrade to the existing stockyards and outflow facilities;
- Duplication of the existing rail loop and addition of a second Train Loadout;
- Advanced mine de-watering to support mining at Southern Flank;
- Installation of supporting non-processes infrastructure (eg power lines, access roads) to support new mining area: and
- Expansion of existing non-processing infrastructure (NPI) and industrial facilities to support production

For the purpose of assessment, three different areas have been recognised in relation to the potential impacts on stygofauna associated with the Proposal (Figure 2). These are:

- Groundwater Assessment Area – the proposed additional area of reduction in groundwater levels of ≥2 m associated with implementation of the Proposal. The cumulative impacts of all mining operations within the catchment were considered when calculating drawdown;
- Approved Drawdown Area - the area previously approved under Ministerial Statement 491 for groundwater drawdown of ≥2 m, noting that this area has been reduced in some places where it falls outside the Groundwater Assessment Area to reflect current modelling; and
- Reference Area - areas of no groundwater drawdown within the regional catchments.

This report provides an assessment of the potential impacts to stygofauna in the Groundwater Assessment Area as a result of implementation of the Proposal, and considers cumulative impacts to all species occurring within the Groundwater Assessment Area and Approved Drawdown Area.

1.4. Report Objectives

The objectives of this assessment were:

(1) To identify the stygofauna species present in the Groundwater Assessment Area.

(2) To assess the potential impacts on stygofauna within the Groundwater Assessment Area and the cumulative impacts on species within the Approved Drawdown Area from implementation of the Proposal.

The framework in which the assessment was set is that the lowering of groundwater levels through mine dewatering and groundwater abstraction by 2 m or more from the natural state may reduce the occurrence of stygofauna (see Section 2.1.2 for more detail). Hence information about the stygofauna species present within the Groundwater Assessment Area and their likely range outside this area is important for assessment.

1.5. Survey Program

The stygofauna surveys undertaken within the Groundwater Assessment Area were mostly part of a broad-scale subterranean fauna survey known as the Regional Subterranean Fauna Sampling Program (RSFSP) that began in November 2007. To date, the RSFSP has resulted in survey of more than 30 mining and exploration areas across the Pilbara, including Mining Area C and nearby locations in the Weeli Wolli and Coondewanna catchments. More recently in 2015, baseline stygofauna surveys have been conducted to the west and east of Mining Area C and around Southern Flank.

2. BACKGROUND

2.1. Stygofauna

Stygofauna are aquatic animals that live in groundwater. They are predominantly crustaceans, although stygofaunal worms, snails and water mites also exist. In addition, groundwater contains nematodes, bdelloid rotifers and some other groups with taxonomy so poorly resolved that stygal species cannot be reliably distinguished from surface forms. In general, stygofauna are characterised

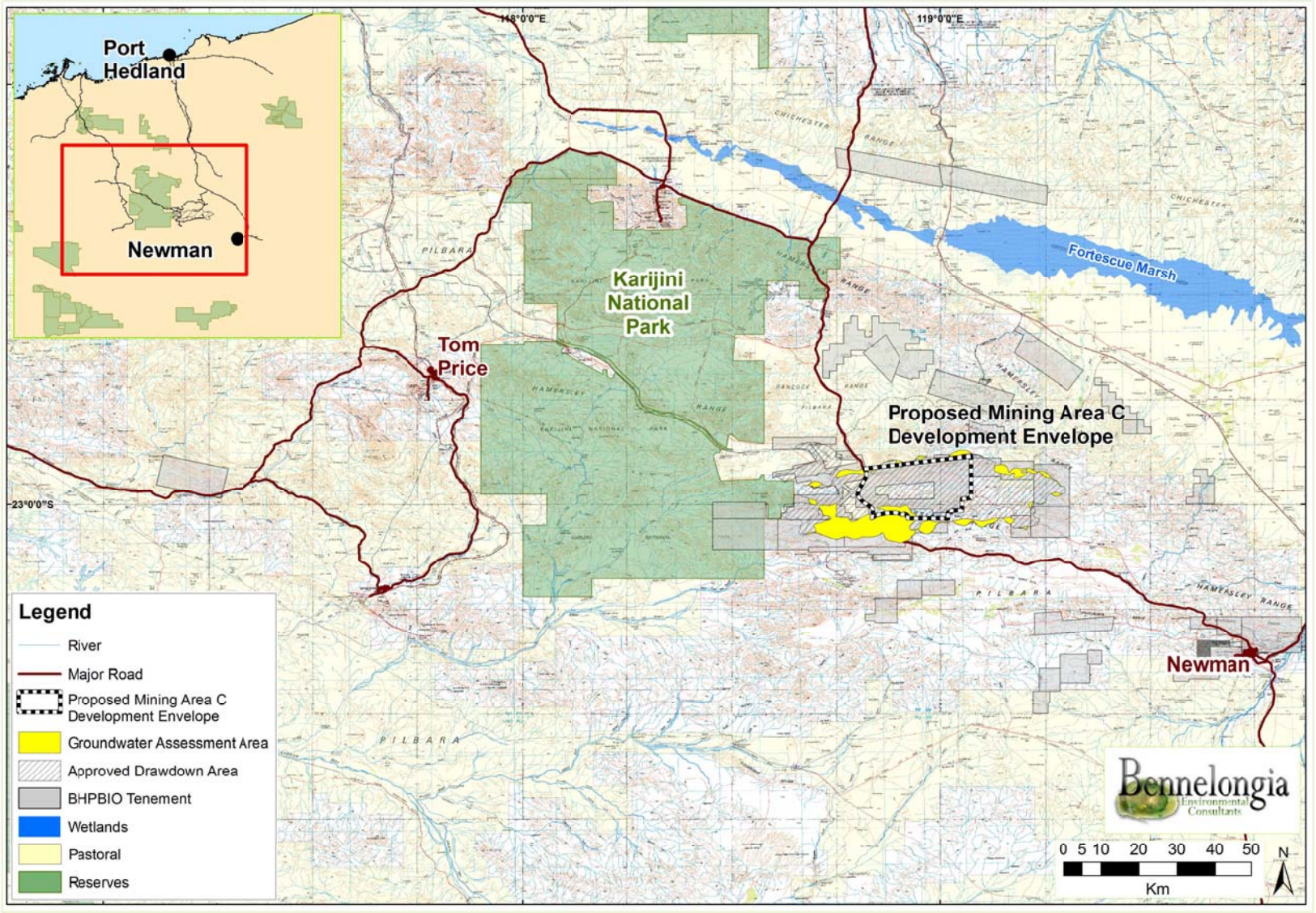

Figure 1. Location of the proposed Mining Area C Development Envelope and Groundwater Assessment Area.

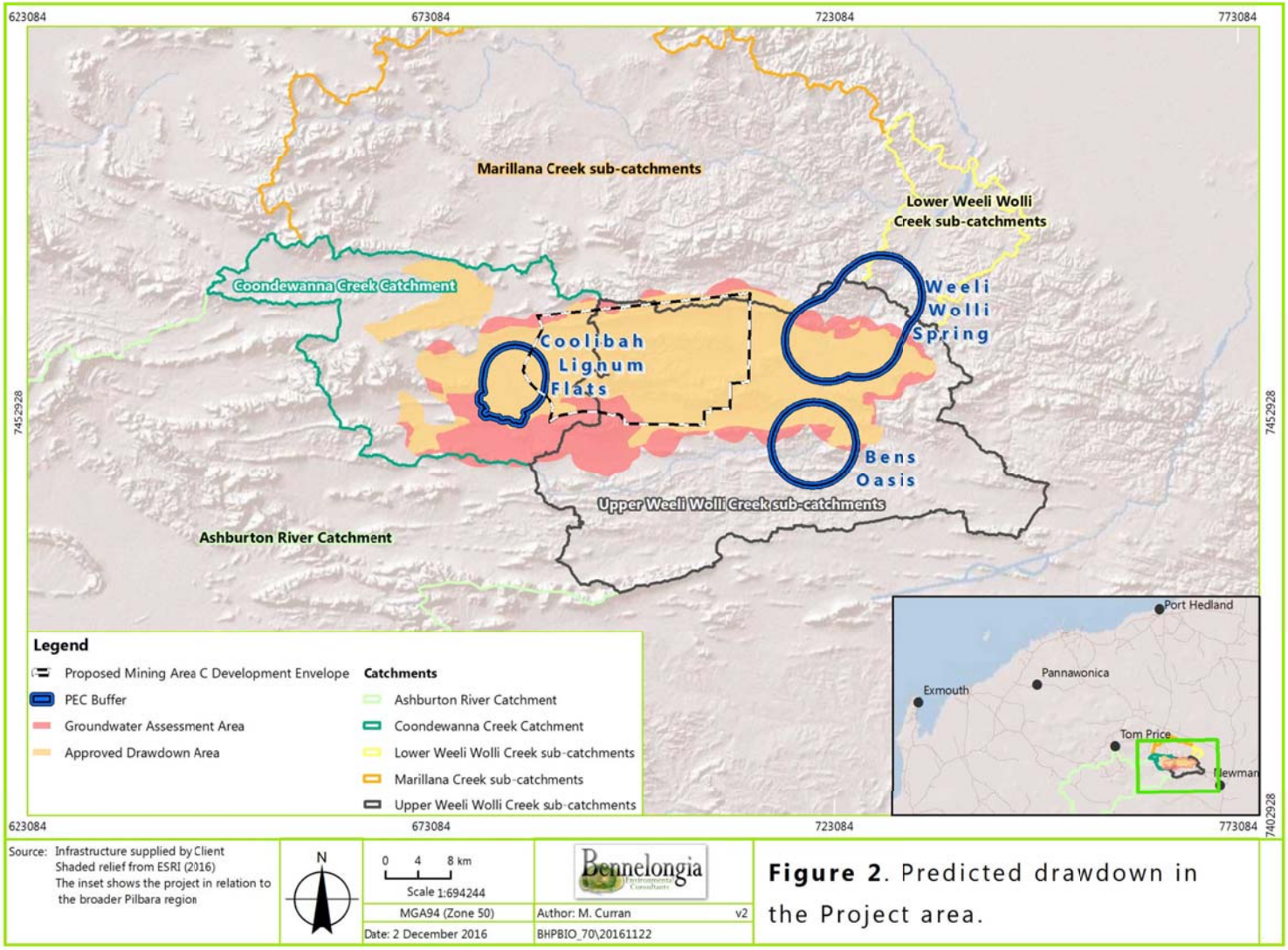

Figure 2. The Groundwater Assessment Area in relation to the proposed Mining Area C Development Envelope, Approved Drawdown Area, Weeli Wolli Spring and Coolibah-Lignum Flats PECs, and catchment areas.

by the loss of eyes and skin pigmentation and the development of a vermiform body shape and more elongated appendages than surface relatives, although some species retain reduced eyes and not all have a vermiform shape. Stygofauna species are a focus of environmental assessment because a high proportion of them have restricted distributions (Gibert and Deharveng 2002). According to Eberhard *et al.* (2009), about 70 % of Pilbara stygofauna species are likely to be short range endemics (SREs) as defined by Harvey (2002), with many of them having much smaller ranges than Harvey's criterion of 10,000 km^2. Species with restricted ranges are vulnerable to extinction following habitat destruction or environmental changes (Ponder and Colgan 2002; Fontaine *et al.* 2007).

Studies to date suggest that the Pilbara region contains the richest stygofauna communities in Australia, with up to 54 species collected from individual bores and approximately 350 species collected from the region by 2005 (Eberhard *et al.* 2009). New species are constantly being discovered (Finston *et al.* 2008; Karanovic and Hancock 2009) and it has been estimated that more than 550 species of stygofauna may occur in the region (Halse *et al.* 2014).

2.1.1. Habitat Requirements

Stygofauna occur in an array of different groundwater habitats including porous, karstic and fractured-rock aquifers, springs and the hyporheos of streams (Eberhard *et al.* 2005). Calcrete and alluvium are typically considered to be productive habitats for stygofauna, although mafic volcanics support rich stygofauna communities compared with the moderate abundance of communities in banded iron formation (Halse *et al.* 2014). Both lateral and vertical connectivity of fissures and voids are important for the occurrence of stygofauna. Lateral connectivity enables animals to move about underground, while vertical connectivity through to the surface enables recharge of carbon and nutrients to the stygofauna community. There is a clear correlation between transmissivity of an aquifer and its suitability for stygofauna.

Stygofauna have mostly been recorded in fresh to brackish groundwater but may occur in salinities (expressed as conductivity) of up to 55,000 µS/cm (Watts and Humphreys 2006; Schulz *et al.* 2013). Apart from salinity, the physicochemical tolerance of stygofauna to different groundwater parameters, especially in the Pilbara, has been poorly defined (see Halse *et al.* 2014).

2.1.2. Principal Impacts of Mining on Stygofauna

Only impacts causing direct habitat loss are likely to threaten the persistence of stygofauna species. Two activities lead to most of the stygofauna habitat loss associated with mining. These are:

(1) *Groundwater drawdown*. Drawdown of aquifers from dewatering of mine pits or the abstraction of groundwater for ore processing is likely to threaten the persistence of any stygofauna species restricted to the area of drawdown.

(2) *Pit excavation*. Removal of stygofauna habitat when excavating mine pits is likely to threaten the persistence of any stygofauna species restricted to the mine pit. This impact can be assessed when considering groundwater drawdown because the mine pits are contained within the area of drawdown.

Identifying the amount of drawdown required to threaten the persistence of a stygofauna species is potentially a complex process. Natural annual variations in baseline groundwater levels in hard rock aquifers are usually <1 m (Worley Parsons 2012), alluvial aquifers may show slightly more variation (Waterhouse and Howe 1994), while annual baseline changes in alluvial aquifers along the Pilbara coast outside of the flow paths of rivers are mostly about 2 m with very occasional larger changes after substantial recharge events (data from Department of Water, Water Information Reporting, http://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx).

The threshold drawdown at which stygofauna species may be threatened because of loss of their preferred habitat is likely to be smaller in shallow or stratified aquifers than in deep uniform ones. However, in most stygofauna assessments in the Pilbara and adjacent areas the threshold has been set more or less independently of the depth of the aquifer and its characteristics. Modelled groundwater drawdowns of between ≥1 to ≥5 m 'over and above natural groundwater fluctuations' have been used for different projects (e.g. Biota 2008, 2010; Bennelongia 2013; MWH 2014). If appropriately applied, such thresholds represent about twice the level of natural fluctuations in Pilbara baseline groundwater levels, so that any drawdown exceeding the threshold is reducing stygofauna habitat in a way that rarely occurs naturally. Most of the area of groundwater impact will, of course, experience much more drawdown than the assessment threshold.

For this assessment a modelled drawdown of ≥2 m compared with pre-drawdown conditions is considered to have the potential to impact on stygofauna because it represents the point where the scale of anthropogenic change exceeds the extent of natural fluctuations in baseline groundwater levels. Pre-drawdown conditions are represented by a single value in the modelling, rather than a consideration of the range of natural groundwater fluctuations.

2.1.3. Other Impacts of Mining on Stygofauna

There has been little research into the impact of reduced habitat quality, rather than direct habitat removal, on stygofauna. Factors potentially reducing habitat quality include water quality changes, changed habitat structure, reduced energy sources, or ingress of pollutants (see Humphreys 2009). In this assessment, it is considered that reduced habitat quality is more likely to result in lowered animal densities than to threaten species persistence. Possible consequences of some factors reducing habitat quality are summarised below:

(1) *Water quality changes*. In most situations, water quality changes occupy relatively small areas (Rösner 1998; Zhu *et al*. 2001), although increases in groundwater salinity may be more extensive (Commander *et al*. 1994; Sharma and Al-Busaidi 2001) and salinity changes may potentially threaten some species in the Pilbara, where stygofauna occur mostly in fresh water (<1,000 mg/L). The tolerance of stygofauna species in the Groundwater Assessment Area to increased salinity is unknown but based on surface studies it is likely that overall stygofauna species richness will decline sharply if groundwater salinity reaches 2,000 mg/L (Pinder *et al*. 2010). Changes of this magnitude have been observed in parts of the Pilbara as a result of mining (Commander *et al*. 1994).

(2) *Percussion from blasting*. Blasting may have a direct effect on stygofauna through percussion and indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and causing transient increases in groundwater turbidity. Subterranean fauna have been collected adjacent to areas where blasting is occurring regularly (Bennelongia 2008), suggesting that impacts are experienced only over short distances and are unlikely to be significant.

(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. The effects of reduced carbon and nutrient input are likely to be expressed over many years and are unlikely to significantly impact on stygofauna as lateral movement of groundwater should bring in carbon and nutrients.

(4) *Aquifer recharge from run-off over disturbed ground*. Quality of recharged water within mine sites is often poor because of rock break-up and soil disturbance (e.g. Gajowiec 1993; McAuley and Kozar 2006). Impacts will be minimised through management of surface water and installing drainage channels, sumps and pump in the pit to prevent recharge though the pit floor. While poor quality of recharge water may reduce population densities, it is unlikely to affect species persistence.

(5) *Contamination of groundwater by hydrocarbons*. Any contamination is likely to be localised and will be minimised by engineering and management practices to ensure the containment of hydrocarbon products.

2.2. Legislative Framework

Environmental Assessment Guideline 12 (EPA 2013), which supersedes the framework provided in Guidance Statement No. 54 (EPA 2003), provides advice on assessment of stygofauna within Western Australia. The recommendations regarding sampling methods in Guidance Statement 54A (EPA 2007) remain in place. The assessment of new activities within the Proposed Mining Area C Development Envelope was conducted according to the general principles laid out in these documents.

Legislative protection of species and communities in Western Australia is provided at two levels. The *Wildlife Conservation Act 1950* (WC Act) operates at the state level, while the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) operates at the national level. No stygofauna communities or species listed under the EPBC Act occur at Mining Area C or nearby areas (Department of Environment 2016). Similarly, no stygofauna species listed under the WC Act occurs at Mining Area C or in the vicinity (Department of Parks and Wildlife [DPaW] 2016). Communities are not listed under the WC Act but a list of threatened communities prepared by the DPaW is endorsed by the Minister for the Environment. No threatened stygofauna community occurs in the vicinity of Mining Area C.

There is a further, informal process whereby priority species and priority ecological communities (PECs) are listed by DPaW. Two PECs occur in the Groundwater Assessment Area (Figure 2). They are Weeli Wolli Spring PEC and Coolibah-Lignum Flats PEC (DEC 2014). The Coolibah-Lignum Flats PEC is listed for its unique flora attributes. It is not recognised for its value to stygofauna and hence is not discussed further in this document.

Weeli Wolli Spring PEC

The Weeli Wolli Spring PEC comprises Weeli Wolli Spring and a permanent water hole colloquially known as Ben's Oasis (Figure 2). Weeli Wolli Spring is considered to support a unique community of animals and plants, including endemic species of stygofauna (van Leeuwen 2009). The richness of stygofauna species in the PEC is attributed to the large-scale calcrete and alluvial aquifer system (van Leeuwen 2009; DPaW 2015). Two species of stygofauna are considered by DPaW to be endemic to Weeli Wolli Spring itself: the water mite *Arrenurus* sp. nov. 1 (PSS) and the oligochaete *Ainudrilus* sp. WA26 (PSS) (van Leeuwen 2009). Despite being included as a part of the Weeli Wolli PEC, very little is known about the value of stygofauna communities that are associated with Ben's Oasis.

2.3. Environmental Impact Assessment

All known locations of stygofauna within the Coondewanna and Weeli Wolli catchments were mapped in relation to the Approved Drawdown Area and the Groundwater Assessment Area. Species recorded within the Groundwater Assessment Area that have not also been recorded within the Reference Area or surrounds were identified as species that may potentially be threatened by groundwater drawdown. Species recorded within the Groundwater Assessment Area and Reference Areas or surrounds were not considered to be at risk from groundwater drawdown and are treated as not being of conservation significance.

Species of stygofauna that have been assessed under EMP Revisions 1 through to 6 are included in species counts but consideration of the implications of drawdown is restricted to those species known only from the Groundwater Assessment Area (or the Groundwater Assessment Area and Approved Drawdown Area) for which the level of impact will change from previous assessments.

Some specimens collected during sampling were too damaged, juvenile or the wrong sex to be identified to species level. In most cases, they probably belong to species that were identified from other specimens. However, in a few cases the specimens must belong to species not collected elsewhere because their genus (or whatever identification level was possible) was not represented by any other specimens, and therefore the specimens could not represent a species already collected. In this case the specimen(s) was included as a separate species with a higher taxonomic level.

Flat worms (Platyhelminthes), round worms (Nematodes) and rotifers are included in species counts but are typically not assessed in EIA in Western Australia because the taxonomic frameworks for these groups are insufficient for reliable identification at the species level. Further, the poorly developed knowledge of life histories of these groups makes it difficult to distinguish between true stygofauna and surface dwelling species.

3. GROUNDWATER ASSESSMENT AREA

The Proposed Mining Area C Development Envelope and associated Groundwater Assessment Area that constitute the Proposal lie primarily within the Upper Weeli Wolli subcatchment, which ultimately drains into Fortescue Marsh. The western part of the Groundwater Assessment Area falls within the Coondewanna catchment, an internally-draining surface water system with a catchment area of approximately 866 km^2

Three primary aquifers exist within the Upper Weeli Wolli subcatchment: 1) the orebody aquifer, developed through mineralisation of banded iron formation; 2) the Wittenoom dolomite which is located within the topographic low areas; and 3) the overlying alluvial tertiary detritals and calcretes. The permeability and storage volumes of the aquifers vary laterally and vertically through each aquifer unit and the hydraulic connection between the systems is considered to be variable and constrained by structural controls, mineralisation and vertical permeabilities. Recharge of the groundwater system primarily occurs in the Coondewanna Flats area with groundwater moving through the Southern Flank and North Flank valleys to ultimately discharge at Weeli Wolli Spring.

Assessing the likely impacts on stygofauna as a result of the dewatering associated with the Proposal is a complex process. The existing mining operations and associated de-watering at Mining Area C and Hope Downs have led to a large area of approved groundwater drawdown in the vicinity of Mining Area C (Figure 2). This approved drawdown is located within the Upper Weeli Wolli subcatchment and Coondewanna catchment. The Hope Downs mining operation is approved to partially dewater the Weeli Wolli Spring PEC and also to discharge water into that PEC (EPA 2001, 2011).

The groundwater drawdown resulting from the additional mining and groundwater abstraction in the Proposed Mining Area C Development Envelope has been modelled. Two categories of groundwater drawdown are recognised; the Approved Groundwater Drawdown Area covers 855.2 km^2 and the Groundwater Assessment Area covers 261.5 km^2 (Figure 2) (see Section 1.3).

A part of the Groundwater Assessment Area lies within the buffer of the Weeli Wolli Spring PEC and covers Weeli Wolli Spring itself, which is considered to be the most ecologically significant stygofauna receptor within the Upper Weeli Wolli subcatchment. The Weeli Wolli Spring PEC and buffer occupy an area of 266.4 km^2 (Weeli Wolli occupies 182.2 km^2 and Ben's Oasis occupies 84.2 km^2). Within these areas, 101.8 km^2 of drawdown has previously been assessed. The Groundwater Assessment Area covers an additional 20.9 km^2 (11.5% of the relevant section of PEC) at Weeli Wolli Springs and 9.0 km^2 (10.7%) at Ben's Oasis. The cumulative impact of mine dewatering will cover 52.4% of the PEC and buffer at Weeli Wolli and 43.2 % of the Ben's Oasis buffer (Figure 3).

4. HYDROGEOLOGY

4.1. Geology of the Weeli Wolli Creek Catchment

The geology of the Weeli Wolli Creek catchment is dominated by the Hamersley Group and Tertiary Detritals valley-fill successions. Mining Area C contains Marra Mamba Iron Formation in the Jirrpalpur Range and Brockman Iron Formation in the Packsaddle Range. Tertiary Detrital successions occur in the Northern Flank and other valleys to depths of up to 200 m. Calcrete also occurs in these valley-fill successions, formed because of fluctuating water table settings during the Tertiary to Recent periods (Johnson and Wright 2001). Southern Flank lies on the southern limb of the Weeli Wolli anticline, with the Marra Mamba Iron Formation being the outcropping stratigraphy. The main structural features are two thrust faults, which dip shallowly to the south and are observed to be continuous across the area of Southern Flank. Folding is strongest proximal to the faults (BHPBIO 2016a)

4.2. Hydrogeology of the Upper Weeli Wolli Subcatchment

The local hydrogeology in the Upper Weeli Wolli subcatchment has been described in RPS (2013) and the information is summarised here. Weeli Wolli Creek and its tributaries flow along valleys confined by hills of Marra Mamba and Brockman Iron Formation. Preferential weathering of the Wittenoom Formation between these outcrops resulted in a low lying area that has since been filled with Tertiary Detritals deposits largely composed of alluvium sourced from the surrounding outcrop and chemically precipitated calcrete. Tertiary sediments are up to 75 m thick upstream of the spring and approximately 20 m thick at the spring.

In the bedrock under Weeli Wolli Spring and the calcrete aquifer immediately upstream of it there is:

- Wittenoom Formation. The Paraburdoo member farthest from the spring has a high permeability whereas the Bee Gorge member, stratigraphically higher than the Paraburdoo member and closer to the spring, is of low permeability. The Wittenoom formation occurs at depths of between 40-70 mbgl and gets shallower closer to the spring as the more weathering resistant Bee Gorge member subcrops.
- Mount Sylvia Formation (low permeability).
- Mount McRae Shale (low permeability).
- Brockman Iron Formation (unmineralised and of low permeability).

The Brockman Iron Formation and Mt McRae Shale are particularly resistant to erosion and form a prominent ridge (Wildflower Range) along the northern extent of the catchment. Weeli Wolli Creek flows through this ridge (across the regional geological strike) in a narrow fault-controlled valley. Under the creek, the erosion-resistant Brockman Iron and Mt McRae Formations rise to shallow subcrop (i.e. they form a rock-bar).

The Tertiary sediments contain an extensive calcrete deposit that has a saturated thickness of around 5 m and is vuggy and permeable. Based on the morphology of Australian groundwater calcrete and because the base of the calcrete sits just below the water table, Weeli Wolli Spring is likely to be an area of active calcrete formation. The calcrete is incised by the creek channel which is in-filled with Quaternary alluvium. The calcrete is underlain by poorly sorted alluvium of clay, sands and gravels that overlies the bedrock.

4.3. Geology of the Coondewanna Catchment

The Coondewanna catchment lies adjacent to the Jirrpalpur Range and is dominated by the Wittenoom Formation stratigraphic units, while Tertiary Detrital valley-fill successions reside in low-lying topographic areas. Areas of calcrete occur across the valley-fill, ranging in thickness from 3 m to 14 m. Dolomite is also present within the catchment, persisting below the Tertiary boundary of the

detrital sequence. Based on drilling data, the dolomite is likely to occur across the entire catchment area. Dolerite dykes occur in the southeast areas of the catchment.

4.4. Hydrogeology of the Coondewanna Catchment

The local hydrogeology in the Coondewanna catchment has been described in URS (2014) and is summarised below.

The Coondewanna surface water catchment operates as an internally draining system. However, it is hydraulically connected to the regional aquifer systems and groundwater is interpreted to flow east into the North and South Flank valleys.

The key hydrogeological units present within the Coondewanna catchment include:

- Tertiary Detritals valley-fill;
- Calcrete/silcrete; and
- Dolomite.

Overall, the structure of aquifers in the Coondewanna catchment is highly variable and not well documented. Weathered, vuggy and karstic formations associated with hydrated zones, dolomite within the Wittenoom Formation and alluvial successions may act as locally significant aquifers. Calcrete/ silcrete horizons show only small cavities and vugs, which may mean the upper detrital zone contains perched aquifers with which calcrete is associated.

The northeast to southwest striking dolerite dykes in the southeast of the catchment may form hydraulic barriers and impede groundwater flow, causing local mounding and shallow water tables upstream of the dykes. The water table is around 18-23 mbgl in most of the catchment. There is a drop of around 30 m in groundwater levels (to 50+ mbgl) across the dykes in the southeast.

5. STYGOFAUNA SURVEYS

5.1. Stygofauna Surveys in the Groundwater Assessment Area

Altogether, 224 stygofauna samples have been collected within the Groundwater Assessment Area. An additional 724 were collected from the Approved Drawdown Area and 222 samples were collected from the Reference Area to provide information on the wider distribution of stygofauna outside the areas of drawdown (Table 1, Figure 3). Some stygofauna were also collected as by-catch during troglofauna sampling.

Details of sampling methods are provided in Appendix 1 with the dates and locations of the surveys provided in Appendix 2. Additional information on species ranges was obtained from other BHP Billiton stygofauna sampling programs, previous surveys by Eberhard and Humphreys (1999), Biota (2004a, 2004b), Pilbara Biodiversity Survey (Halse *et al.* 2014), and surveys of Rio Tinto's Hope Downs (Biota 2006) and Yandicoogina Projects (Biota 2005, 2010).

Table 1. Numbers of stygofauna samples collected in the Groundwater Assessment Area and Reference Area.

Area	Samples
Groundwater Assessment Area	224
Approved Drawdown Area	724
Reference Area	222
Total Samples	1170

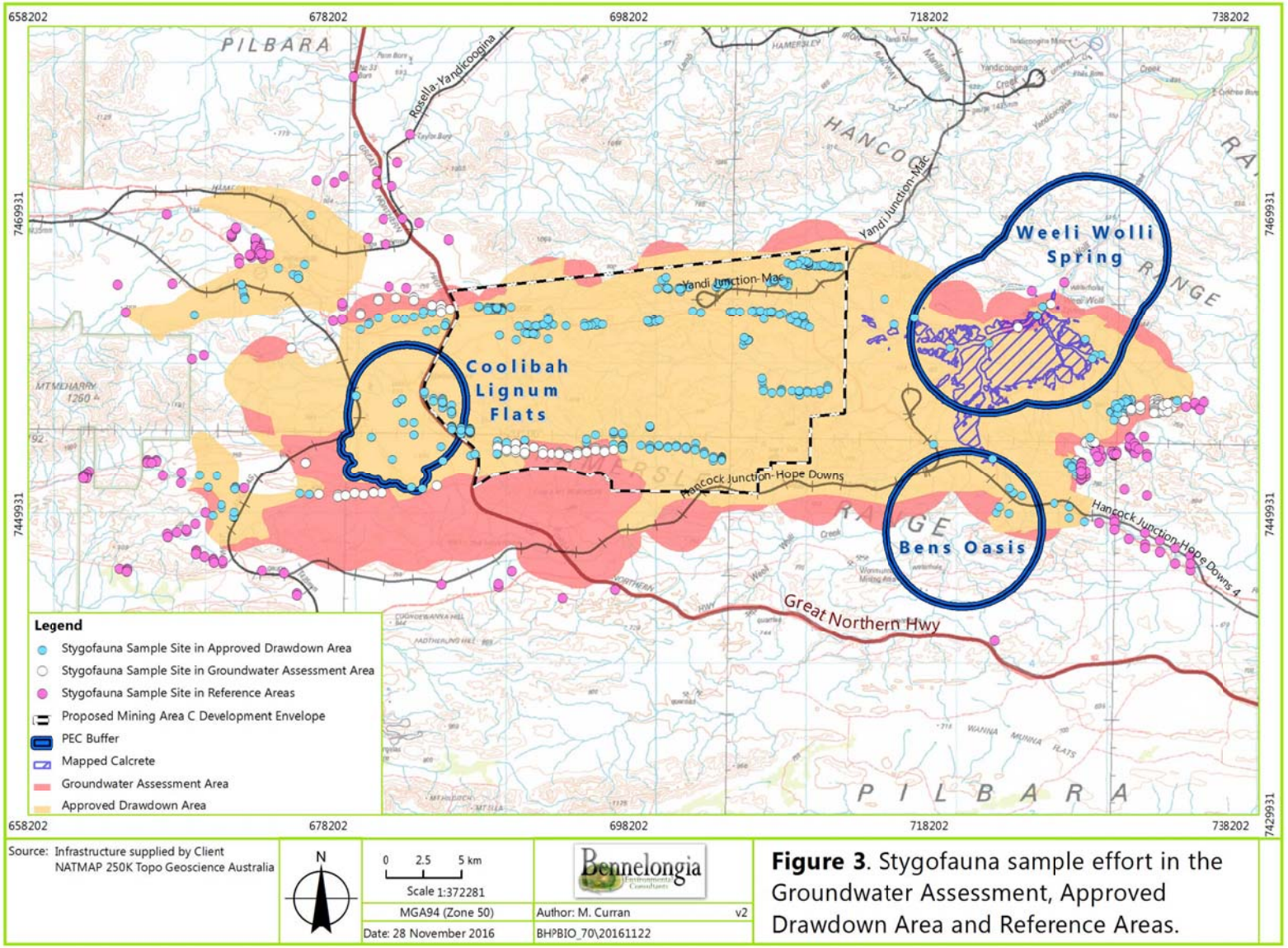

Figure 3. Stygofauna sample effort in the Groundwater Assessment, Approved Drawdown Area and Reference Areas

Table 2. Stygofauna species collected within the Groundwater Assessment Area, Groundwater Drawdown Area and Reference Areas.

Note: Includes specimens collected as by-catch during troglofauna sampling. Higher order level identifications that are not considered to represent additional species are shown in Appendix 3.
Cosmopolitan = distribution across much of the world.

Taxonomy	Lowest ID	Groundwater Assessment Area (GAA)	Approved Drawdown Area (ADA)	Reference Area	Recorded Outside of the GAA and ADA	Occurs in PEC buffer	Other Occurrences, Comments
Platyhelminthes							
Turbellaria	Turbellaria sp.		5		Not assessed in EIAs[1]		Probably widespread[2]
Nematoda							
	Nematoda sp.	45	94	282	Not assessed in EIAs[1]	WW	Probably widespread[2]
Rotifera							
Eurotatoria							
Bdelloidea							
Philodinidae	*Rotaria* sp.		1		Not assessed in EIAs[1]		Probably widespread[2]
	Bdelloidea sp. 2:2		3	500	Not assessed in EIAs[1]		Probably widespread[2]
	Bdelloidea sp. 2:3			101	Not assessed in EIAs[1]		Probably widespread[2]
	Bdelloidea sp. 5:4		1		Not assessed in EIAs[1]		Probably widespread[2]
Monogononta							
Floscullariacea							
Filiniidae	*Filinia* sp.	2	5	6	Not assessed in EIAs[1]		Probably widespread[2]
Annelida							
Aphanoneura							
Aeolosomatidae	*Aeolosoma* sp. 1 (PSS)		1		Yes		Pilbara-wide[2,3]
Clitellata							
Haplotaxida							
Naididae	*Dero nivea*			180	Yes		Cosmopolitan[5]
	Pristina longiseta		5		Yes		Cosmopolitan[5]
Phreodrilidae	Phreodrilidae sp. S06	1			Yes		Elsewhere in Pilbara[4]
	Phreodrilidae with dissimilar ventral chaetae	20	23	76	Yes	WW, BO	Pilbara-wide[2,3]
	Phreodrilidae with similar ventral chaetae		12	14	Yes		Pilbara-wide[2,3]
Tubificidae	*Ainudrilus* sp. WA26 (PSS)	11			No	WW	Known only from these records
Enchytraeida							

Taxonomy	Lowest ID	Groundwater Assessment Area (GAA)	Approved Drawdown Area (ADA)	Reference Area	Recorded Outside of the GAA and ADA	Occurs in PEC buffer	Other Occurrences, Comments
Enchytraeidae	Enchytraeidae sp. S01		19		Yes		Packsaddle Range in approved drawdown, previously assessed
	Enchytraeus sp. 1 (PSS) Pilbara	1	16	172	Yes	WW	Species complex, Pilbara-wide[2,3]
	Enchytraeus sp. 2 (PSS) Pilbara	1	1		Yes	WW	Species complex, Pilbara-wide[2,3]
Arthropoda							
Chelicerata							
Arachnida							
Trombidiformes							
Halacaridae	Halacaridae sp. B01	1	1		Yes	WW	Known only from these records
Unionicolidae	*Recifella* sp. P1 (nr *umala*) (PSW)	1			Yes	WW	Hamersley Range[2]
Crustacea							
Ostracoda							
Popocopida							
Candonidae	*Areacandona* cf. *mulgae*		1		Yes	WW	Near West Angelas[2]
	Meridiescandona facies	35	5	19	Yes	WW	Weeli Wolli catchment[7]
	Meridiescandona lucerna		1		Yes	WW	Weeli Wolli catchment, eastern Fortescue[3,7]
	Meridiescandona marillanae			16	Yes	WW	Lower Weeli Wolli, Marillana catchments[3]
	Notacandona boultoni	43	3	2	Yes	WW	Weeli Wolli catchmenti[3]
	Notacandona modesta	20	5		Yes	WW	Eastern Upper Weeli Wolli catchment[4]
	Origocandona grommike			8	Yes	WW	Camp Hill and perhaps more widely[3]
Cyprididae	*Cypretta seurati*			15	Yes		Cosmopolitan[8,9,10]
Limnocytheridae	*Gomphodella yandii*	76	1	22	Yes	WW	Eastern Weeli Wolli catchmenti[3]
Maxillopoda							
Calanoida							
Ridgewayiidae	*Stygoridgewayia trispinosa*		1	1	Yes		Pilbara, Exmouth peninsula[11]
Cyclopoida							
Cyclopidae	*Diacyclops cockingi*	85	53	11	Yes	WW	Pilbara-wide[2,12]
	Diacyclops humphreysi humphreysi	28	41	1142	Yes	WW	Pilbara-wide[2,13]

Taxonomy	Lowest ID	Groundwater Assessment Area (GAA)	Approved Drawdown Area (ADA)	Reference Area	Recorded Outside of the GAA and ADA	Occurs in PEC buffer	Other Occurrences, Comments
	Diacyclops sobeprolatus		2	72	Yes		Pilbara-wide[2,13]
	Dussartcyclops sp. B10		3		No		Known only from this record, previously assessed
	Mesocyclops brooksi	2		8	Yes	WW	Southern Australia[2,12]
	Metacyclops pilbaricus		1	13	Yes		Pilbara-wide[2,13]
	Metacyclops sp. B01 (nr *pilbaricus*)		1		Yes		Central Pilbara[2,13]
	Microcyclops varicans		1	63	Yes		Cosmopolitan[14]
	Pilbaracyclops sp. B03 (nr *frustratio*)		3		Yes		Central Pilbara[2,13]
	Thermocyclops decipiens		1		Yes		Cosmopolitan[14]
Harpacticoida							
Ameiridae	*Gordanitocrella trajani*	74	23	63	Yes	WW	Eastern Weeli Wolli catchment[3,15]
Canthocamptidae	*Australocamptus* sp.		1	25	Yes		Coondewanna catchment
	nr *Epactophanes* sp. B01		1		No		Known only from this record, previously assessed
Miraciidae	*Schizopera* sp. B02	7	1		No	WW	Known only from these records[4]
Parastenocarididae	*Parastenocaris jane*		1		Yes		Pilbara-wide[2,13]
Malacostraca							
Syncarida							
Bathynellidae	*Bathynella* sp. 1	1			No	WW	Known only from this record
Bathynellidae	*Bathynella* sp. 2		4		No		Known only from this record, previously assessed
Parabathynellidae	*Atopobathynella* sp. B04		15		Yes		Eastern Weeli Wolli catchment[3]
	Notobathynella sp.	2	2		No		Known only from these records[4]
	nr *Billibathynella* sp. B02 (=Parabathynellidae sp. S03)	15	57		Yes		Weeli Wolli and Coondewanna catchments[3]
	nr Notobathynella sp. S01		21		No		Known only from these records[3], previously assessed
Amphipoda							
Paramelitidae	*Chydaekata* sp. B01		4	7	Yes		Coondewanna catchment[3]

Taxonomy	Lowest ID	Groundwater Assessment Area (GAA)	Approved Drawdown Area (ADA)	Reference Area	Recorded Outside of the GAA and ADA	Occurs in PEC buffer	Other Occurrences, Comments
	Chydaekata sp. E	27	7	6	Yes	WW, BO	Lower Weeli Wolli catchment[3]
	Maarrka weeliwollii	3	7	11	Yes	WW	Lower Weeli Wolli and Marillana catchments[3]
	Paramelitidae Genus 2 sp. B02	44	211	9	Yes	WW, BO	Eastern Weeli Wolli catchment[3]
	Paramelitidae Genus 2 sp. B03		5	6	Yes	WW	Lower Weeli Wolli and Marillana catchments[3]
	Paramelitidae sp. B03	175	30	6	Yes		Weeli Wolli catchments[3]
	Paramelitidae sp. B04			1	Yes		Known only from a single drill hole[3]
	Paramelitidae sp. B16			4	Yes		Lower Weeli Wolli and Marillana catchments[4]
	Paramelitidae sp. S04 (BR South)	55	33		Yes		Known only from these records[3]
Isopoda							
Tainisopidae	*Pygolabis weeliwolli*	16	7	20	Yes	WW	Lower Weeli Wolli and Marillana catchments[3,16,17]

[1]EPA (2007); [2]Halse et al. (2014); [3]Regional Subterranean Fauna Sampling Program; [4]Bennelongia unpublished data; [5]Pinder and Brinkhurst 1994; [6]Biota (2010); [7]Karanovic (2007); [8]Reeves *et al.* 2007; [9]Okubo 1973; [10]Martens and Savatenalinton (2011); [11]Tang *et al.* (2008); [12]Karanovic (2006); [15]Karanovic and Hancock (2009); [13]Pesce and De Laurentiis (1996); [14]Sars (1863); [16]Keable and Wilson (2006); [17]Finston et al. (2009).

5.2. Stygofauna Occurrence and Abundance

Within the Groundwater Assessment Area, Approved Drawdown Area and Reference Area, 4,412 specimens of stygofauna have been collected (Table 2). These specimens represent at least 60 species and belong to 10 higher level groups: flatworms (1 species), nematodes (treated as 1 species, but potentially more), rotifers (5 species), segmented worms (10 species), mites (2 species), ostracods (9 species), copepods (16 species), syncarids (6 species), amphipods (9 species) and isopods (1 species) (Table 2). Of the 60 stygofauna species collected, 27 species were recorded in the Groundwater Assessment Area (Table 2).

The numerically dominant groups and species were nematodes (Nematoda sp.), rotifers (Bdelloidea sp. 2:2, Bdelloidea sp. 2:3), worms (*Dero nivea*, Phreodrilidae with dissimilar ventral chaetae, *Enchytraeus* sp. 1 (PSS) Pilbara), ostracods (*Gomphodella yandi*), cyclopoid copepods (*Diacyclops cockingi* and *D. humphreysi humphreysi*), harpacticoid copepods (*Gordonitocrella trajani*) and amphipods (Paramelitidae Genus 2 sp. B02, Paramelitidae sp. B03). Most of these species were represented by more than 100 specimens. Twenty-five species were represented by <10 specimens (Table 2).

Weeli Wolli Spring itself is the richer of the two parts of the Weeli Wolli Spring PEC, with 26 stygofauna species recorded within this part of the Weeli Wolli Spring and buffer. Twenty-four of these were collected in the Groundwater Assessment Area or Approved Drawdown Area. Only three species have been collected within the buffer at Ben's Oasis.

6. IMPACT EVALUATION

6.1. Habitat Connectivity

The considerable extent and habitat connectivity of the alluvial aquifers (and to a lesser extent the calcrete deposits) of the Tertiary Detritals valley-fill successions in the Weeli Wolli Creek and Coondewanna catchments probably provide for easy dispersal of stygofauna species between areas of groundwater drawdown and surrounding aquifers. For example, the amphipods Paramelitidae Genus 2 sp. B2, *Chydaekata* sp. E and *Maarrka weeliwolli* occur both in the Groundwater Assessment Area, Approved Drawdown Area and surrounding catchments (Upper and Lower Weeli Wolli subcatchments, Marillana subcatchment), as does the isopod *Pygolabis weeliwolli*. This suggests there are few, if any, physical barriers to restrict the wider ranges of species occurring in the Groundwater Assessment Area.

Stygofauna are rarely species-rich or abundant in the Pilbara if depth to the watertable is much more than 30 m (Halse *et al.* 2014). Using modelled depth to watertable of 40 m as the threshold for prospective stygofauna habitat, the eastern part of the Groundwater Assessment Area and Approved Drawdown Area around the Weeli Wolli PEC is considered prospective for stygofauna (Figure 4). A large section of the western part of the Groundwater Assessment Area and Approved Drawdown Area also appears to be prospective, while the intervening central part of the Groundwater Assessment Area and Approved Drawdown Area has a relatively deep watertable and is likely to support low abundances of stygofauna and few species (Figure 4).

There is little information about the likely effect of a deeper watertable on habitat connectivity, although it might be expected to reduce connectivity as a consequence of reducing animal abundance and species richness. Although several species of stygofaunal isopod and amphipod are quite widespread in the Weeli Wolli Creek catchment, only the amphipod Paramelitidae Genus 2 sp. B02 occurs in both the eastern and western parts of the Groundwater Assessment Area and Approved Drawdown Area (see Bennelongia 2015).

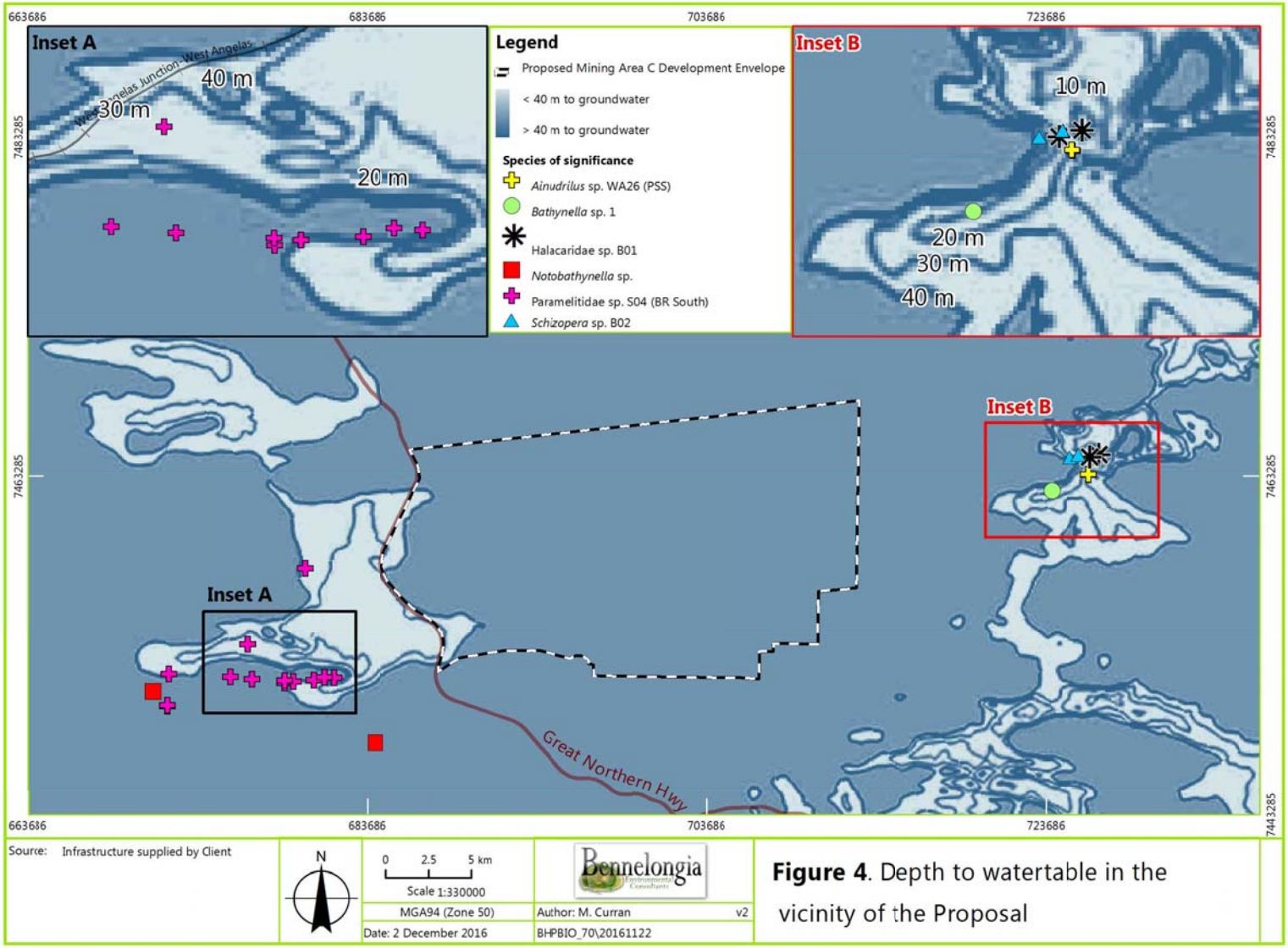

Figure 4. Depth to watertable in the vicinity of the Proposal.
Groundwater contours (m) shown in insets; locations of species of potential conservation significance also shown.

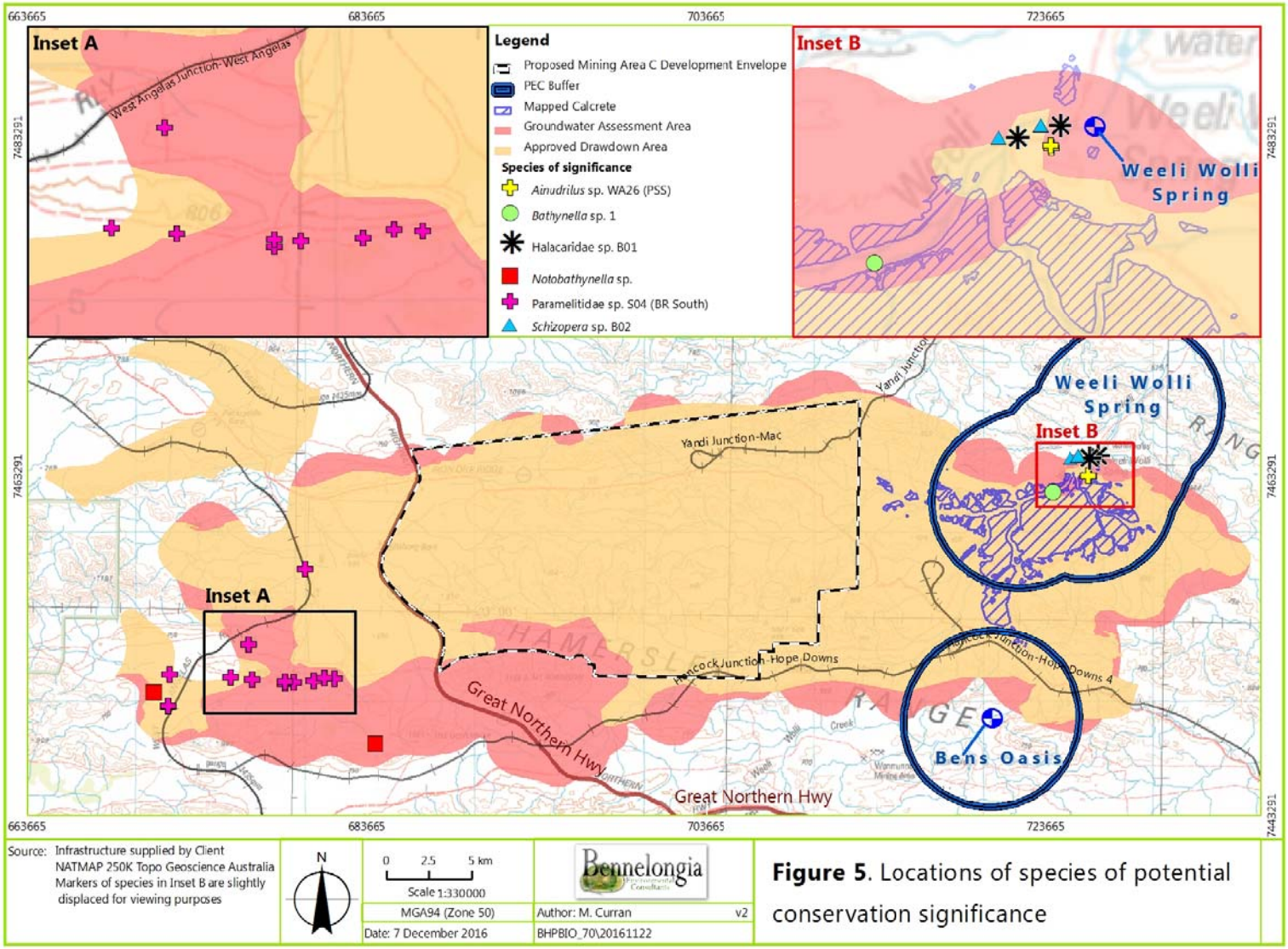

Figure 5. Locations of species of potential conservation significance.
(Conservation significant species are known only from Groundwater Assessment Area, or Groundwater Assessment Area and Approved Drawdown Area).

6.2. Future Conservation Status

Six species (the worm *Ainudrilus* sp. WA26 (PSS), mite Halacaridae sp. B01, copepod *Schizopera* sp. B02, syncarids *Bathynella* sp. 1 and *Notobathynella* sp. and amphipod Paramelitidae sp. S04 (BR South)) are known only from the Groundwater Assessment Area or this area and the Approved Drawdown Area (Figure 5). The locations of these species are provided in Appendix 4 and more information on their distribution is provided below.

6.2.1. Impacts to species

Ainudrilus sp. WA26 (PSS)

The oligochaete *Ainudrilus* sp. WA26 (PSS) was collected from bore GWB0032S at Weeli Wolli Spring in May 2010 and from bore GWB0032D (part of the same nested piezometer) by DPaW in April 2003. It is one of the species recognized by van Leeuwen (2009) to be endemic to the Weeli Wolli Spring. Although not well sampled, nearly all surface species of *Ainudrilus* in Australia are known from single localities or relatively small areas (Pinder and Brinkhurst 2000; Pinder and Halse 2001), suggesting *Ainudrilus* sp. WA26 (PSS) is also likely to have a small range. However, this species is located only 500 m from the Groundwater Assessment Area boundary and is considered likely to occur downstream of the Weeli Wolli Spring and the Groundwater Assessment Area because there are no apparent hydrological barriers to downstream movement. The potential conservation threat to *Bathynella* sp. is considered to be low

Halacaridae sp. B01

The water mite Halacaridae sp. B01 was collected from two bores 500 m apart at Weeli Wolli Spring. One record is in the Approved Drawdown Area and the other is in the Groundwater Assessment Area. Most mites of this family are marine, although freshwater species do occur in north-western Australia and Halse *et al.* (2014) recorded at least two species of stygofaunal halacarids in the Pilbara. One of these was represented by multiple records with a range of nearly 400 km and one was known from a single record at Paraburdoo. Thus, the likely range of Halacaridae sp. B01 is uncertain but it may be wide-ranging. A northwards extension of the range of Halacaridae sp. B01 by 500 m would mean it is known from outside the Groundwater Assessment Area and Approved Drawdown Area. Given that habitat connectivity along Weeli Wolli Creek is likely to be high for all stygofaunal species, Halacaridae sp. B01 is considered likely to occur outside the areas of drawdown. Consequently, although there is some uncertainty about the species' biology the potential conservation threat to Halacaridae sp. B01 is considered to be low.

Schizopera sp. B02

The genus *Schizopera* is very diverse in the Yilgarn and Pilbara and many species have been described from these regions (e.g. Karanovic and Cooper 2012; Karanovic and McRae 2013). Species diversity in calcretes can be very high although only a single species has been recorded in the vicinity of the Proposal. *Schizopera* sp. B02 is known from the western side of Weeli Wolli Spring and has been recorded in five samples, with four samples from nested piezometer bores GWB0032S and GWB0032D and one sample from bore GWB0017D. The two sampling locations are within 500 m of each other. While the known range of *Schizopera* sp. B02 is small, a northwards extension of this range by 500 m would mean the species is known from outside the Groundwater Assessment Area and Approved Drawdown Area. Given that habitat connectivity along Weeli Wolli Creek is likely to be high for all stygofaunal species, *Schizopera* sp. B02 is considered likely to occur outside the areas of drawdown. Therefore, the potential conservation threat to *Schizopera* sp. B02 is considered to be low.

Bathynella sp. 1

Syncarids are a common element of stygal communities worldwide and are frequently collected during stygofauna surveys in Australia. Some Western Australian species of the family Parabathynellidae have been studied both genetically (Abrams *et al.* 2012; Guzik *et al.* 2008) and

taxonomically (e.g. Cho and Humphreys 2010; Cho *et al*. 2005). Some species of the family Bathynellidae in the Pilbara (to which the genus *Bathynella* belongs) are currently the subject of a PhD study by Guilia Perina (see Perina *et al*. 2016). The available data indicate there is high diversity of *Bathynella* species and that ranges are typically short. *Bathynella* sp. 1 was collected in the Groundwater Assessment Area near Weeli Wolli Spring and is treated as separate species from *Bathynella* sp. B2 in the Approved Drawdown Area because they are 27 km apart, although they are both genus level identifications. If the range of *Bathynella* sp. B1 extends >2 km northwards it would occur outside the Groundwater Assessment Area. It is considered likely that the species occurs farther north because of the occurrence of extensive suitable habitat along Weeli Wolli Creek. Therefore, the potential conservation threat to *Bathynella* sp. 1 is considered to be low.

Notobathynella sp.

Four individuals of *Notobathynella* sp. have been recorded, two from a single bore in the Approved Drawdown Area and an additional two from a second bore 13.4 km away in the Groundwater Assessment Area. Both bores are in areas that are not prospective for stygofauna because the watertable is deep (Figure 4) and a depauperate stygofauna community would be expected. As with *Bathynella* species, *Notobathynella* sp. is likely to have a small range (see Abrams *et al*. 2013) and it is unclear whether the specimens in the two locations are the same or separate species. However, both bores are within 1.5 km of the edge of the Groundwater Assessment Area or Approved Drawdown Area and there appears to be no hydrological barrier preventing the species' range(s) from extending eastwards or southwards into areas of no impact (Figure 5). Therefore, the conservation threat to *Notobathynella* sp. is considered to be low, irrespective of whether the specimens belong to one or two species.

Paramelitidae sp. S04 (BR South)

Eighty-eight individuals of Paramelitidae sp. S04 (BR South) have been recorded in 21 samples from 13 drill holes with a linear range of approximately 11 km. While there is no hydrological barrier, such as a dyke, to prevent a broad western extension of the range of Paramelitidae sp. S04 (BR South), the depth to groundwater increases in the west (Figure 4) and the effect of greater depth on the suitability of habitat for Paramelitidae sp. S04 (BR South) is unknown. However, at the local scale Paramelitidae sp. S04 (BR South) is certain to occur outside the Groundwater Assessment Area on the western side of bore EXR0733. This bore is located only 5 m within the Groundwater Assessment Area. While there are no figures on the home ranges of stygofauna species within an aquifer, larger, active stygofauna species such as amphipods are likely to have ranges extending over distances of at least several metres. On this basis, the animal collected from bore EXR0733 may itself have been partially occupying the habitat outside the Groundwater Assessment Area.

The habitat to the west of bore EXR0733 is hydrogeologically the same as that around the bore and was shown to provide habitat for Paramelitidae sp. S04 (BR South) by the collection of another individual of Paramelitidae sp. S04 (BR South) at bore AN0119R, which is approximately 4 km west of EXR0733 and once again inside the Groundwater Assessment Area by 280 m (Figure 5). This indicates it is highly likely that the 4 km of habitat between the two bores (and outside the Groundwater Assessment Area) forms part of the range of Paramelitidae sp. S04 (BR South).

Given the very strong evidence that the distribution of Paramelitidae sp. S04 (BR South) extends outside the Groundwater Assessment Area, the conservation threat to this species from groundwater drawdown associated with the Proposal is considered to be very low.

6.2.2. Impacts on the Weeli Wolli Spring PEC

Modelling suggests that the extent of groundwater drawdown associated with the Proposal itself will not exceed 1 m at Weeli Wolli Spring (BHPBIO 2016b). In 2054, following the end of aquifer replenish-

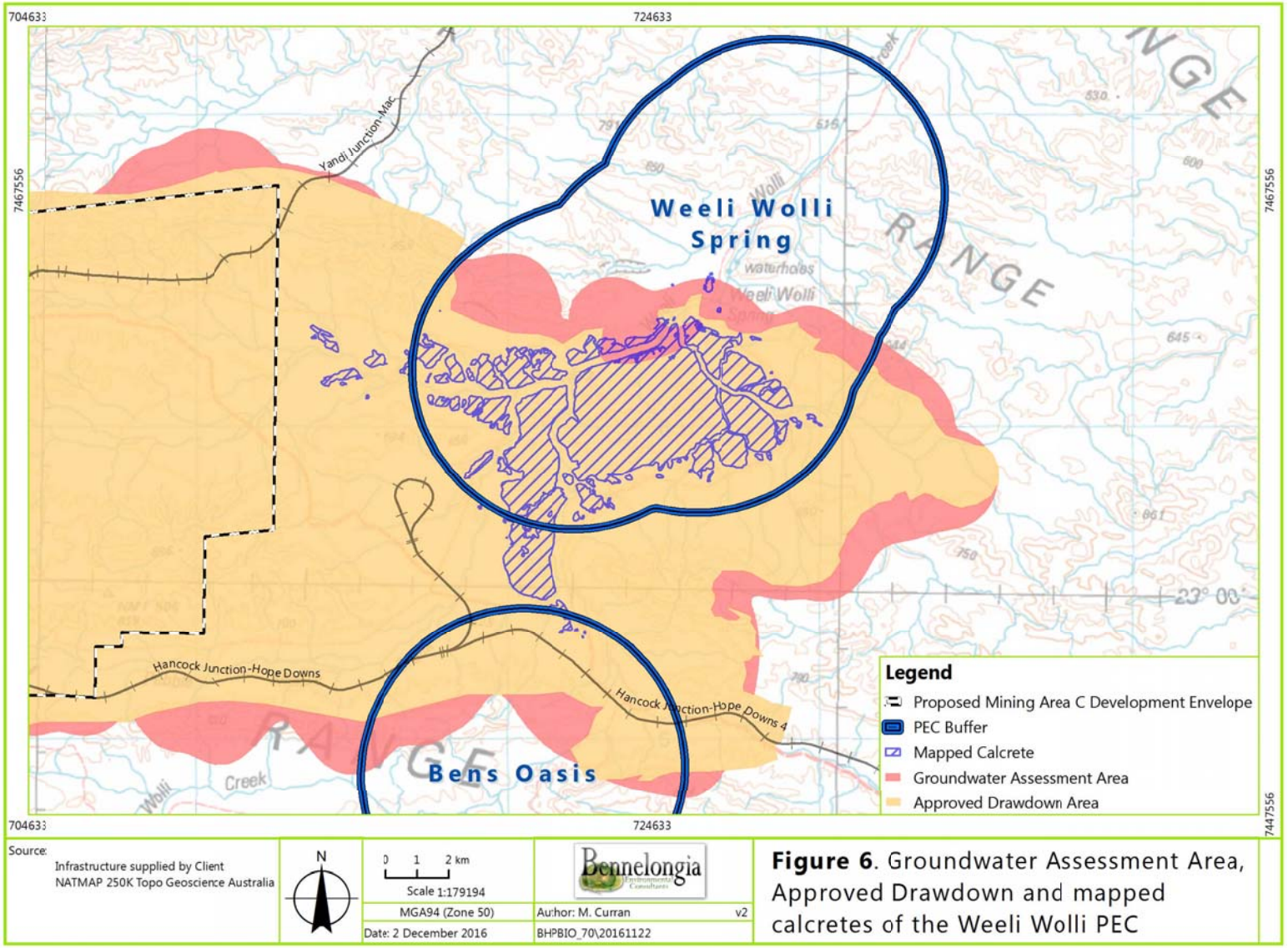

Figure 6. Groundwater Assessment Area, Approved Drawdown and mapped calcretes of the Weeli Wolli PEC.

ment and mitigation actions at Hope Downs, the dewatering at Southern Flank is predicted to result in between 0.2 and 0.5 m of groundwater drawdown at the spring (BHPBIO 2016b).

Cumulative groundwater drawdown from all dewatering activities shows a more significant change, whereby water levels in the Weeli Wolli Spring area will be lowered by an amount between 3 to 14 m. Modelling suggests this is primarily associated with abstraction from Hope Downs (BHPBIO 2016b). The timing and success of Hope Downs closure plans in regard to the recovery of groundwater levels will also influence the potential for a continued impact at Weeli Wolli Spring.

Modelling suggests that following closure of Hope Downs the combined cumulative groundwater drawdown in 2054 is likely to be within a range of 1 – 2. 5 m in the spring area, with the predicted median drawdown being 1.75 m. This is similar to the previously assessed change of 1.6 m in the spring area (BHPBIO 2016b).

Habitat connectivity along Weeli Wolli Creek is likely to be high for all stygofaunal species (Bennelongia, 2015), so that most of the species found in the PEC also occur in both the Lower Weeli Wolli and Marillana subcatchments (e.g. *Meridiescandona marillanae*). Thus, while modelling suggests that the cumulative impact of the Proposal and other groundwater operations within the catchment will result in some groundwater drawdown across the small area of calcrete previously unaffected by drawdown (Figure 6), this drawdown is considered unlikely to have a significant effect on the conservation values of the PEC. It is considered unlikely that PEC species will be threatened as a result of drawdown for the reasons outlined in Section 6.2.1. Any changes to the ecological character of the PEC are likely to be the result of the larger drawdown associated with the operations of Hope Downs, although the replenishment and mitigation measures being undertaken in conjunction with the Hope Downs operations should minimise such changes.

No groundwater drawdown is anticipated at the Ben's Oasis component of the Weeli Wolli Spring PEC as a result of dewatering from the Proposal or cumulative drawdown within the Upper Weeli Wolli subcatchment.

7. CONCLUSION

Stygofauna surveys in the Groundwater Assessment Area, Approved Drawdown Area and Reference Area were conducted in accordance with the recommendations of EPA Environmental Assessment Guideline 12 and Guidance Statement 54A. In total, 1170 stygofauna samples relevant to this assessment have been collected, with 224 samples from the Groundwater Assessment Area, 724 samples from the Approved Drawdown Area and 222 samples from the Reference Area. Sampling effort and survey methods at Mining Area C meet the EPA's expectations for stygofauna survey.

Of the 60 stygofauna species collected during sampling, 27 species were recorded in the Groundwater Assessment Area. Of these 27 species, six (the worm *Ainudrilus* sp. WA26 PSS), mite Halacaridae sp. B1, copepod *Schizopera* sp. B02, syncarids *Bathynella* sp. 1 and *Notobathynella* sp., and amphipod Paramelitidae sp. S04 (BR South) are currently known only from the Groundwater Assessment Area. However, it is likely that the distributions of all six species extend outside the Groundwater Assessment Area and there is little conservation threat to these species from dewatering.

Weeli Wolli Spring PEC and its buffer contains 36.1 km^2 of calcrete, of which 34.4 km^2 is within the Approved Drawdown Area and may potentially experience drawdown of ≥2 m, mostly associated with dewatering activities at Hope Downs. A further 1.6 km^2 is within the Groundwater Assessment Area and is also predicted to experience ≥2 m drawdown as a result of the Proposal and operations at Hope Downs. The conservation values of individual stygofauna species occurring within the

Groundwater Assessment Area are unlikely to be threatened because of the existence of abundant stygofauna habitat downstream in the Lower Weeli Wolli and Marillana subcatchments.

As a result, it is considered that the Proposal meets the EPA's objective for stygofauna to maintain representation, diversity, viability and ecological function at the species level. Given what is known of the distribution of stygofauna in the Pilbara generally, and the pattern of distributions in the vicinity of the Proposal, it is unlikely that the Groundwater Assessment Area contains outlying, genetically or ecologically unique populations of stygofauna species (geographically separated from the main ranges of the species) that may be threatened by the Proposal. Therefore, the Proposal is also considered to meet the EPA's objectives at the population level.

While it is unlikely any species or unique populations will be threatened by the proposal, the predicted occurrence of groundwater drawdown within the calcrete area inside the Groundwater Assessment Area suggests the EPA's objective to maintain representation, diversity, viability and ecological function at the assemblage level may possibly not be maintained without mitigation measures. However, any impact on the stygofauna assemblage of the Weeli Wolli Spring PEC as a result of drawdown in the Groundwater Assessment Area is likely to be small compared with the effects of drawdown in the Approved Drawdown Area. In both areas, the primary cause of impact is the operation of Hope Downs, which will result in 14 m of (mitigated) drawdown many years in advance of the smaller drawdown caused primarily by the Proposal. This smaller drawdown has a likely maximum extent (80^{th} percentile of model predictions) of 2.5 m. It is considered that a drawdown of this magnitude is unlikely to cause any further alteration in the stygofauna assemblage and ecological character of the PEC.

8. LITERATURE

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APPENDICES

Appendix 1 - Field and Laboratory Methods

Sampling Technique

Stygofauna sampling followed the methods recommended by EPA (2007). At each drill hole, six net hauls were made using a weighted plankton net (three hauls with a 50 µm mesh net and three with a 150 µm mesh net). During each net haul, the net was lowered gently to the bottom of the drill hole, agitated briefly to stir benthic and epibenthic stygofauna into the water column, then retrieved slowly. 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 when moving from one drill hole to the next to prevent contamination between sites.

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. Stygofauna 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.

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Appendix 2 - Summary of Timing of all Stygofauna Surveys at Mining Area C and Southern Flank

Table 1. Sampling dates of baseline surveys undertaken at Mining Area C and Southern Flank

Study Area	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
A Deposit	07 - 09 December 2008	05 September 2011	06 March 2015			
B Deposit	05-07 May 2008	05 March 2010	24 May 2010			
D Deposit	05-07 May 2008					
F Deposit	06 December 2007	05-07 May 2008				
R Deposit	10 April 2008	25 May 2010				
P1 Deposit	29 May 2008					
P3 Deposit	13 April 2008	25-26 June 2010				
P6 Deposit	21 April 2008					
Southern Flank	21 April 2008	16 Feb – 28 March 2010	04 May – 26 June 2010	07 March – 11 July 2012	17 Feb – 29 April 2016	24-25 August 2016

Appendix 3 - Stygofauna identified only to higher levels (immature or damaged specimens).

Note: Includes specimens collected as by-catch during troglofauna sampling (see Appendix 1 for details).

Taxonomy	Lowest ID	Groundwater Assessment Area	Approved Drawdown Area	Reference Area	Occurs in PEC	Likely Species
Annelida						
Clitellata	Oligochaeta sp.	7	38	13		Any of the Haplotaxida or Enchytraeida species
Haplotaxida						
Phreodrilidae	Phreodrilidae sp.	8	19	145		Phreodrilidae sp. S06
Tubificidae	*Ainudrilus* sp.	27	1	0	WW	*Ainudrilus* sp. WA26 (PSS)
Enchytraeida						
Enchytraeidae	Enchytraeidae sp.	7	106	479		Enchytraeidae sp. S01, Enchytraeus sp. 1 (PSS) Pilbara or *Enchytraeus* sp. 2 (PSS) Pilbara
Rotifera						
Eurotatoria						
Bdelloidea	Bdelloidea sp.	1		20	WW	Bdelloidea sp. 2:2 of Bdelloidea sp. 2:3
	Rotifera sp.			1		*Filinia* sp.
Arthropoda						
Crustacea						
Ostracoda	Ostracoda sp. unident.			204		Any of the ostracod species

Taxonomy	Lowest ID	Groundwater Assessment Area	Approved Drawdown Area	Reference Area	Occurs in PEC	Likely Species
Popocopida						
Candonidae	Candonidae sp.			11	WW	*Areacandona* cf. *mulgae, Deminutiocandona murrayi, Meridiescandona facies, Meridiescandona lucerna* (PSS), *Meridiescandona marillanae, Notacandona boultoni, Notacandona modesta, Notacandona quasiboultoni,* or *Origocandona grommike*
	Meridiescandona sp.	1		2	WW	*Meridiescandona facies, Meridiescandona lucerna* (PSS) or *Meridiescandona marillanae*
	Notacandona ?boultoni			2		*Notacandona boultoni*
	Notacandona sp.			2		*Notacandona boultoni, Notacandona modesta,* or*Notacandona quasiboultoni*
Cypridídae	*Cypretta* sp.		16	1		*Cypretta seurati*
Maxillopoda						
	Copepoda sp.	1	4	51	WW	Any of the Calanoida, Cyclopoida or Harpacticioda species
Calanoida						
Ridgewayiidae	*Stygoridgewayia* sp.			1		*Stygoridgewayia trispinosa*
Cyclopoida						
Cyclopidae	*Diacyclops* sp.	1	1	18	WW	*Diacyclops cockingi, Diacyclops humphreysi humphreysi* or *Diacyclops sobeprolatus*
	Mesocyclops sp.			6		*Mesocyclops brooksi*
	Metacyclops sp.		3	0		*Metacyclops pilbaricus* or *Metacyclops* sp. B01 (nr *pilbaricus*)
	Thermocyclops sp.		1	8		*Thermocyclops decipiens*
Harpacticoida						
Parastenocarididae	Parastenocarididae sp.		1	0		*Parastenocaris jane*
	Parastenocaris sp.		1	116		*Parastenocaris jane*
Malacostraca						
Syncarida						
Parabathynellidae	*Atopobathynella* sp.	1		1		*Atopobathynella* sp. B04
	nr *Billibathynella* sp.			1		nr *Billibathynella* sp. B01 or nr *Billibathynella* sp. B02
Amphipoda	Amphipoda sp.		8	27		Any of the Amphipoda species
Paramelitidae	*Chydaekata* sp.		1	135		*Chydaekata* sp. B01
	Maarrka sp.		1	1		*Maarrka weeliwollii*
	Paramelitidae sp.	38	22	272	WW, BO	Paramelitidae Genus 2 sp. B02, Paramelitidae Genus 2 sp. B03, Paramelitidae sp. B03, Paramelitidae sp. B04 or Paramelitidae sp. S04 (BR South)
Isopoda						

Taxonomy	Lowest ID	Groundwater Assessment Area	Approved Drawdown Area	Reference Area	Occurs in PEC	Likely Species
Tainisopidae	*Pygolabis* sp.		2	44		*Pygolabis weeliwolli*

Appendix 4 – Locations of restricted species and species of note

Species	General Location	Bore	LatDec	LonDec	SampleDate	Number of individuals
Ainudrilus sp. WA26 (PSS)	Upper Weeli Wolli	GWB0032S	-22.9173	119.2056	5/27/2010	11
	Upper Weeli Wolli	GWB0032D	-22.9175	119.2057	11/4/2010	29
Halacaridae sp. B01	Upper Weeli Wolli	GWB0017S	-22.9187	119.2006	22/03/2015	1
	Upper Weeli Wolli	GWB0032S	-22.9173	119.2056	22/03/2015	1
Bathynella sp. 1	Upper Weeli Wolli	GWB0016S	-22.9317	119.1848	5/27/2010	1
Bathynella sp. 2	Southern Flank	SF3016R	-23.0102	118.9330	2/17/2016	4
Notobathynella sp.	Governor Range	EXR1136	-23.0706	118.7977	3/25/2009	2
	Alligator Jaws	EXR0933	-23.0448	118.6698	2/14/2009	2
Schizopera sp. B02	Upper Weeli Wolli	GWB0032S	-22.9173	119.2056	5/10/2011	1
	Upper Weeli Wolli	GWB0017D	-22.9187	119.2007	8/18/2011	1
	Upper Weeli Wolli	GWB0032S	-22.9173	119.2056	11/02/2011	1
	Upper Weeli Wolli	GWB0032S	-22.9173	119.2056	3/22/2015	4
	Upper Weeli Wolli	GWB0032D	-22.9174	119.2057	3/22/2015	1
Paramelitidae sp. S04 (BR South)	Boundary Ridge South	EXR0739	-23.0394	118.7453	3/13/2008	13
	Boundary Ridge South	EXR0739	-23.0394	118.7453	6/19/2008	11
	Boundary Ridge South	EXR0733	-23.0366	118.7144	3/14/2008	1
	Boundary Ridge South	EXR0742	-23.0362	118.7681	3/13/2008	1
	Boundary Ridge South	EXR0742	-23.0362	118.7681	11/28/2008	1
	Boundary Ridge South	EXR0748	-23.0385	118.7503	6/19/2008	1
	Boundary Ridge South	EXR0748	-23.0385	118.7503	10/04/2008	1
	Boundary Ridge South	EXR0718	-23.0364	118.7734	10/04/2008	3
	Boundary Ridge South	EXR0722	-23.0378	118.7619	10/04/2008	1
	Boundary Ridge South	EXR0722	-23.0378	118.7619	11/28/2008	3
	Boundary Ridge South	EXR0722	-23.0378	118.7619	11/28/2008	3
	Boundary Ridge South	EXR0738	-23.0382	118.7452	3/15/2008	5
	Boundary Ridge South	EXR0729	-23.0375	118.7266	10/06/2008	2
	Boundary Ridge South	EXR0729	-23.0375	118.7266	3/14/2008	3
	Boundary Ridge North	GWB0038	-23.0189	118.7241	7/16/2008	2
	Boundary Ridge North	GWB0038	-23.0189	118.7241	10/06/2008	3
	Boundary Ridge North	GWB0038	-23.0189	118.7241	2/24/2009	6
	Coondewanna Flat	GWB0037	-22.9781	118.7562	2/24/2009	1
	Alligator Jaws	AN0119R	-23.0352	118.6786	23/08/2016	1
	Alligator Jaws	WARP60	-23.0519	118.6718	25/08/2016	9
	Alligator Jaws	WARP31	-23.0524	118.6782	25/08/2016	16