BENGALLA Mining Company

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Stygofauna Assessment

Continuation of Bengalla Mine - Stygofauna Assessment

Prepared for
Hansen Bailey and Bengalla Mining Company

June 2013

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Executive Summary

Eco Logical Australia (ELA) has been commissioned by Hansen Bailey Environmental Consultants (Hansen Bailey) on behalf of Bengalla Mining Company Pty Limited (BMC) to undertake a stygofauna impact assessment for the Bengalla Continuation of Mining Project (the Project). The assessment is to form part of an Environmental Impact Statement (EIS) being prepared by Hansen Bailey to support an application for Development Consent under Part 4 Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to enable mining to continue directly west at a rate of up 15 Million tonnes per annum (Mtpa) for a 24 year period.

The stygofauna impact assessment provides:

- A desktop assessment of previous stygofauna surveys in the Hunter Valley;
- An assessment of the likely occurrence of stygofauna within the study area Figure 1based on the information from previous surveys;
- A field assessment within the study area to confirm the occurrence of stygofauna;
- An assessment of the potential impacts to stygofauna; and
- Recommendations for mitigation and management.

The Hunter River alluvial aquifer upstream and downstream of the Project has been confirmed as suitable stygofauna habitat (Hancock and Boulton 2009). Although mining will not occur on the alluvial floodplain, dewatering has caused some drawdown in the northern section of the Hunter River alluvial aquifer south of the mine (AGE 2013). From 2014, as the mine moves westward, the reduction in inflow to the alluvium will become less and the extent of drawdown will decline (AGE 2013). Groundwater inflow to the Hunter River alluvium is currently reducing by approximately 0.45 ML/day (AGE 2013). At the commencement of the Project, the reduction in inflows to the Hunter River alluvium will be 0.65 ML/day. By Year 10, as the mine moves away from the alluvium, this declines to 0.25 ML/day and then stabilises by Year 21 (AGE 2013). Therefore, the overall impact of the Project will be to reduce the extent of drawdown currently occurring in the alluvial aquifer.

ELA sampled thirteen bores and wells for stygofauna in July 2012. Eight samples were collected from the Hunter River Alluvial Aquifer, and five were collected from the Permian rock aquifers. Seven of the sampled bores contained stygofauna, with the only non-alluvial bore being BG45. Ten of the bores were re-sampled in September 2012, bringing the total number of samples to 23. No new taxa were collected during the second round of sampling. The second round of samples collected fauna from three bores that did not yield any fauna in the first round, emphasising the need for multiple sampling rounds in assessments of stygofauna distribution. No stygofauna were collected from SMB1 in July 2012, but 691 animals from 4 taxa were collected from the same bore in September. This bore is in an area experiencing significant drawdown from the Wantana extension, but given the high number of animals occurring here, the impact of this dewatering on the stygofauna community appears to be minimal.

Six stygofauna taxa were collected over both survey rounds. Cyclopoid crustaceans were the most numerous and frequently encountered taxon, and occurred in large numbers in BG3 and SMB1. Other taxa were *Notobathynella* sp. 1, *Bathynella* sp. 1, *Chillagoe* sp. 1, Ostracoda, and Oligochaeta. Not all taxa were identified to species, but based on existing knowledge of Hunter Valley stygofauna it is unlikely that there are any species endemic to the area impacted by drawdown.

Although stygofauna occur in high numbers in some bores, all taxa collected are known from other parts of the Hunter River alluvial aquifer and are not endemic to the Project Area. The stygofauna specimens collected during this survey were taken while dewatering south-east of the pit is at its modelled maximum. As the mine moves westward, the extent of dewatering in the alluvial aquifer will decline, reducing any impact the current level of dewatering has on the stygofauna community.

The project poses no direct threat to the stygofauna community, so no additional surveys are recommended unless there are unforeseen rapid changes to groundwater quality.

1 Introduction

1.1 BACKGROUND

Eco Logical Australia (ELA) was commissioned by Hansen Bailey, on behalf of Bengalla Mining Company (BMC), to undertake a stygofauna impact assessment for the Continuation of Bengalla Mine Project (the Project). This assessment will form part of the Environmental Impact Statement supporting an application for Development Consent under Part 4, Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.2 EXISTING OPERATIONS

BMC operates the Bengalla Coal mine in the upper Hunter Valley, 4 km west of Muswellbrook (**Figure 1**).

Bengalla is an open cut strip-mining operation where mining advances to the west in dragline strips approximately 60 m wide. Pre-stripped overburden is removed by loader or excavator in advance of the dragline operation and subsequent coaling. Mining is conducted by dragline, loading units, trucks, and various other ancillary equipment.

Bengalla was approved to operate for a 21 year period from 1996 (i.e. until 2017) and to produce up to 8.7 Million tonnes per annum (Mtpa) of ROM coal. Approval was granted for the extraction of a total coal resource of approximately 146 Million tonnes (Mt) of ROM coal within a defined area. Additional coal reserves have always been known to exist further to the west of the approved coal extraction boundary.

BMC has been granted four modifications to DA 211/93 which have generally facilitated the following:

- Increasing the Overburden Emplacement Area (OEA) height by 30 m to Reduced Level (RL) 270 m;
- Upgrade of the Coal Handling and Preparation Plant (CHPP) to allow two staged washing;
- The construction of temporary tailings drying areas;
- Increasing maximum allowable production levels to 10.7 Mtpa ROM coal;
- The relocation of the overland conveyor and associated ROM coal dump hopper;
- Extension of mining operations into an additional 32 hectare area (Wantana Extension) to recover an addition 7.5 Mt of ROM coal over a period of approximately 5 years;
- Modifications to the approved infrastructure to enable efficiencies across the operation;
- Construction of the Bengalla Link Road Stage 2 on an alternate alignment to that originally approved;
- Acceleration of mining operations in the Wantana Extension to align these with existing operations in the remainder of Bengalla; and
- Implementation of an overburden emplacement strategy to resolve the overburden emplacement capacity issues experienced at Bengalla.

1.3 THE PROJECT

The Project involves the continuation of mining to the west of the existing extraction limit at a rate of 15 Mtpa for 24 years. The Project will enable the extraction of an additional 316 Mt of ROM coal from the Whittingham Coal Measures. **Figure 1** provides an indicative layout of the Project.

The Project is generally comprised of:

- Open cut mining towards the west at a rate of up to 15 Mtpa ROM coal for 24 years;
- Continued use of the existing dragline, truck fleet and excavator fleet (with progressive replacement);
- An out of pit Overburden Emplacement Area (OEA) to the west of Dry Creek which may be utilised for excess spoil material until it is intercepted by mining;
- Continued use, extension or relocation to existing infrastructure, including administration and parking facilities, in-pit facilities (including dragline shut down and erection pad), helipad, tyre laydown area, explosives and reload storage facility, core shed workshop and administration buildings, roads, reject bin, ROM Hopper, water management infrastructure, supporting power infrastructure, and ancillary infrastructure;
- Construction and use of various items of new infrastructure (including radio tower, extensions to Main Infrastructure Area (MIA), MTP Staged Discharge Dam and associated water reticulation infrastructure, additional ROM coal stockpile and upgrade to the emergency ROM coal stockpile along with associated conveyor network);
- Processing, handling and transportation of coal via the (upgraded) CHPP and rail loop for export and domestic sale;
- Continued rejects and tailings co-disposal in the Eastern OEA and temporary in pit reject emplacement;
- Relocation of a 3 km section of Bengalla Link Road around Year 15 near the existing mine access road to facilitate coal extraction;
- The diversion of Dry Creek via dams and pipe work with a later permanent alignment of Dry Creek through rehabilitation areas when emplacement areas are suitably advanced;
- Relocation of water storage infrastructure as mining progresses through existing dams (including the Staged Discharge Dam, raw water dam); and
- A workforce of approximately 900 full time equivalent personnel (plus contractors) at peak production.

1.4 SCOPE OF WORK

The Scope of Work for ELA is to produce a Stygofauna Impact Assessment for the Project suitable to support a Development Consent Application under Part 4.1 of the EP &A Act. The report will become an appendix to the EIS for the Project.

The Project has been granted State Significant Development (SSD) status under the EP&A Act (SSD-5170). DP&I issued the Director General's Requirements (DGRs) for the Project on 13 March 2012. The NSW Office of Water's Regulator's submission to the DGRs in relation to stygofauna has been considered in the scope of this assessment.

The scope of work for the stygofauna impact assessment included:

- A review of literature of previous stygofauna assessments in the Hunter River alluvial aquifer and area surrounding the Project;
- Review and incorporation of relevant data and information from the groundwater impact assessment that has been developed for the Project by separate consultants;
- With the assistance of the above, a conference call with a groundwater specialist from Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) and review of aerial photography and geology to understand the groundwater regime within the area to identify distinctive domains with stygofauna potential;
- Design and implementation of a sampling program;
- Review of predicted groundwater impacts and an assessment of the potential impacts to each groundwater domain that may contain stygofauna;
- Assess the potential regional, state and national impacts on these stygofauna;
- Discuss the impact of groundwater depressurisation predicted for the Project (and cumulative impacts with other mines in the region) and other landuses in the region including pumping from the aquifer(s) for agricultural purposes; and
- Provide recommendations in relation to any future groundwater monitoring regimes that could be implemented to monitor the impacts of the Project on stygofauna, or other management if required.

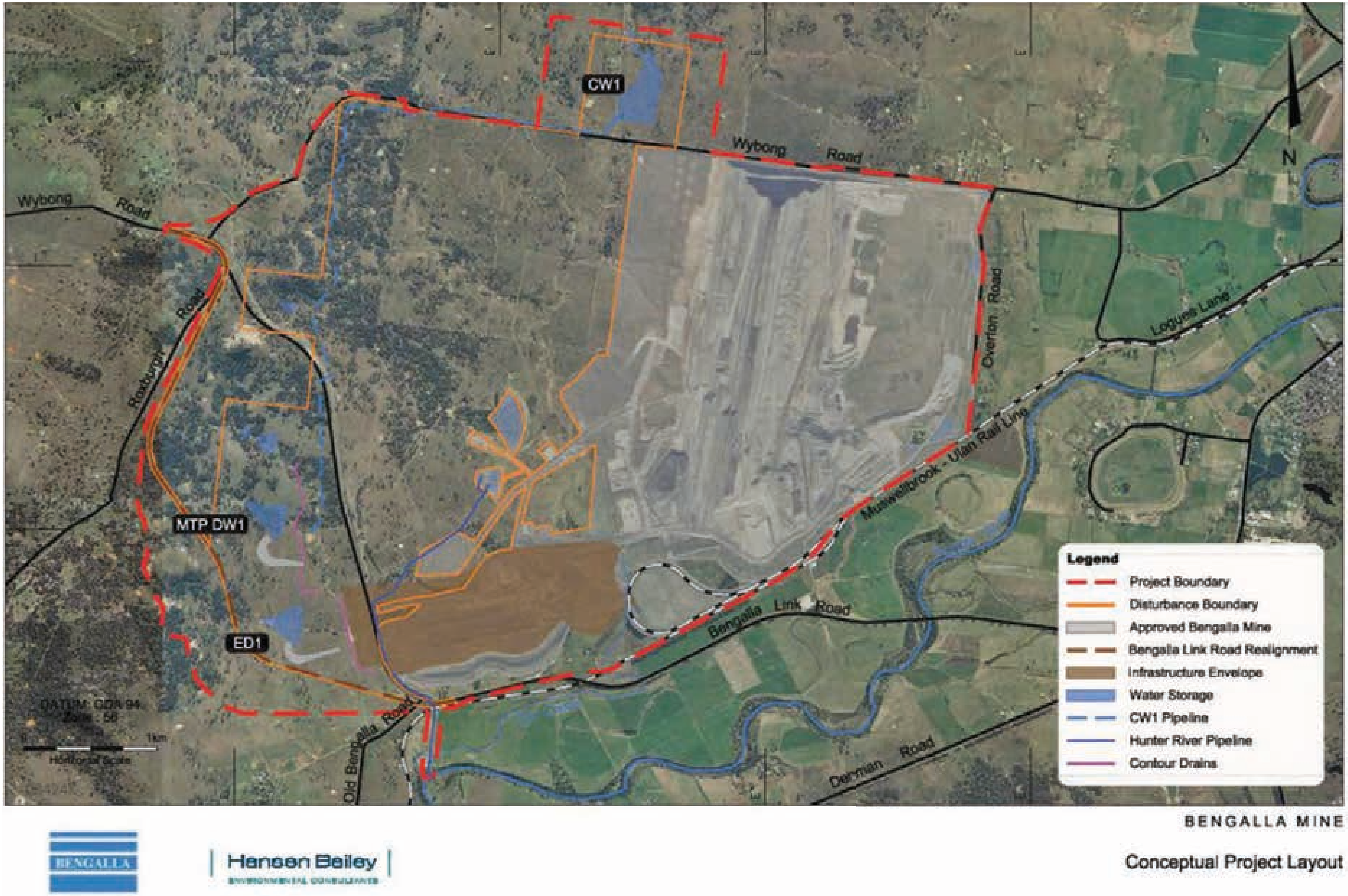

Figure 1: Conceptual project layout

2 Legislative Framework

2.1 ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979

The EP&A Act is the overarching planning legislation in NSW. This Act provides for the creation of planning instruments that guide land use, and sets out guidelines for the assessment of developments. The Act also aims to encourage ecologically sustainable development in NSW and to protect natural habitat, flora and fauna.

2.1.1 Director-General's Environmental Assessment Requirements

The EIS for the Project must be prepared in accordance with the DGRs. This assessment, which forms part of the EIS, addresses the Environmental Assessment Requirements (EARs) relating to biodiversity, specifically the requirement for:

> *A detailed assessment of potential impacts of the development on any terrestrial or aquatic threatened species or populations and their habitats, endangered ecological communities and groundwater dependent ecosystems.*

This report assesses the impact of the Project on the 'aquifer ecosystem' type of groundwater dependent ecosystem (GDE). The assessment of potential impacts is made in Section 8.

2.2 NSW STATE GROUNDWATER QUALITY PROTECTION POLICY 1998

The *NSW State Groundwater Quality Protection Policy 1998* is designed to encourage the ecologically sustainable management of NSW's groundwater resources. The principles of the policy that are applicable to the protection and management of stygofauna include:

- *All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained;*
- *Groundwater pollution should be prevented so that future remediation is not required;*
- *Groundwater Dependent Ecosystems will be afforded protection;*
- *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource;* and
- *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.*

2.3 NSW GROUNDWATER DEPENDENT ECOSYSTEMS POLICY 2002

The *NSW Groundwater Dependent Ecosystems Policy 2002* is designed to protect ecosystems which rely on groundwater for survival, and the ecological processes and biodiversity associated with them. Under the policy, stygofauna are considered as the faunal component of aquifer ecosystems.

The policy applies the following principles:

- *The scientific, ecological, aesthetic and economic values of groundwater dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.*
- *Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of Groundwater Dependent Ecosystems.*
- *Priority should be given to ensure that sufficient groundwater of suitable quality is available at the times when it is needed:*
    - *For protecting ecosystems which are known to be, or are most likely to be, groundwater dependent; and*
    - *For Groundwater Dependent Ecosystems which are under an immediate or high degree of threat from groundwater-related activities.*
- *Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect Groundwater Dependent Ecosystems. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.*
- *Planning, approval and management of developments and land-use activities should aim to minimise adverse impacts on Groundwater Dependent Ecosystems by:*
    - *Maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems;*
    - *Not polluting or causing adverse changes in groundwater quality; and*
    - *Rehabilitating groundwater systems where practical.*

2.3.1 NSW Office of Water Requirements

In a letter dated 21 March 2012, the NSW Office of Water outlines nine requirements for the EIS to satisfy the NSW GDE policy. These requirements are included below in **Table 1**. Note that this report only addresses items relevant to stygofauna and aquifer ecosystems.

No other regulators submissions to the DGRs, relating to GDEs, were received for the Project.

Table 1. NSW Office of Water GDE requirements for the Project

REQUIREMENT	HOW REQUIREMENT IS ADDRESSED	WHERE IT IS ADDRESSED
Identification of potential GDEs within and adjacent to the proposed development site.	This assessment confirms that the section of the Hunter River Alluvial Aquifer adjacent to Bengalla is a GDE.	Section 5, Section 7
Details of current GDEs condition based on minimum monthly data collected over a minimum time period of two years.	The current survey is the first attempt to collect stygofauna from bores at Bengalla. Two rounds of sampling confirm that no endemic species occur. Stygofauna data from previous studies along the Hunter River alluvial aquifer and adjacent tributaries collected since 2000, have been considered in making this assessment. As stygofauna generally occur in low abundances in aquifers, monthly sampling is not recommended as it could deplete populations. WA EPA (2007) and Hancock and Boulton (2009) recommend a minimum period of three months between sampling.	Section 7
Details of groundwater quality and quantity requirements for all GDEs based on minimum fortnightly data collected over a minimum time period of two years	Previous groundwater reports and groundwater quality and water level data were considered during this assessment. The Draft Bengalla Continuation Groundwater Impact Assessment was used to determine how groundwater levels may change as mining progresses.	Section 3, Section 6
Details of a flora and fauna assessment for all GDEs, including both terrestrial and aquatic (stygofauna, macroinvertebrate and macrophyte) diversity and abundance assessments	The survey methods used in this assessment follow the guidelines for sampling in Western Australia and Queensland in surveys of stygofauna diversity and abundance.	Section 6, Section 7.2
Detailed assessment of any potential impacts to GDEs	This document assesses the potential for changes in water level and water quality to impact on the stygofauna community.	Section 8
Critical thresholds for negligible impacts	This Project is unlikely to have any impact on the stygofauna community of the alluvial aquifer, as the mine will move away from the alluvium	Section 8
Detailed description of any measures to avoid or minimise adverse impacts on GDEs.	This Project is unlikely to have any impact on the stygofauna community of the alluvial aquifer, as the mine will move away from the alluvium	Section 9
Details of ongoing monitoring and protection programs for potential offset areas	No ongoing monitoring is required	Section 9
Contingency strategies to remediate, reduce or manage potential impacts.	This Project is unlikely to have any impact on the stygofauna community of the alluvial aquifer, as the mine will move away from the alluvium	Section 9

3 Ecological Requirements of Stygofauna

This section summarises the groundwater quality and quantity requirements of stygofauna.

3.1 BACKGROUND - FACTORS INFLUENCING BIOLOGICAL DISTRIBUTION IN AQUIFERS

Stygofauna are animals that live in groundwater. Recent estimates suggest there could be as many as 2680 species in the western half of the Australian continent, although approximately 12 % of these have been described (Guzik et al 2011). It is difficult to estimate the diversity of eastern Australian aquifers, but they may be just as diverse as western aquifers.

As with all fauna, groundwater invertebrates require favourable conditions to inhabit an aquifer, but with this many species, there is a broad range of variability in ecological requirements. Not all aquifers are suitable for stygofauna, and those that are suitable may become unsuitable as a result of human activities or natural changes. Biological distribution in groundwater is influenced by historical, geological, hydrological, physico-chemical, and biological properties (Strayer 1994, Hancock et al 2005). There is still a lot being learned about stygofauna ecology, particularly in the eastern states where there have been relatively few surveys compared to Western Australia. Nevertheless, it is possible to briefly summarise what is already known about aquifer conditions likely to influence distribution.

3.1.1 Aquifer type

Stygofauna have been collected from many aquifer types, including fractured basalt, fractured sandstone aquifers, and pesolithic aquifers, but are most common in karstic and alluvial aquifers. Critical aquifer characteristics are the hydraulic conductivity, depth to water table, and porosity.

Generally, stygofauna occur more frequently in alluvial aquifers and karst than in other geological formations (Hancock et al 2005, Humphreys 2008). Alluvial aquifers occur beneath floodplains, which often provide the following conditions favourable to stygofauna:

- Water table is shallow, so there is recharge of infiltrating rainwater and organic matter, and the water table is accessible to floodplain tree roots
- There is often some degree of hydrological connectivity with surface rivers. This is particularly influential in regulated rivers where artificial flow releases from upstream dams may provide aquifer recharge of organic matter and oxygen in periods where natural surface flow would be absent
- Compared to deeper aquifers, water in alluvial aquifers is young and has a rapid flux.

3.1.2 Hydraulic conductivity

Hydraulic conductivity indicates how rapidly water flows through an aquifer. This is important to stygofauna communities because the flux of water through an aquifer often influences how rapidly organic matter and oxygen concentrations can be replenished.

3.1.3 Depth of water table

Depth to water table influences the amount of organic matter and oxygen that are available to aquifer foodwebs. With increasing depth below the land surface, the concentration of organic matter dissolved in infiltrating rainwater diminishes as it is absorbed in transit by soil bacteria and plant roots. Shallow water tables of less than 15 m have been found to favour high diversity in alluvial aquifers in eastern Australia (Hancock and Boulton 2008).

Another source of organic matter to aquifer invertebrates is the presence of phreatophytic roots (Jasinska et al. 1996). Root density is likely to be higher in shallower aquifers, and the resultant availability of organic matter provides food to diverse stygofauna communities (Hancock and Boulton 2008).

3.1.4 Connectivity to recharge areas

A large proportion of the organic matter that fuels aquifer food webs has its origin at the surface and enters groundwater in particulate or dissolved forms. Therefore, sections of aquifers that are nearer to recharge areas are likely to have higher diversity and abundance than those that are further away since the transfer of organic matter and oxygen is greater at these sites (Datry et al 2004).

3.1.5 A space for living

Stygofauna can only live in aquifers with enough space for them to move around in. Space is present in the solute cavities in karst, between pesolithic sediments in calcrete, and fractures in sandstone and basalt. In sedimentary aquifers, the size of porespace between particles often correlates to the size of the animals present, with larger species occurring in aquifers of coarser material (Strayer 1994).

Also important when considering the space available for living is the connectivity between pores, cavities, and fractures. These act as migration pathways to allow fauna to move around in the aquifer and are likely to be important in recolonising following disturbance.

3.1.6 Evolutionary history

Most stygofauna evolved from ancestors that once lived in surface freshwater or marine environments. As a result, it is possible that they have retained some of the traits and environmental tolerances of their ancestry. As an example, in coastal areas where ancestral stygofauna species may have come from a marine origin, contemporary taxa may be tolerant of high salinity (Humphreys 2008, Hancock and Steward 2004). Conversely, taxa with a freshwater ancestry may prefer lower salinities (Hancock and Boulton 2008).

3.1.7 Food availability

Stygofauna have adapted to the resource-starved conditions in aquifers and can tolerate low concentrations of organic matter (Hahn 2006, Strayer 1994). Food is available to stygofauna as particulate organic matter, groundwater bacteria, or as roots of phreatic trees. In its dissolved or fine particulate form, organic matter enters aquifers with recharging water. Dissolved organic matter is taken up by groundwater bacteria, which are then imbibed by smaller stygofauna. Most stygofauna are opportunistic omnivores.

3.1.8 Water regime

Local or regional climate and river-flow regimes can influence aquifer recharge, and so affect the organic matter flux in the aquifer. Periods of high, steady rainfall can increase hydrological connectivity between the land surface and the aquifer and can reduce depth to water table. Exchange between rivers, the hyporheic zone, and aquifers can be an important source of nutrients to stygofauna communities (Dole-Olivier et al 1994), so flow fluctuations that enhance hyporheic exchange can subsequently enrich stygofauna communities in deeper parts of the aquifer.

3.1.9 Salinity

Stygofauna in inland aquifers are generally restricted to fresh or partly brackish water. Hancock and Boulton (2008) suggest that most taxa collected from alluvial aquifers in NSW and Queensland prefer EC less than 5,000 μS/cm. In surveys of coastal areas and near salt lakes in Western Australia, stygofauna were collected from aquifers with salinities at or exceeding sea water (Watts and Humphreys 2004). *EPA Guidance Statement 54a* recommends 60,000 mg/L as the salinity above which stygofauna are unlikely (EPA 2007).

3.1.10 Dissolved oxygen

Stygofauna are able to tolerate very low concentrations of dissolved oxygen. Hahn (2006) observed a strong decrease in concentrations below 1.0 mg/L, but found some fauna in concentrations down to 0.5 mg/L. Some taxa are able to survive virtually no oxygen for temporary periods for up to 6 months (Malard and Hervant 1999, Henry and Danielopol 1999). Aquifers can be heterogeneous environments, so may contain patches of water with sufficient oxygen concentration to be suitable for stygofauna. As dissolved oxygen is measured from water pumped from bores, it can be difficult to identify where these patches occur.

4 Groundwater Regime at Bengalla

4.1 CURRENT GROUNDWATER REGIME

Two distinct water-bearing geological units occur in the Project Area. A thin layer of alluvial sediments occurs along the Hunter River and other creek valleys, with the underlying and surrounding rock strata consisting of Permian Coal sequence with overburden and interburden consisting of lithic sandstone interbedded with siltstone, tuffaceous claystone and mudstone (AGE 2013).

4.1.1 Alluvial aquifer

The Quaternary alluvial deposits of the Hunter River, south of the Project Boundary are about 15 m deep and thin towards the north (AGE 2010). The basal sand and gravel deposits are 2.5-4.0 m thick and overlain by silt and clay with occasional water-bearing sand lenses (AGE 2007). The saturated thickness of the alluvium is between 2.0 and 6.0 m in most areas, although a thickness of 10.0 m has been measured at BG5 (AGE 2007).

Smaller creeks and gullies in the study area, including Dry Creek, have thin deposits of unconsolidated silts, sand and fine gravels of mixed colluvial-alluvial origin. These deposits are of limited extent and do not have significant groundwater storage capacity, although they do discharge to creeks for short periods of time to maintain temporary baseflow.

The alluvial aquifer receives much of its recharge from infiltrating rainfall (AGE 2007), although water table fluctuations also correspond strongly to flow in the Hunter River (AGE 2010), suggesting a high level of connectivity between aquifer and river. The alluvial aquifer also receives some recharge from upwelling water from the Permian aquifers (AGE 2013).

Groundwater in the alluvial aquifer has a pH of between 6.7 and 7.4, so is generally neutral (AGE 2007). EC is between 810 and 1,410 μS/cm (AGE 2007), although values up to 2,190 have been recorded at SMB2 (AGE 2010).

4.1.2 Permian Aquifers

Permian sedimentary rocks underlie the alluvial aquifer and extend north of the alluvium boundary. These strata can be categorised into two hydrogeological units. The sandstone and siltstone that comprise the majority of the interburden and overburden are very low yielding or essentially dry, while the coal seams, which are the main water bearing strata in the Permian sequence, have a low to moderate permeability (AGE 2007).

The Permian aquifers are recharged by rainfall and flow with a shallow gradient to discharge into the alluvial aquifer or directly into creeks and rivers (AGE 2007). Water in the Permian aquifer is variable and has EC between 880 and 7,620 μS/cm, and pH ranging from 6.7 and 7.3 (AGE 2007).

4.2 EXPECTED CHANGES TO THE GROUNDWATER REGIME RESULTING FROM THE PROJECT

Under the Project, BMC will continue mining in a westerly direction from the current site, moving away from the alluvial aquifer. At completion, the western edge of the pit will be west of Dry Creek, which will require realignment. Most of the excavation will occur in Permian sediments.

Mining will not occur on the alluvial floodplain but dewatering has caused some drawdown in the northern section of the Hunter River alluvial aquifer south of the mine (AGE 2013). From 2013, as the mine moves westward, the reduction in inflow to the alluvium will become less and the extent of drawdown will decline (AGE 2013). Groundwater inflow to the Hunter River alluvium is currently reduced by approximately 0.45 ML/day (AGE 2013). At the commencement of the Continuation Project, inflows to the Hunter River alluvium will be reduced by 0.65 ML/day. By Year 10, as the mine moves away from the alluvium, this declines to 0.25 ML/day and then stabilises by Year 21 (AGE 2013).

5 Desktop Assessment of Stygofauna in the Hunter Valley

5.1 HUNTER RIVER HYPORHEIC SURVEY

Stygofauna research in the Hunter Valley began in 2000, with a four year survey investigating the impacts of river flow variation on groundwater adjacent to the Hunter River (Hancock 2004, 2006). During this survey, samples were collected beneath the bed sediments and lateral bars of nine sites along the Hunter River, Goulburn River and Wollombi Brook (**Figure 2**).

Hyporheic zones are the area of river bed where groundwater and surface water mix, and often contain surface water, hyporheic, and groundwater taxa (Marmonier and Creuzé des Châtelliers 1991). The results from the survey validated such diversity in the invertebrate community, with groundwater representatives from Microturbellaria (flatworms), Oligochaeta (aquatic worms), and Ostracoda, Cyclopoida, and Harpacticoida (microcrustacea) recorded at all sites (**Table 2**). At the time of the survey, stygofauna taxonomy for microcrustaceans was poorly developed for eastern Australia, therefore it was not possible to identify specimens to species level; however, groundwater affinity was inferred by the presence of troglomorphic characteristics (e.g. blindness, elongation and depigmentation; Coineau 2000, Danielopol et al. 1994). This was later confirmed in consultation with international experts (Pierre Marmonier, Tom Karanovic, Ivana Karanovic *pers comm.*).

Two genera of Bathynellacea (an order of crustacean) were collected from the hyporheic zone. *Bathynella* sp. was collected from Hunter River sites at Bowmans Bridge, Dights Crossing, Aberdeen and from the Goulburn River at Sandy Hollow. *Notobathynella* sp. occurred at Denman, Dights Crossing, and Aberdeen. The largest stygofauna taxon collected was a single species (Peter Serov *pers comm.*) of the undescribed Anaspidacean family; Family A. Specimens were collected at all Hunter River sites except Dights Crossing.

The amphipod family, Paramaletidae, occurred at six hyporheic sites. It is often difficult to distinguish between amphipod species based solely on morphological characters (Finston et al. 2004) and until recently, molecular techniques were not sufficiently available to allow identification to species level. As a result, there is uncertainty about the number of species present in the Hunter hyporheic specimens, although they are thought to be members of the genus *Chillagoe*.

One species of the isopod *Heterias* sp. 1 was also collected at five sites along the Hunter River.

A complete inventory of the species identified in the survey is shown in **Table 2**.

Table 2: Stygofauna collected in the Hunter River Hyporheic Survey

LOCATION	ALLUVIAL AQUIFER SAMPLED	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida
Bowman Bridge	Hunter River	■	■	■		■	■	■	■	■	■
Jerrys Plains	Hunter River	■	■			■			■	■	■
Moses Crossing	Hunter River	■	■			■	■	■	■	■	■
Denman	Hunter River	■	■		■	■	■	■	■	■	■
Dights Crossing	Hunter River	■	■	■	■		■	■	■	■	■
Warkworth	Wollombi Brook	■	■						■	■	■
Sandy Hollow	Goulburn River	■	■	■					■	■	■
Aberdeen	Hunter River	■	■	■	■	■	■	■	■	■	■
Maison Dieu	Hunter River	■	■			■	■		■	■	■

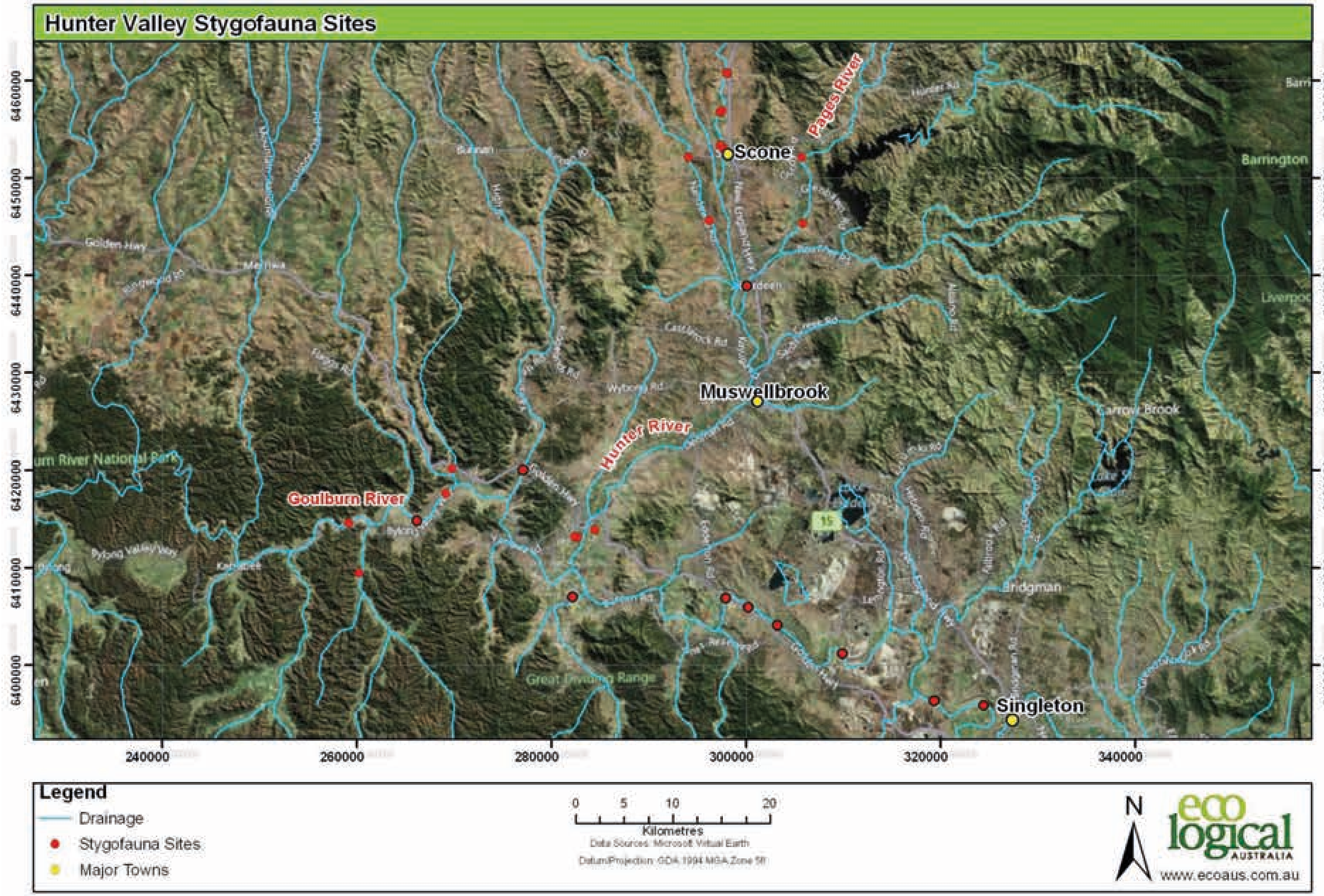

Figure 2: Location of past stygofauna survey points in the Hunter Valley

5.2 HUNTER VALLEY ALLUVIAL AQUIFER SURVEY

The confirmation that stygofauna was present throughout much of the Hunter Valley led to further sampling between 2004 and 2008 of bores in the Hunter River, Pages River, Dart Brook, and Kingdon Ponds alluvial aquifers (Hancock and Boulton 2008, 2009; Watts *et al.* 2007). Samples were collected from 40 groundwater monitoring bores operated by mining companies and the NSW Office of Water (**Figure 2**). The results of the sampling program increased the number of known stygofauna taxa in the Hunter Valley to at least 26 groups with this number likely to rise as more of the collected taxa are formally described (Ana Camacho, Tom Karanovic, Ivana Karanovic *pers comm.*). To date, copepods and ostracods from Denman, Muswellbrook, Pages Creek, Dart Brook (north), and Kingdon Ponds samples have been identified to a species level.

Dart Brook, Pages Creek, and Kingdon Ponds alluvial aquifers each had similar diversity to the Hunter River alluvial aquifer at Denman. The Hunter River alluvial aquifer near Denman and the Pages Creek alluvial aquifer had 20 stygofauna taxa. The northern Dart Brook bores had 21 taxa, while Kingdon Ponds had 18 taxa and the Hunter River alluvial aquifer near Muswellbrook had only eight taxa.

A list of the species identified in the survey is shown in **Table 3**. None of the species known from the Hunter Valley are listed under the *Threatened Species Conservation Act* 1995, nor the *Environmental Protection and Biodiversity Conservation Act (EPBC Act)* 1999. However, this reflects the relatively few surveys and sparse research that has been done on NSW stygofauna, rather than an indication that the species are widespread and at no risk. In Western Australia, where stygofauna research has been occurring since the early 1990's, there are two fish (Blind Gudgeon *Milyeringa veritas* and Cave Eel *Lasinectus exleyi*) and one invertebrate (the remipede *Lasinectus exleyi*) listed as vulnerable under the EPBC Act. In NSW, the main legislation protecting stygofauna is the *NSW GDE Policy* 2002 (Section 2.3).

Table 3. Stygofauna Identified in the Hunter Valley Alluvial Aquifer Survey

Location	Alluvial aquifer sampled	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida	Eucyclops cf. ruttneri	*Diacyclops cryonastes*	*Diacyclops* sp. 1	*Metacyclops* sp. 1	*Haplocyclops* sp. 1	*Elaphoidella* sp. 1	*Australocamptus* sp. 1	*Hancockcamptus* sp. 1	*Huntercamptus* sp. 1	*Huntercamptus* sp. 2	*Huntervallia* sp. 1	Aturidae sp 1	Elmidae sp 1	*Carabhydrus stephanieae*	*Limnobodesis* sp nov	*Hydrobiidae* sp nov
Denman bores	Hunter	■	■	■	■	■	■	■	■	■	■	■	■	■				■		■	■	■		■	■		■
Muswellbrook bores	Hunter	■	■				■		■	■		■	■	■													
Dartbrook bores south	Dartbrook	■	■				■		■	■	■																
Goulburn bores	Goulburn	■		■	■					■	■																
Pages bores	Pages	■	■	■	■	■	■		■	■	■	■	■	■			■	■		■		■	■	■	■	■	
Dartbrook bores north	Dartbrook	■		■	■	■	■	■	■	■	■	■	■	■	■			■		■	■	■	■	■	■	■	
Kingdon Ponds bores	Kingdon	■		■	■	■	■			■	■	■	■	■		■	■	■	■	■	■			■	■		

Of the stygofauna identified to a species level in the survey, only four (*Notobathynella* sp. nov. 3, Anaspid Family A sp. 1, *Dyacyclops cryonastes*, and possibly *Eucyclops* cf *ruttneri*) out of 19 are known to occur at sites beyond the Hunter Valley. With the exception of a previously undescribed species of Hydrobiidae snail, all taxa collected from the Hunter River aquifer occurred in at least one of the tributary aquifers.

Similarly, the majority of species in Dart Brook, Pages Creek and Kingdon Ponds bores were shared with at least one other aquifer. This suggests that approximately 80% of the species recorded are endemic to the region with the many species typically occurring in more than one alluvial aquifer. Only four species are endemic to single aquifers: *Metacyclops* sp. 1, *Haplocyclops* sp. 1, *Hancockcamptus* sp. 1, and *Hydrobiidae* sp. nov. (**Table 3**).

5.3 OTHER SURVEYS

Other opportunistic sampling for stygofauna has been conducted by Dr Grant Hose (University of Technology, Sydney) from some of the bores sampled in the 2004 to 2008 Hunter Valley Alluvial Aquifer Survey. No further taxa were found during these surveys.

A survey of the Hunter River hyporheic zone at Bengalla was conducted by Sarah Mika of the University of New England as part of the Upper Hunter River Rehabilitation Initiative, which ran from 2002 to 2007 and was partly funded by Bengalla. This survey did not find any stygofauna living in the river bed gravels, nor beneath adjacent gravel bars (Sarah Mika *pers comm.*).

5.4 LIKELIHOOD THAT THE PROJECT BOUNDARY WILL CONTAIN STYGOFAUNA

The nearest part of the Hunter River alluvial aquifer to the Project Boundary that is known to have stygofauna is the hyporheic zone of the Hunter River at Denman, approximately 20 km downstream of the site.

Stygofauna are also known from the Hunter River at Aberdeen, and given the similarity in the fauna of both these sites, it can be assumed that the Hunter River alluvial aquifer is a corridor through which groundwater fauna disperse. Therefore, it is likely that there will be some stygofauna in the Hunter River alluvial aquifer adjacent to the Project.

6 Field Survey

6.1 TIMING AND PERSONNEL

The first round of sampling was conducted 16 to 18 July 2012 by Senior Groundwater Ecologist Dr Peter Hancock and Ecologist Daniel McKenzie. The second round of samples were collected between 25 to 27 September by Dr Peter Hancock and Aquatic Ecologist Nathalie van der Veer.

6.2 SAMPLE SITES

Sample sites were selected on the likelihood of having suitable stygofauna habitat. Selection was based on available hydrogeological information, and an attempt was made to choose bores or wells spread over the Project Boundary. Sites were selected immediately upstream of the Project Boundary to act as 'upstream' control points. Seventeen bores were initially listed for sampling.

Seventeen bores or wells were visited between 16 and 18 July 2012 (**Figure 3**), but four of these were not sampled because they were dry or too narrow to allow access to a stygofauna sampling net. Eight of the thirteen bores sampled entered in the Hunter River alluvial aquifer, and five entered the Permian rock aquifer (**Table 4**).

The second round of sampling focussed on bores in the alluvial aquifer. This round increased the survey effort by using a groundwater pump as well as the net to collect samples where bore construction allowed. The objective of this round was to determine if there were any taxa present that were not collected during the first round. Five bores were sampled with the combined net and pump method, and five bores were sampled with just the net (**Table 4**). All bores sampled in the second round were initially sampled in the first round.

6.3 METHODS

6.3.1 Groundwater physico-chemistry

Water table depth for each bore or well was measured using a dip tape. For bores that were sampled with the net only, a bailer was used to remove 5 L of water. The fifth litre was used for measuring groundwater temperature, electrical conductivity (EC), dissolved oxygen (DO), and pH with a YSI556 multi-parameter meter. For bores that were pumped during the second round of sampling, water quality was measured from the pumped water. Measurements were taken every 50 L, with the measurement from the final 10 litres included in the results table.

6.3.2 Stygofauna sampling

Samples were collected using methods consistent with monitoring guidelines in Western Australia and Queensland (WA Guidance Statement 54a, EPA 2007). Stygofauna were collected using a weighted 50 μm mesh conical net. A 40 mm diameter net was used to sample 50 mm monitoring bores, and a 250 mm diameter net was used to sample agricultural wells. Nets were lowered to the bottom of each bore or well, bounced four times to dislodge bottom-resting fauna and slowly retrieved. Once at the surface, net contents were emptied into a 50 μm mesh sieve. This process was repeated until the contents of six net hauls were in the sieve. The sample was preserved in a jar with 100 % ethanol and returned to the laboratory.

For the second round of sampling, pump samples were collected immediately after netting. A Watterra groundwater pump extracted up to 300 L of water from each bore. The water was passed through a 50 μm mesh sieve, and the sieve contents transferred to a jar containing 100 % ethanol.

6.3.3 Laboratory analysis

Samples were processed in a channelled sorting tray using a Leica M80 dissecting microscope with 7.5 to 60x magnification. All stygofauna were identified using existing keys and taxonomic expertise.

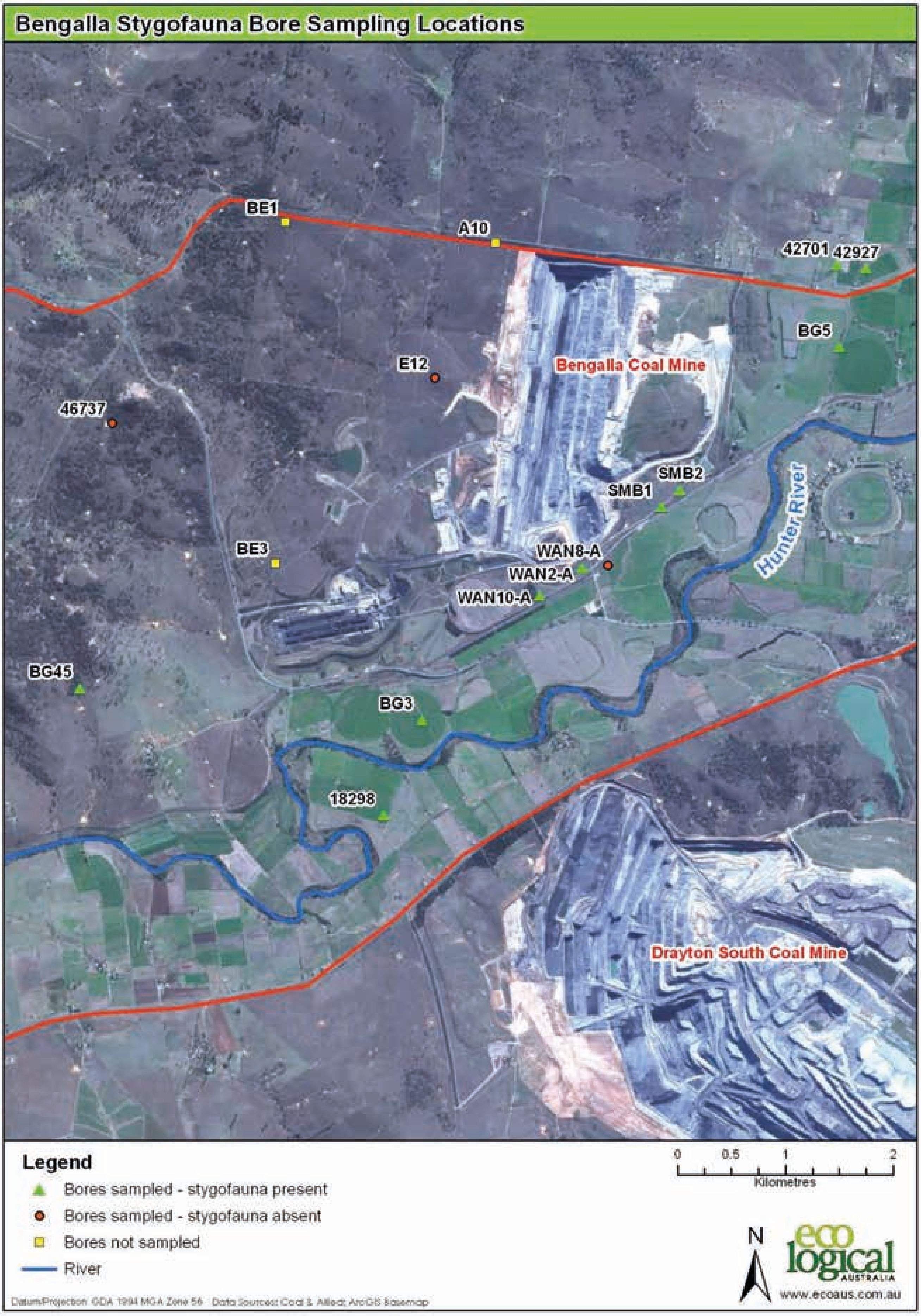

Figure 3. Location of bores sampled and visited for stygofauna sampling at Bengalla

Table 4: Bores and wells sampled at Bengalla in 2012. Letters in parentheses indicate method used: n for net, and p for pump

BORE	EASTING	NORTHING	AQUIFER	TYPE	SAMPLED JULY 2012	SAMPLED SEPT 2012
42701	298586	6428632	Deep Rock Aquifer *	Well	Y (n)	Y (n)
E12	294850	6427589	Shallow Hard Rock Aquifer	Monitoring bore	Y (n)	
BG5	298609	6427874	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n, p)
42927	298851	6428600	Alluvial Aquifer	Well	Y (n)	
18298	294376	6423529	Alluvial Aquifer	Well	Y (n)	Y (n)
BG3	294731	6424413	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n)
46737	291862	6427170	Shallow Hard Rock Aquifer	Windmill	Y (n)	
WAN10A	295828	6425571	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n, p)
WAN8A	296457	6425854	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n)
WAN2A	296217	6425824	Vaux Seam	Monitoring bore	Y (n)	Y (n, p)
SMB2	297125	6426550	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n, p)
SMB1	296955	6426392	Alluvial Aquifer	Monitoring bore	Y (n)	Y (n, p)
BG45	291559	6424708	Shallow Hard Rock Aquifer	Windmill	Y (n)	Y (n)

7 Results

7.1 ABIOTIC VARIABLES

Groundwater level was shallower than 15 m for all bores except 46737, BE3 and E12 (**Table 5**). EC in the alluvial aquifer ranged from 728 to 3,351 μS/cm (excluding WAN8A, which appears to be anomalous to surrounding bores). One bore (BE3) in the deep hard rock aquifer had an EC of 7,783 μS/cm, while the two bores (E12 and BG45) in the shallow hard rock aquifer, had EC of between 4,295 and 8,109 μS/cm.

Dissolved oxygen concentration was between 7.3 and 76.5 % saturation for bores in the alluvial aquifer (excluding WAN8A, **Table 5**). The deeper rock aquifers had concentrations between 13.8 and 19 % saturation. Dissolved oxygen (DO) concentration in 42701 was 49.2 and 65.9 % saturation, which is in the range of alluvial aquifers and may, when considered with the low EC, indicate that the water in this well entered as surface runoff through scour holes observed in the bottom of the well casing.

The water measured in WAN8A appeared to be anomalous, as it differed from other samples taken nearby (**Table 5**). As well as the high EC (7,707 and 8,197 μS/cm), pH from this bore was 12.35 and 12.74 (checked twice after confirming with pH standards that the probe was operating correctly) on the two dates sampled, compared to 6.64 – 7.39 in all other bores. EC in this bore rose dramatically between April 2009 and January 2010, peaking at almost 9,000 μS/cm (AGE 2013). For the current stygofauna sampling, the water table was 10.9 m below ground level in WAN8A, placing it just above the screened section of the bore (11-14 m, AGE 2011), but during sampling the bore extended only 60 cm beyond the water table so may be collapsed or blocked.

Table 5. Water level and physico-chemistry of bores sampled at Bengalla

BORE	WATER LEVEL (m bgl)		EC (mS/cm)		pH		DO (% SATURATION)		DO (mg/L)		TEMPERATURE (^{o}C)		NO. HAULS		VOL. PUMPED (L)
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 2
42701	10.01	10.33	873	928	7.29	7.3	49.2	65.9	4.48	5.92	19.55	20.28	6	2	
E12	50.72												3		
BG5	9.44	9.5	1210	1280	6.99	6.92	41.6	55.2	4.01	4.98	18.65	20.13	6	6	300
42927	10.98		1078		7.06		67.3		6.25		17.65		6		
BE3	41.26		7783		7.17		19		1.6		20.4				
18298	9.02	9.29	728	804	7.39	7.19	66.2	76.5	6.46	6.85	15.6	20.57	6	6	-
BG3	7.4	7.24	3205	3351	7.02	7.08	41	47	3.95	4.22	17.6	19.51	6	6	-
46737	39.71		8109		6.83		14.3		1.26		19.87		3		
WAN10A	8.02	8.14	1608	1130	7.37	6.96	19.4	21.5	1.79	1.98	18.76	19.15	6	6	300
WAN8A	10.9	10.93	7707	8197	12.35	12.74	79.6	71.8	7.2	6.52	19.06	18.73	1	4	
WAN2A	11.17	12.12	1115	1026	6.64	6.35	16.3	54.2	1.47	4.88	19.31	19.93	6	6	200
SMB2	13.25	13.2	2304	2398	7.22	6.97	46.6	51.3	4.16	4.68	18.93	19.32	6	6	300
SMB1	12.92	13.24	1740	1761	7.37	7.11	7.3	51.2	3.59	4.68	19.23	19.46	6	6	200
BG45	14.94	13.1	6647	4295	6.77	6.71	13.8	19.7	1.28	1.74	18.03	20.6	6	6	-

7.2 STYGOFAUNA

Stygofauna were collected from ten bores, nine of which occurred on the alluvial aquifer (**Table 6**). The tenth bore (BG45) was a disused windmill hole that entered the shallow hard rock aquifer. The presence of fauna in this bore indicates that the hard rock aquifer may be connected to an overlying lens of sediment associated with the shallow gully where the windmill is located.

Six invertebrate taxa were collected in the study area, with cyclopoid copepods being the most numerous. Cyclopoids were collected from nine bores, including BG45, and were the most numerous taxon encountered. There were 1018 cyclopoids collected over the two sampling rounds, with 609 animals coming from SMB1. BG3 had the second highest cyclopoid abundance with 195 animals. Cyclopoids could not be identified to species level without further expertise as there are no suitable taxonomic keys for eastern Australia, so identification was only taken to Family. Although the cyclopoids were morphologically similar to each other, it is possible that several species were present.

All taxa were present in the alluvial aquifer upstream of Bengalla. *Bathynella* sp. occurred only in BG5 in Round 1, but in four other bores in Round 2. *Notobathynella* sp. occurs only in BG3 in Round 1, but was collected from an additional four bores in Round 2. Paramelitid amphipods (**Figure 4**) occurred along the length of the alluvial aquifer, although were not collected from every bore.

No stygofauna were collected from SMB1, 18298, and WAN2A during the first round of sampling, but all three bores had fauna in the second round. SMB1 had the most fauna of any bore, with 691 animals collected in September 2012.

Oligochaete worms were collected from six bores, although it is not possible to determine if these are stygofauna, since oligochaetes are also common members in soil invertebrate fauna.

Figure 4: Stygofauna amphipod in the family Paramelitidae (*Chillagoe* sp.), collected from SMB2

Table 6: Stygofauna collected at Bengalla in 2012

ORDER	FAMILY	GENUS/ SPECIES	BG3		SMB1		SMB2		18298		42927	
			July	Sept	July	Sept	July	Sept	July	Sept	July	Sept
Bathynellacea	Parabathynellidae	*Notobathynella* sp.	6	6		2		1				
Bathynellacea	Bathynellidae	*Bathynella* sp.		3		69		2				
Amphipoda	Paramelitidae	*Chillagoe* sp.					1				1	
Cyclopoida	Cyclopidae		28	167		609	2	31		4		
Ostrocoda			7							6	4	
Oligochaeta			2	13		11					9	

ORDER	FAMILY	GENUS/ SPECIES	42701		WAN10A		WAN2A		BG5		BG45	
			July	Sept	July	Sept	July	Sept	July	Sept	July	Sept
Bathynellacea	Parabathynellidae	*Notobathynella* sp.				2						
Bathynellacea	Bathynellidae	*Bathynella* sp.				2			1			
Amphipoda	Paramelitidae	*Chillagoe* sp.		1	1	3			1	2		
Cyclopoida	Cyclopidae		18	40		15		1	79	23	1	
Ostrocoda				4	12	4						
Oligochaeta						4			3		6	

8 Impact Assessment

The purpose of this section is to assess whether the proposed changes to the groundwater regime at the Project will have any impact on the stygofauna community.

8.1 POTENTIAL IMPACTS TO STYGOFAUNA

A review of previous assessments and the literature found that stygofauna occur widely in the Hunter River Alluvial Aquifer and several tributary aquifers upstream of Singleton. This is despite more than 100 years of agricultural exploitation in the area. Although no stygofauna were previously known from the Hunter River hyporheic zone at Bengalla (Sarah Mika *pers comm.*), at least six taxa were collected during the current survey.

Both the speed and magnitude of water table drawdown can threaten stygofauna communities (Hancock et al 2005), but the proposed Project is not expected to significantly increase drawdown in the alluvial aquifer. Drawdown from the Wantana extension is currently near its modelled maximum. The high numbers of fauna and the presence of all six taxa in the immediate vicinity of the pit, suggests that the current level of drawdown has had minimal impact on the stygofauna community.

The extent of current drawdown should decrease as mining moves westward away from the alluvium (AGE 2013). With this westward movement, aquifer water level should move towards the pre-mining levels and provided there are no significant changes to water quality, stygofauna should recolonise the currently dewatered sediments. An exception to this could be at WAN8A, where there have been rapid changes in pH and EC since 2009.

8.2 ENDEMISM OF THE FAUNA COLLECTED

Six taxa were collected from the Hunter River alluvial aquifer. Of these six taxa, it is possible that the cyclopoida could include several species that were not detected in our identification. Although the animals looked morphologically similar, copepod taxonomy requires highly specialised skills, particularly for specimens collected in eastern Australia where few taxonomic keys exist. As there are no keys available, and expertise in Australia is limited there is often a waiting period of several months for identification, and specimens may require despatch to South Korea (Tom Karanovic *pers comm*).

The Hunter River aquifer near Denman has at least 20 stygofauna taxa, as does the Pages River alluvial aquifer. Dart Brook has 21 taxa and Kingdon Ponds has 18 (Hancock and Boulton 2009). The *Notobathynella* sp. 1, *Bathynella* sp. 1 and *Chillagoe* sp. 1 each represent single species. However, the cyclopoids and ostracods may consist of several species. All of the taxa collected at Bengalla were known from other parts of the Hunter Valley (Hancock and Boulton 2009), so are not endemic to the section within the Project Boundary. Only six taxa were collected from Bengalla, which is fewer than other aquifers of the Hunter Valley, although additional sampling associated with the Project Area and more detailed taxonomic analyses are likely to reveal a higher diversity.

9 Conclusion and Recommendations

The Hunter River alluvial aquifer adjacent to the Project contains at least six species of stygofauna. More species are likely to be confirmed with more sampling and specialist taxonomic identification of the collected specimens. The fauna collected confirm that this part of the aquifer is a Groundwater Dependent Ecosystem (GDE) like other reaches of the Hunter alluvium.

Cyclopoid copepods and oligochaete worms were collected from BG45 to the west of the Project. This bore is likely to be connected to a shallow lens of sediment in a gully that eventually meets the Hunter alluvium.

None of the taxa collected to date are endemic to the Project Boundary. It is unlikely that there will be endemic species whose distribution is confined solely to the narrow band of alluvium to be dewatered.

Under the Project, pit movement will be towards the west. No direct excavation will occur in the alluvial aquifer. The stygofauna specimens collected during this survey were taken while dewatering south-east of the pit is at its modelled maximum. As the mine moves westward, the extent of dewatering in the alluvial aquifer will decline, reducing any impact the current level of dewatering has on the stygofauna community.

The project poses no direct threat to the stygofauna community, so no additional surveys are recommended unless there are unforeseen rapid changes to groundwater quality.

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