Stygofauna Impact Assessment

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Drayton South Coal Project
Stygofauna Impact Assessment

Prepared for
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Executive Summary

Eco Logical Australia Pty Ltd was commissioned by Hansen Bailey Environmental Consultants, on behalf of Anglo American Metallurgical Coal Pty Ltd to complete a stygofauna impact assessment for the Drayton South Coal Project. Anglo American is seeking Project Approval under Part 3A of the *Environmental Planning & Assessment Act 1979* to facilitate the continuation of the existing Drayton Mine by the development of an open cut and highwall coal mining operation and associated infrastructure within the Drayton South area.

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 based 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.

From the desktop assessment, diverse stygofauna communities were identified in the Hunter Valley, with the nearest confirmed stygofauna habitat to the study area being in the Hunter River alluvial aquifer. Due to the proximity to other known stygofauna communities, it was concluded that stygofauna was likely to occur within the alluvial aquifers of the Hunter River (just outside of the study area) and Saddlers Creek (within the study area). Weathered Permian aquifers were also considered as potential habitat for stygofauna, particularly where it is adjacent to alluvial aquifers and the electrical conductivity was low.

Field sampling in September 2011 confirmed the presence of two taxa of stygofauna in the Saddlers Creek alluvial aquifer, including a member of the copepod genus *Diacyclops*, and an ostracod. Neither of these specimens is endemic to the area, although their presence indicates that there could be a more diverse stygofaunal community in the aquifer. Follow-up sampling of bores in the Saddlers Creek and Hunter River alluvial aquifers in October 2011 did not result in the collection of any further stygofauna specimens, suggesting that stygofauna are present in very low densities.

The Saddlers Creek alluvial aquifer is the only known stygofauna habitat likely to experience impacts from the Project. Impacts are likely to include reduced input from upwelling Permian water and rainfall infiltration over overburden emplacement areas, and depressurisation of parts of the Saddlers Creek aquifer as a result of mining activities. As stygofauna in this aquifer appear sparsely distributed and the impacts to the aquifer minimal, no significant impacts to stygofauna are expected.

1 Introduction

Eco Logical Australia Pty Ltd (ELA) was commissioned by Hansen Bailey Environmental Consultants (Hansen Bailey), on behalf of Anglo American Metallurgical Coal Pty Ltd (Anglo American) to complete a stygofauna impact assessment for the Drayton South Coal Project (the Project). The purpose of the assessment is to form part of an Environmental Assessment (EA) being prepared by Hansen Bailey to support an application for a contemporary Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to facilitate the continuation of the existing Drayton Mine by the development of an open cut and highwall coal mining operation and associated infrastructure within the Drayton South area.

The scope of work completed by ELA for this assessment included:

- Review of the literature and previous assessments undertaken within the Hunter River alluvial aquifer and study area;
- Verification of the regional groundwater regime and geology and identification of distinctive domains that may represent stygofauna habitat;
- Validation of stygofauna habitation in the study area;
- A review and description of the predicted groundwater impacts, including groundwater depressurisation caused by the Project and other land uses in the region such as coal mining and agriculture;
- An assessment of the potential impacts to stygofauna within the study area; and
- Provision of recommended mitigation, management and monitoring measures, where applicable.

1.1 PROJECT DESCRIPTION

Drayton Mine is managed by Anglo Coal (Drayton Management) Pty Ltd which is owned by Anglo American. Drayton Mine commenced production in 1983 and currently holds Project Approval 06_0202 (dated 1 February 2008) that expires in 2017, at which time the operation will have to close.

The Project will allow for the continuation of mining at Drayton Mine by the development of open cut and highwall mining operations within the Drayton South mining area while continuing to use the existing infrastructure and equipment from Drayton Mine.

The Project is located approximately 10 km north west of Jerrys Plains and approximately 13 km south of the township of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW). The Project is predominately situated within the Muswellbrook Shire Local Government Area (LGA), with the south west portion falling within the Singleton LGA. Figure 1 illustrates the location of the Project. The Project is located within close proximity to two thoroughbred horse studs, two power stations and several existing coal mines.

The Project will extend the life of Drayton Mine by a further 27 years ensuring the continuity of employment for its workforce, the ongoing utilisation of its infrastructure and the orderly rehabilitation of Drayton Mine's completed mine areas.

Anglo American is seeking Project Approval under Part 3A of the EP&A Act to facilitate the extraction of coal by both open cut and highwall mining methods within Exploration Licence (EL) 5460 for a period of 27 years. The Project Application Boundary (Project Boundary) is shown in Figure 1.

The Project generally comprises:

- The continuation of operations at Drayton Mine as presently approved with minor additional mining areas within the East, North and South Pits;
- The development of an open cut and highwall mining operation extracting up to 7 Mtpa of ROM coal over a period of 27 years;
- Use of the existing Drayton Mine workforce and equipment fleet (with an addition of a highwall miner and coal haulage fleet);
    - The Drayton Mine fleet consists of at least a dragline, excavators, a fleet of haul trucks, dozers, graders, water carts and associated supporting equipment;
- The use of Drayton Mine's existing voids for rejects and tailings disposal and water storage to allow for the optimisation of the Drayton Mine final landform;
- Use of the existing Drayton Mine infrastructure including the Coal Handling and Preparation Plant (CHPP), rail loop and associated loadout infrastructure, workshops, bath houses and administration offices;
- The construction of a transport corridor between Drayton South and Drayton Mine;
- Use of the Antiene Rail Spur off the Main Northern Railway to transport product coal to the Port of Newcastle for export;
- The diversion of a section of Edderton Road; and
- The installation of water management and power reticulation infrastructure for Drayton South.

All access to the Project will continue to be via the Drayton Mine Access Road off Thomas Mitchell Drive and will use the transport corridor to travel between Drayton Mine and Drayton South. An emergency entry / exit will be required to be developed and maintained off Edderton Road for health and safety purposes only.

The conceptual layout of the Project is shown in Figure 2.

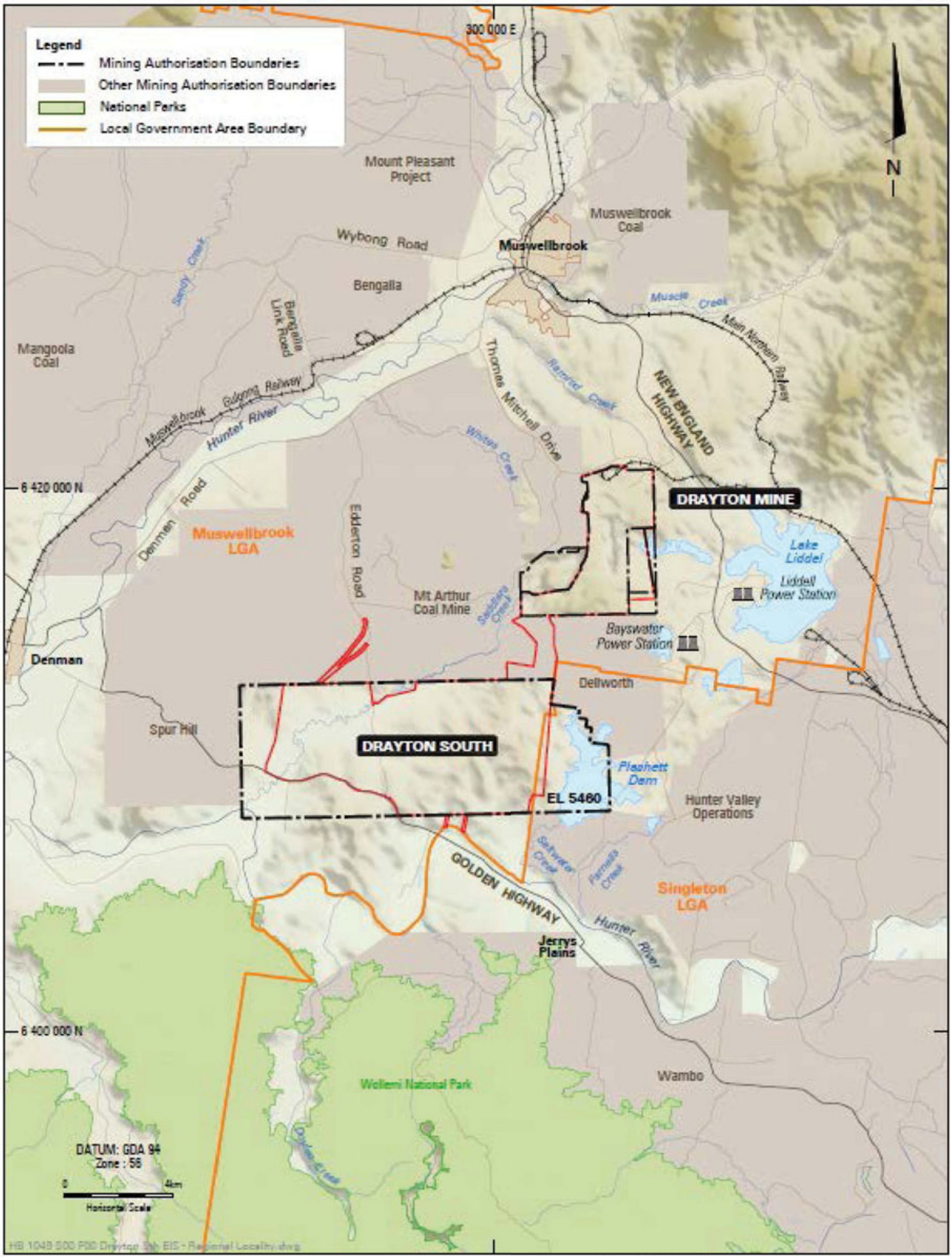

Figure 1: Regional Locality Plan

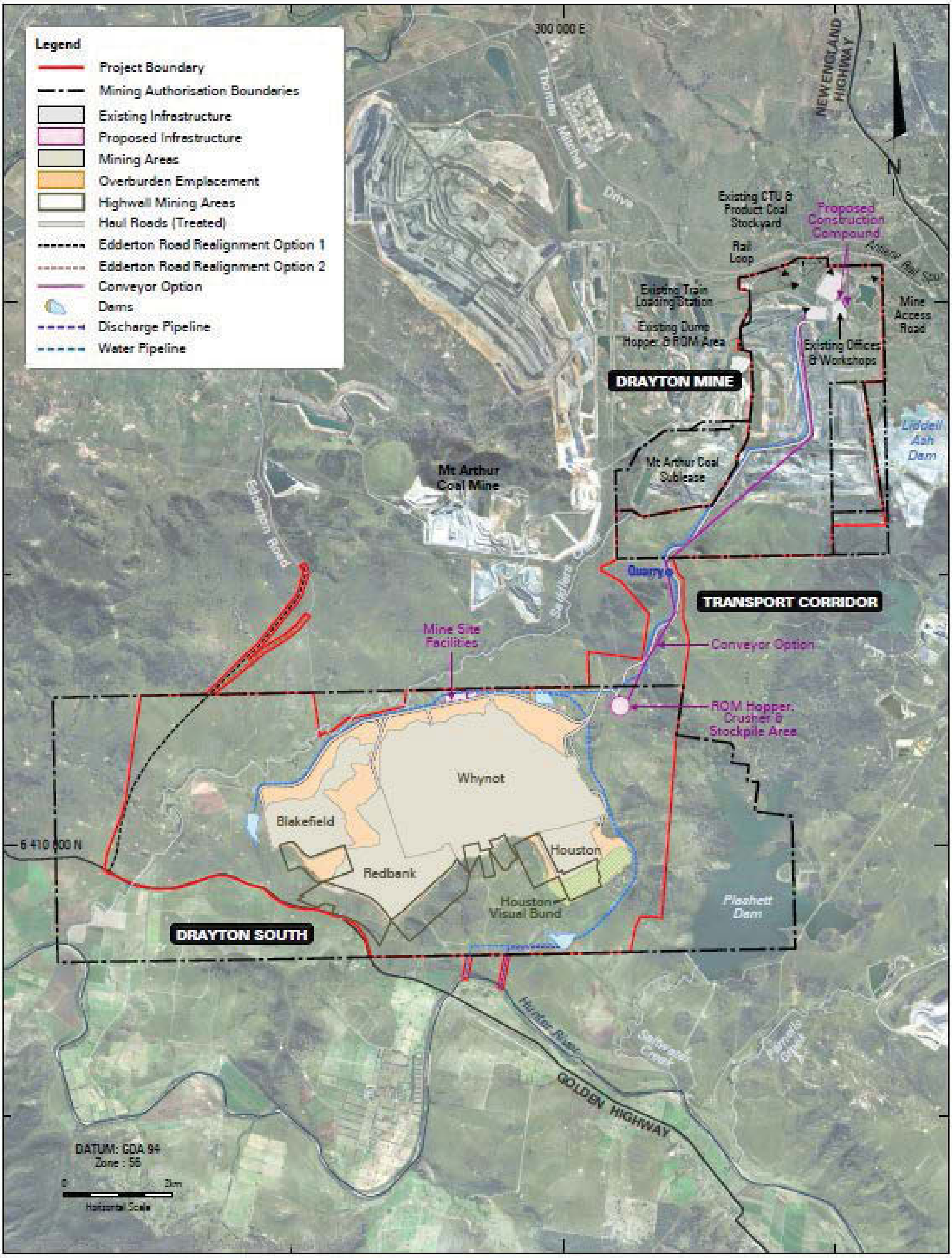

Figure 2: Conceptual Project Layout

1.2 STUDY AREA

The study area comprises an overall area of approximately 4,597 ha (Figure 2) and includes the proposed Drayton South disturbance footprint and the transport corridor. Three groundwater bore locations (MB4, MB1 and Plashett Well) situated outside the study area have also been assessed. This assessment does not address Drayton Mine.

1.3 STYGOFAUNA ECOLOGY

Stygofauna are typically represented by crustacean invertebrates that live in groundwater environments. These organisms have special adaptations to survive in the relatively resource-poor aquifers, where there is no light, space is limited, and food is scarce (Humphreys 2008). Adaptations include blindness, slow metabolism, reduced body size, elongation, and low reproduction rates (Coineau 2000). As there is no photosynthesis below ground, subterranean environments rely on inputs of organic matter from the surface to provide the basis of the food web (Schneider et al. 2011). In alluvial aquifers there are often gradients in species diversity associated with the distance from recharge areas, where dissolved or fine particulate organic matter enters the aquifer (Datry et al. 2004). Tree roots are also important sources of organic matter for groundwater food webs (Hancock and Boulton 2008, Jasinska et al. 1996).

Increasing awareness is being given to the importance of maintaining high biodiversity and ecosystem function, particularly in resource-poor environments (Dangles et al. 2011). Many ecosystem functions provide essential services to humans, saving both money and resources (Boulton et al. 2008). Despite their small size, the cumulative effect of stygofauna metabolism and movement can play an important part in maintaining groundwater quality. This process is evident in alluvial aquifers where water flowing though sediment particles is cleaned during transit, in much the same way as water moving through slow sand filters or trickle filters in water and sewage treatment (Hancock et al. 2005). It is likely that through their movement and grazing of sediment-bound microbes, stygofauna also help prevent aquifer sediments from clogging (Hancock et al. 2005).

Unlike many surface aquatic species, stygofauna have no aerial life stages, and are limited in their ability to disperse. Consequently, movement through aquifers is relatively slow and often restricted to convoluted passages between sediment grains or along fractures in rock. This also means that there is often little or no transfer of genetic material between disconnected aquifers, or even within aquifers if lenses of low hydraulic conductivity create barriers. With genetic isolation occurring in adjacent aquifers or isolated sections of the same aquifer, species may begin to evolve, resulting eventually in the development of new species (Watts et al.2007). Aquifers that have been isolated for long periods often contain several unique species of stygofauna with very limited distributions.

As aquifers are relatively stable compared to surface aquatic environments with little or no daily fluctuations in parameters such as temperature, water level, and EC, many stygofauna taxa are sensitive to rapidly changing conditions (Hancock et al. 2005). Activities such as water table draw down, the removal of aquifer material for mining or quarrying, or rapid changes to water quality can all have detrimental effects to stygofauna communities and possibly cause extinctions (Humphreys 2008).

It is a combination of the features outlined above that have driven concerns for the potential loss of stygofauna biodiversity, particularly in areas subjected to rapid and extensive anthropogenic changes. The key attributes of stygofauna that may place them at risk are:

- The adaptation to relatively stable conditions and vulnerability to rapid changes in water table level, temperature, and salinity;

- The limited ability to disperse through aquifers, and intuitively recolonise following disturbance; and
- The high degree of endemism, with entire species restricted to only small geographic areas.

Concerns over the impact of mining and other large development projects, and concerns for State responsibility to maintain biodiversity, prompted the Western Australian and Queensland Governments to require stygofauna sampling as part of Environmental Impact Assessments (WA EPA 2003, 2007). In New South Wales, a recent case in the Land and Environment Court (*Newcastle and Hunter Valley Speleological Society Inc v Upper Hunter Shire Council and Stoneco Pty Limited* (2010)) resulted in the adoption of the Precautionary Principle to ensure no stygofauna species are threatened by the operation. This case is consistent with the NSW Groundwater Dependent Ecosystems Policy (2002), which requires the use of the Precautionary Principle where management knowledge is lacking.

1.4 RELATED STUDIES

The studies which are to be read in conjunction with this assessment include the following:

- The EA groundwater impact assessment;
- The EA ecology impact assessment; and
- The EA geochemistry impact assessment.

The assessment of potential impacts on Groundwater Dependent Ecosystems is described in the ecology and groundwater impact assessments (see Appendix J and N of the EA).

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. The Act also aims to encourage ecologically sustainable development in NSW and to protect natural habitat, flora and fauna. In October 2011, Part 3A of the EP&A Act was repealed. However, the Project has been granted the benefit of transitional provisions, and as such, is a development to which Part 3A still applies.

2.1.1 Director-General's Environmental Assessment Requirements

The EA for the Project must be prepared in accordance with the Director-General's Environmental Assessment Requirements (EARs). This assessment, which forms part of the EA, addresses the EARs relating to biodiversity. Table 1 lists the EARs that are relevant to this assessment and the sections in this report where these EARs are addressed.

Table 1: Director-General's Environmental Assessment Requirements

Key Issue	Requirement	Report Section
Biodiversity	A detailed assessment of the potential impacts of the project on any terrestrial and aquatic threatened species or populations and their habitats, endangered ecological communities or groundwater dependent ecosystems	Section 4, 5, 6, 7 and 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 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.*

3 Existing Environment

3.1 GEOLOGY

The geology of the study area and its surrounds consists of a Permian coal seam sequence, the Wittingham Coal Measures, which includes the Whybrow, Redbank Creek, Wambo, Whynot and Blakefield seams. These seams are located in the upper part of the Jerrys Plains Subgroup of the Wittingham Coal Measures. The Whybrow seam is part of the Mt Leonard Formation and the remaining four seams form part of the Malabar Formation. The Mt Leonard Formation is a mainly coarse classic unit with lithologies ranging from massive sandstone to conglomerate with intercalated thin coal seams. The Malabar Formation is about 160 m thick and typically consists of sandstone, siltstone, conglomerate, coal and minor claystone.

The Permian coal seams are overlain by deposits of Quaternary soils and colluvial units (Table 2). The 1:250,000 Singleton Soil Landscape Series Sheet (SI 56-1) indicates that most of the study area is characterised by the Brays Hill soil landscape. Land in the north west of the study area associated with Saddlers Creek and its tributaries are underlain by soils of the Bayswater landscape grouping. Quaternary deposits consisting of unconsolidated silt, sand, and minor fine gravels are adjacent to Saddlers Creek and average less than 10 m thick. Alluvial deposits of the Hunter River, immediately south of the study area are up to 13 m thick and contain a basal gravel layer between 2.5 to 4 m in thickness.

Table 2: Geology of the Study Area and its Surrounds

Age	Coal Measures	Subgroup	Local Coal Seam	Lithology	Thickness (m)
Quaternary				Residual soils and colluvium units including all blanketing sandy, loamy and clay soils	0-10
Late Permian	Wittingham Coal Measures	Jerrys Plains Subgroup	Whybrow	Sandstone, conglomerate, coal seams, siltstone and claystone	2.5 - 4
			Redbank Creek		4 - 6
			Wambo		0.5
			Whynot		2
			Blakefield		2.2

3.2 HYDROGEOLOGY

3.2.1 Alluvial Aquifers

Alluvial aquifers are present along the Hunter River, Saddlers Creek, and Saltwater Creek/Plashett Dam. Saddlers Creek alluvial deposits are more extensive near their confluence with the Hunter River and consist of unconsolidated silt, sand, and minor gravels. Aquifers associated with the creeks are thin and limited in their extent, with little capacity for groundwater storage. Recharge comes from infiltrating rainfall and surface runoff from elevated bedrock sub-crop areas, as well as upward leakage from underlying coal measures. Groundwater persists for a short period after events to provide baseflow to creeks and gullies. Flow in Saddlers Creek is moderately saline, indicating its connection to underlying coal measures.

The Hunter River alluvial aquifers, to the south of the study area, are a significant source of groundwater. The alluvium is up to 13 m thick and contains basal gravel in the lower 2.5 to 4 m. Silt and clay overlies the basal gravel and the sediments contain water-bearing sand lenses. Yield from stock and irrigation bores immediately to the south of the study area ranges from 1 to 21 L/s. Bulk hydraulic conductivity is highly variable, ranging approximately from 1 m/day in silt deposits, to more than 100 m/day in wet sandy gravels. Recharge of the Hunter River alluvial aquifer during very dry periods is mostly from regulated flow along the Hunter River. The Hunter River alluvium also receives recharge from upward leakage from coal measures, infiltrating rainfall, and runoff from upslope areas. Within the aquifer, there is a gentle gradient towards the Hunter River, which acts as a regional sink to the system.

Water in the Hunter River alluvial aquifer is generally potable close to the river, but varies in salinity in more distant sediments. This is a result of saline water discharging under pressure from the coal measures. Electrical conductivity (EC) of water in the Hunter River alluvial aquifer is between 644 and 6700 μS/cm, while pH ranges from almost neutral to slightly alkaline (6.9 to 8.4).

3.2.2 Weathered Permian Aquifers

Weathered Permian aquifers are made of surficial soils and weathered rock. Aquifer depth is likely to be influenced by the depth of weathering and the extent and frequency of fracturing. Perched aquifers occur immediately to the north of the study area at the interface between soil and rock, but none have yet been recorded onsite. However, the regolith is expected to act as temporary water storage during sustained wet periods and provide limited recharge to underlying coal measures. The underlying Permian coal seams have very low hydraulic conductivities compared to the weathered section and this may result in the presence of shallow springs.

3.2.3 Permian Aquifers

Permian coal seams sub-crop on the eastern side of the study area and occur as a regular layered sedimentary sequence across the remainder of the area. The Permian strata consist of a very low yielding to dry sandstone and lesser siltstone, and low to moderately permeable coal seams. The sandstones and siltstones are very low yielding and comprise most of the interburden/overburden, while the coal seams are the main water-bearing strata in the Permian sequence. Hydraulic conductivity for the coal seams ranges from to 6.2×10^{-4} to 1.4×10^{-2} m/day for falling head tests, or 1.9×10^{-5} to 1.3×10^{-1} m/day for airlift yield tests. For the interburden, hydraulic conductivity is between 8.3×10^{-7} and 3.3×10^{-3} m/day. There is a general decline with depth in coal seam hydraulic conductivity.

Recharge to the coal seam aquifers from rainfall is limited. Water levels typically decline under drought conditions, and increase following rainfall events. Recharge occurs via seam sub-crop areas and the overlying weathered Permian strata. Groundwater flows towards the lower lying areas and discharges into the alluvial valleys and creeks, eventually entering the Hunter River.

Water quality of the coal seams is generally poor. EC has a median value of 4570 μS/cm and across the site is between 214 and 14,140 μS/cm. Median pH is 7.1, with a range of 6.2 to 12.1.

4 Desktop Assessment

4.1 PREVIOUS STYGOFAUNA SURVEYS

4.1.1 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 3).

Hyporheic zones are the area of river bed where groundwater and surface water mix, and often contain surface water, hyporheic, and groundwater taxa (Marmonier et al. 1993, 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 3). 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, and Aberdeen, and from the Goulburn River at Sandy Hollow. *Notobathynella* sp. occurred at Denman, Dights Crossing, and Aberdeen. The largest stygofaunal taxon collected was a single species (Peter Serov *pers comm.*) of the undescribed Anaspidacean family, Family A (see cover photo). 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.

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 3.

Table 3: Stygofauna Identified in the Hunter River Hyporheic Survey

Location	Alluvial Aquifer Sampled	Distance from Study Area (km)	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida
Bowman Bridge	Hunter River	<1	■	■	■		■	■	■	■	■	■
Jerrys Plains	Hunter River	11	■	■			■			■	■	■
Moses Crossing	Hunter River	12	■	■			■	■	■	■	■	■
Denman	Hunter River	14	■	■		■	■	■	■	■	■	■
Dights Crossing	Hunter River	17	■	■	■	■		■	■	■	■	■
Warkworth	Wollombi Brook	23	■	■						■	■	■
Sandy Hollow	Goulburn River	27	■	■	■					■	■	■
Aberdeen	Hunter River	30	■	■	■	■	■	■	■	■	■	■
Maison Dieu	Hunter River	30	■	■			■	■		■	■	■

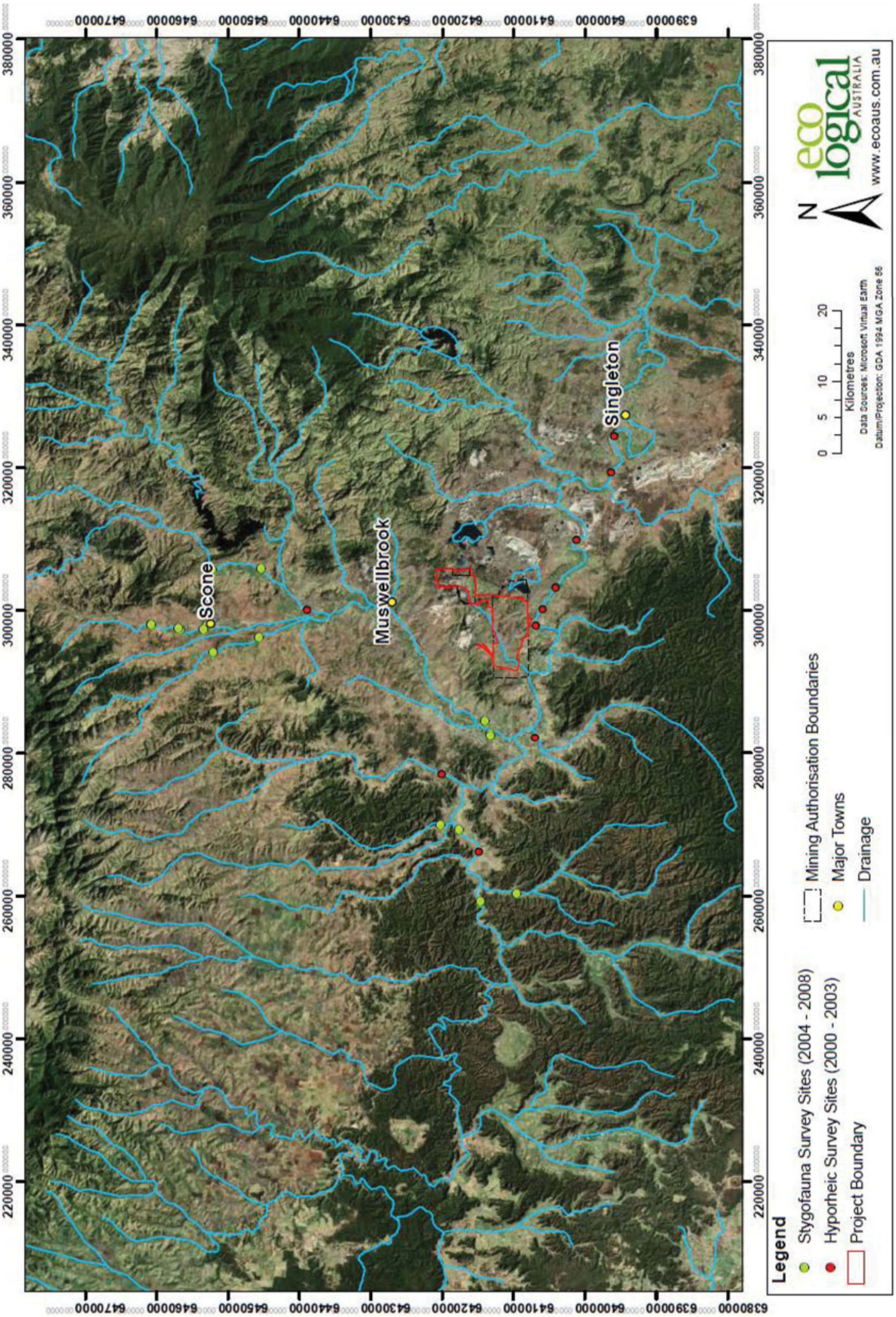

Figure 3: Location of Past Stygofauna Survey Points in the Hunter Valley

4.1.2 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 3). 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 4.

Table 4: Stygofauna Identified in the Hunter Valley Alluvial Aquifer Survey

Location	Alluvial Aquifer Sampled	Distance from Study Area (km)	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida	Eucyclops cf. ruttneri	*Diacydops cryonastes*	Diacydops sp. 1	Metacyclops sp. 1	Haplocyclops sp. 1	Elaphoidella sp. 1	Australocamptus sp. 1	Hankcockcamptus sp. 1	Huntercamptus sp. 1	Huntercamptus sp. 2	Huntervallia sp. 1	Aturidae sp. 1	Elmidae sp. 1	*Carabhydrus*	*Limnobodesis sp. nov*	*Hydrobiidae sp. nov*
Denman	Hunter River	15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓		✓	✓		✓
Muswellbrook	Hunter River	17	✓	✓				✓		✓	✓		✓	✓	✓													
Dart Brook (South)	Dart Brook	27	✓	✓				✓		✓	✓	✓																
Goulburn River	Goulburn River	30	✓		✓	✓					✓	✓																
Pages Creek	Pages Creek	36	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓	✓	✓	✓	
Dart Brook (North)	Dart Brook	42	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	
Kingdon Ponds	Kingdon Ponds	49	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓		

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.

4.1.3 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.

4.2 LIKELIHOOD OF STYGOFAUNA OCCURRING IN THE STUDY AREA

The information summarised in the desktop assessment suggests that stygofauna are likely to occur within the study area based on the proximity to known communities in the Hunter River alluvial aquifer. As such, a sampling program was developed to confirm the presence of such communities. As part of the sampling program for the Project, targeted sampling was undertaken in the section of the Hunter River and Saddlers Creek alluvial aquifers situated within the study area. No samples have been collected previously from the Saddlers Creek alluvial aquifer. Although stygofauna are unlikely to occur in the underlying Permian aquifer due to increasing depth, low hydraulic conductivity and generally high salinity, there may be areas where EC is less than 5000 μS/cm and weathering is likely to have increased the space available for stygofauna. As the Permian aquifers are the most likely to be impacted by the Project, samples were collected to confirm stygofauna inhabitance.

5 Sampling Program

5.1 METHODS

The Western Australian EPA (2003, 2007) specifies that bores selected for stygofauna sampling should be at least three months old before the first sampling. This resting period allows stygofauna to colonise the immediate vicinity of the bore following the disturbance created during construction and subsequent development. Bores are also to remain un-pumped for the three months prior to sampling to prevent the extraction of stygofauna from the bore and surrounding section of aquifer. These sampling specifications outlined by the Western Australian EPA have been used as a guide for this assessment.

During the initial sampling round, nine of the bores were less than three months old (MB01_Alluvial, MB01_Redbank, MB01_Whybrow, MB02_Alluvial, MB02_Regolith, MB03_Alluvial, MB03_Regolith, MB04_Alluvial and MB04_Regolith) and did not have a sufficient resting period between construction and sampling to allow colonisation. These bores were sampled again in October 2011 when the bores were at least three months old.

Overall, 24 bores targeting various aquifers were sampled within the study area between 5 and 8 September 2011 (Table 5). These bores are shown on Figure 4. Following completion of September sampling, nine of these bores (MB01_Alluvial, MB01_Redbank, MB01_Whybrow, MB02_Alluvial, MB02_Regolith, MB03_Alluvial, MB03_Regolith, MB04_Alluvial and MB04_Regolith) were targeted for a second round of sampling on 26 and 27 October 2011, increasing the total number of samples to 33.

Table 5: Sample Locations within the Study Area

Bore	Aquifer	Location (GDA Zone 56 H)		Date Sampled
		Easting	Northing	
DD1057	Permian	0295182	6410459	September
DD1043	Permian	0295198	6409473	September
DD1052	Permian	0296278	6408507	September
DD1015	Permian	0298827	6409899	September
DD1025	Permian	0298766	6411899	September
DD1005	Permian	0298800	6410903	September
DD1032	Permian	0297146	6412498	September
DD1014	Permian	0296799	6410865	September
DD1016	Permian	0297804	6410883	September
DD1030	Permian	0301757	6408963	September
Shearers Well	Weathered Permian	0296916	6410275	September
Shearers Well Bore	Permian	0296920	6410246	September
Bowfield Well	Saddlers Creek Alluvial	0292730	6411050	September
Bowfield House Well	Saddlers Creek Alluvial	0292693	6410966	September
MB02_Alluvial	Saddlers Creek Alluvial	0294998	6411669	September October
MB02_Regolith	Weathered Permian	0294998	6411669	September October

Bore	Aquifer	Location (GDA Zone 56 H)		Date Sampled
		Easting	Northing	
MB03_Alluvial	Saddlers Creek Alluvial	0297272	6412851	September October
MB03_Regolith	Weathered Permian	0297329	6412728	September October
MB04_Alluvial	Hunter Alluvium	0300311	6406220	September October
MB04_Regolith	Weathered Permian	0300304	6406231	September October
Plashett Well	Hunter Alluvial	0300342	6406196	September October
MB01_Alluvial	Hunter Alluvial	0297937	6407457	September October
MB01_Redbank	Permian (Redbank)	0297930	6407454	September October
MB01_Whybrow	Permian (Whybrow)	0297938	6407448	September October

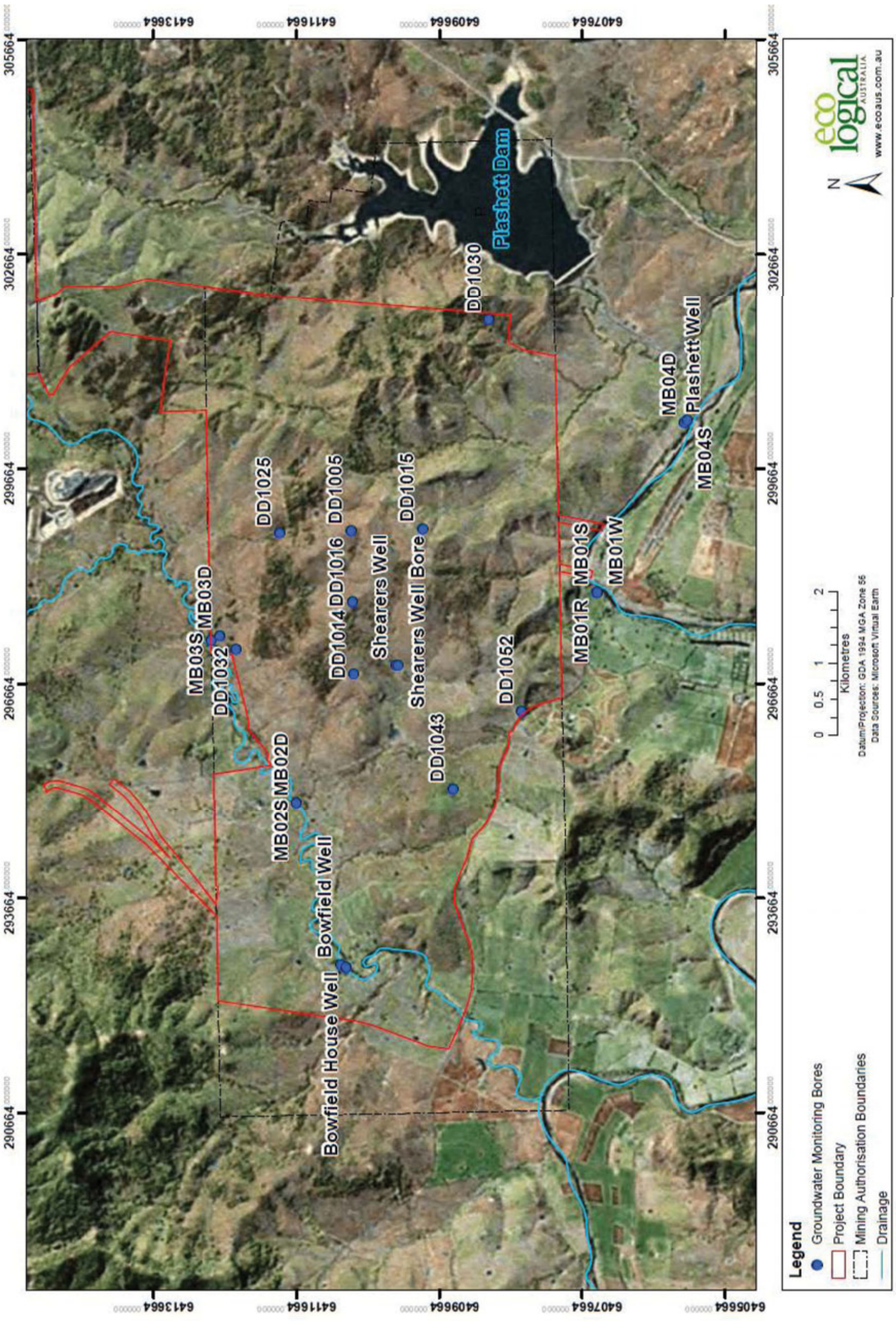

Figure 4: Sample Locations in the Study Area

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5.1.1 Sample Collection

Samples were collected using combined net and pump methods (Hancock and Boulton 2009) where conditions were suitable (i.e. if bore construction allowed, and water table was > 50 m below ground level). The combined protocol was used in cased, vertical groundwater monitoring bores with 50 to 150 mm in internal diameter. For wells and unlined bores, samples were collected using a net only.

Sampling by Net

A weighted sampling net with 50 μm mesh was lowered to the bottom of each bore. The net was raised and dropped over approximately 50 cm three to five times to dislodge resting fauna, then retrieved slowly to the surface (Plate 1). Slow retrieval is necessary to avoid a bow-wave pushing fauna from the net entrance. Once the net was at the surface, it was rinsed into a 50 μm-mesh sieve and then lowered once more to the bottom of the bore. This process was repeated until the contents of six net hauls, where possible, were retrieved. Sieve contents were washed into a sample jar containing water and labelled. Samples were kept cool in an insulated container and examined alive using a dissecting microscope at the end of each day. Following live sorting, the sample was preserved in 100% ethanol and individuals were separated for later identification upon return to the laboratory.

Plate 1: Collection of Samples by Net

Sampling by Pump

After net sampling, a hose was lowered into the bore so that the inlet was either above or below the screened section of the bore. If this was not feasible due to the screened section depth (>50 m), then the hose was lowered as far as possible below the water table. Once in place, 300 L of water was pumped into buckets (Plate 2) and subsequently poured through a 50 μm mesh sieve. This process allows mineral content entrained in the water to settle. Each bucket was elutriated through the sieve, whereby heavier sediments remained at the bottom, while water and organic matter, including fauna, were extracted. Sieve contents were then transferred to a sample jar containing water and kept cool in an insulated container.

Plate 2: Collection of Samples by Pump

Non-biological Data

Water levels were measured at each bore prior to net sampling. Groundwater pH, EC, temperature, and dissolved oxygen were recorded at 10 L, 50 L, and then every subsequent 50 L during pumping.

5.2 LABORATORY ANALYSIS

Samples were initially sorted in the field using a dissecting microscope. Specimens from each taxon were counted and separated for later identification upon return to the laboratory. These were then identified to a species level, where possible, using dissecting and compound microscopes, and available taxonomic keys. Where undescribed taxa were encountered, a morphospecies name was assigned. Many stygofauna species in NSW remain undescribed due to the lack of prior research in the region.

6 Results

6.1 WATER CHEMISTRY

During the September 2011 sampling program, the water chemistry of the Hunter River alluvial aquifer maintained a neutral pH and an EC between 982 and 4920 µS/cm (Table 6). In comparison, the EC of the Saddlers Creek alluvial aquifer ranged from 3253 to 9244 µS/cm and pH varied between 7.2 and 8.2. Water chemistry was not collected from six of the Permian bores. Values for these variables were taken from data collected by AECOM in February 2011. In the Permian aquifer, pH was between 6.7 and 9.9 while EC was between 1285 and 11230 µS/cm. The weathered section of the Permian aquifer had EC between 884 and 6070 µS/cm, and pH from 7.0 to 8.1.

Table 6: Sample Water Chemistry (September 2011)

Bore	Aquifer	EC (µS/cm)	pH	DO (%sat)	DO (mg/L)	Temp. (^{0}C)
DD1057	Permian	3644	9.9	43	3.8	22.9
DD1043	Permian	8207	7.0	40.2	3.31	23.38
DD1052	Permian	2270*	9.5*	n/a	n/a	n/a
DD1015	Permian	5260*	6.8*	n/a	n/a	n/a
DD1025	Permian	1420	6.8	48.4	4.11	20.47
DD1005	Permian	7770*	7.0*	n/a	n/a	n/a
DD1032	Permian	6822	7.9	18	1.52	22.43
DD1014	Permian	11230*	7.4*	n/a	n/a	n/a
DD1016	Permian	6260*	6.9*	n/a	n/a	n/a
DD1030	Permian	1285*	6.8*	n/a	n/a	n/a
Shearers Well	Weathered Permian	884	8.1	34.5	3.33	18.15
Shearers Well Bore	Permian	5188	6.7	31.9	2.76	20.36
Bowfield Well	Saddlers Creek Alluvial	3253	7.5	78.2	7.04	18
Bowfield House Well	Saddlers Creek Alluvial	8509	8.2	108.2	9.59	19.09
MB02_Alluvial	Saddlers Creek Alluvial	9244	7.2	5.9	0.53	18.62
MB02_Regolith	Weathered Permian	6070	7.3	9	0.84	18.03
MB03_Alluvial	Saddlers Creek Alluvial	8771	7.2	63.1	5.63	19.56
MB03_Regolith	Weathered Permian	5088	7.0	31.9	2.91	19.5
MB04_Alluvial	Hunter River Alluvial	1113	7.1	15.1	1.36	19.73
MB04_Regolith	Weathered Permian	3031	7.9	33.01	3.03	19.43
Plashett Well	Hunter River Alluvial	982	7.0	46.9	4.35	18.13
MB01_Alluvial	Hunter River Alluvial	4920	7.0	10.2	0.91	19.98
MB01_Redbank	Permian (Redbank)	6373	6.8	44.8	3.95	20.26
MB01_Whybrow	Permian (Whybrow)	5955	7.0	29.4	2.61	20.05

*Values measured by AECOM in February 2011.

n/a – data not available.

Water chemistry of the nine bores sampled in October 2011 was similar to measurements recorded in September (Table 7).

Table 7: Sample Water Chemistry (October 2011)

Bore	Aquifer	EC (µS/cm)	pH	DO (%sat)	DO (mg/L)	Temp. (^{0}C)
MB02_Alluvial	Saddlers Creek Alluvial	8393	7.27	11.1	1.01	18.12
MB02_Regolith	Weathered Permian	6224	7.43	4.5	0.4	19.21
MB03_Alluvial	Saddlers Creek Alluvial	8536	7.24	17.8	1.69	18.17
MB03_Regolith	Weathered Permian	5286	7.05	8	0.72	19.97
MB04_Alluvial	Hunter River Alluvial	1027	7.08	14.7	1.32	20.15
MB04_Regolith	Weathered Permian	2803	7.96	6.6	0.59	20.18
MB01_Alluvial	Hunter River Alluvial	5163	7.1	16.9	1.51	19.57
MB01_Redbank	Permian (Redbank)	6283	7.21	44.9	4.02	19.38
MB01_Whybrow	Permian (Whybrow)	6242	7.1	40.2	3.53	20.57

6.2 STYGOFAUNA COMMUNITIES

Aquatic invertebrates were collected from Shearers Well, Bowfield House Well and MB02_Alluvial during September 2011.

Fauna in both of Shearers Well and Bowfield House well consisted solely of surface crustaceans, probably introduced to the wells as wind-dispersed eggs. These invertebrates are not stygofauna and therefore are not considered further in this report.

MB02_Alluvial contained two stygofauna taxa (Table 8). A partial specimen of Ostracoda was collected using the pump. Only the external valves of the carapace were present so it was not possible to identify this specimen further. The second taxon collected was a cyclopoid copepod. This was identified as *Diacyclops* sp. using keys and descriptions in Dussart and Defae (2001) and Karanovic (2006) but the species differed to those listed. This species may be representative of the genus *Diacyclops*, which was collected from monitoring bores in the Hunter River alluvial aquifer near Denman and Muswellbrook in 2008, and from bores in the Pages Creek, Dart Brook, and Kingdon Ponds alluvium (P. Hancock unpublished, Tom Karanovic *pers comm.*). These earlier specimens collected by previous regional studies have been sent to a taxonomic specialist and await description, and at this stage are not accessible for direct comparison to that recorded in the study area.

No stygofauna were collected from the nine bores during October 2011.

Table 8: Stygofauna Sample Results

Bore	Aquifer	Ostracoda	Cyclopoida
DD1057	Permian	-	-
DD1043	Permian	-	-
DD1052	Permian	-	-
DD1015	Permian	-	-
DD1025	Permian	-	-
DD1005	Permian	-	-
DD1032	Permian	-	-
DD1014	Permian	-	-
DD1016	Permian	-	-
DD1030	Permian	-	-
Shearers Well	Weathered Permian	-	-
Shearers Well Bore	Permian	-	-
Bowfield Well	Saddlers Creek Alluvial	-	-
Bowfield House Well	Saddlers Creek Alluvial	-	-
MB02_Alluvial	Saddlers Creek Alluvial	1	1
MB02_Regolith	Weathered Permian	-	-
MB03_Alluvial	Saddlers Creek Alluvial	-	-
MB03_Regolith	Weathered Permian	-	-
MB04_Alluvial	Hunter River Alluvial	-	-
MB04_Regolith	Weathered Permian	-	-
Plashett Well	Hunter River Alluvial	-	-
MB01_Alluvial	Hunter River Alluvial	-	-
MB01_Regolith	Permian (Redbank)	-	-
MB01_Whybrow	Permian (Whybrow)	-	-

The presence of *Diacyclops* sp. and evidence of Ostracoda in MB02_Alluvial, indicate that stygofauna are present in the Saddlers Creek alluvial aquifer and have started to colonise the area around the newly installed bores. Considering the young bore age, it is unlikely that the sample collected from MB02_Alluvial is representative of the aquifer community.

Table 9 assesses the likelihood that the bores sampled within the study area contain stygofauna, even if not detected in the September or October 2011 sampling period. The likelihood assessment is based on known hydrogeological and biological information.

Table 9: Likelihood of Stygofauna Presence

Bore	Aquifer	Likelihood	Reason
DD1057	Permian	Unlikely	Hydraulic conductivity too low. Too isolated for sufficient colonisation from alluvium.
DD1043	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen. Too isolated for sufficient colonisation from alluvium.
DD1052	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen. Too isolated for sufficient colonisation from alluvium.
DD1015	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen. Too isolated for sufficient colonisation from alluvium.
DD1025	Permian	Unlikely	Hydraulic conductivity too low. Too isolated for sufficient colonisation from alluvium.
DD1005	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen.
DD1032	Permian	Unlikely	Hydraulic conductivity too low.
DD1014	Permian	Unlikely	Water too salty. Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen.
DD1016	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen.
DD1030	Permian	Unlikely	Hydraulic conductivity too low. Water table too far below land surface for sufficient transfer of organic matter and oxygen.
Shearers Well	Weathered Permian	Unlikely	Hydraulic conductivity too low. Too isolated for sufficient colonisation from alluvium.

Bore	Aquifer	Likelihood	Reason
Bowfield Well	Saddlers Creek Alluvial	Possible	Stygofauna may be present in the groundwater near this well although animals are unlikely to survive in the open well environment because of competition.
Bowfield House Well	Saddlers Creek Alluvial	Possible	Stygofauna are known from this aquifer and may be present near this well.
MB02_Alluvial	Saddlers Creek Alluvial	Confirmed	Sampling detected 2 species.
MB02_Regolith	Weathered Permian	Possible	Stygofauna are known from overlying aquifer, so may be present in the Permian if there is a sufficient connection.
MB03_Alluvial	Saddlers Creek Alluvial	Possible	Stygofauna are known from this aquifer and may be present near this bore.
MB03_Regolith	Weathered Permian	Possible	Stygofauna are known from overlying aquifer, so may be present in the weathered Permian if there is a sufficient connection.
MB04_Alluvial	Hunter Alluvium	Likely	Stygofauna are known from the Hunter River alluvial aquifer
MB04_Regolith	Weathered Permian	Possible	Stygofauna occur in the Hunter River alluvium and may also be present in the weathered Permian beneath this aquifer if there is good connectivity
Plashett Well	Hunter Alluvial	Likely	Stygofauna are known from the Hunter River alluvial aquifer
MB01_Alluvial	Hunter Alluvial	Likely	Stygofauna are known from the Hunter River alluvial aquifer
MB01_Redbank	Permian (Redbank)	Unlikely	Unlikely to have stygofauna because of low porosity
MB01_Whybrow	Permian (Whybrow)	Unlikely	Unlikely to have stygofauna because of low porosity

7 Impact Assessment

7.1 POTENTIAL IMPACTS TO STYGOFAUNA

The vulnerability of stygofauna to impacts from development stems mainly from their lack of ability to adapt to rapid environmental change, their limited dispersal ability and the often restricted range of many species (Hancock et al. 2005, Finston et al. 2004). The Project could pose the following impacts to stygofauna:

- Reduction in water levels in regional aquifers through mine dewatering, seepage into mining areas and fracturing of confining layers. Modifications to drainage patterns at the land surface can also cause changes to the recharge regime. This can strand fauna if draw down occurs too rapidly, or reduce hydrological connectivity with surface environments and disrupt food webs;
- Removal of aquifer matrix, either through coal removal or the removal of overlying or adjacent sedimentary aquifers; and
- Reduction in water quality through increased linkages with aquifers of poor water quality, or through other means such as seepage of acids or heavy metals from overburden.

Each of these potential impacts is discussed below with regard to the Project.

7.2 CHANGES TO GROUNDWATER LEVEL AND RECHARGE REGIMES

As mining proceeds, draw down will occur at a greater rate than the recharge of the coal measures because of groundwater seepage into the mining area during extraction. Draw down is predicted within the Saddlers Creek alluvial aquifer as a result of cumulative impacts associated with the Project and the Mt Arthur Coal mining operations. A 2 m draw down is anticipated along the length of Saddlers Creek upstream from a position that is proximal to the current Edderton Road easement (approximately 6 km) (AGE 2012).

The cumulative impacts of the Project and the Mt Arthur Coal mining operations will also affect the upward flux of water entering the Saddlers Creek alluvium from the Permian aquifer. The pre-mining flux of water into the Saddlers Creek alluvium is approximately 0.31 ML/day. This influx rate will be reduced to about 0.12 ML/day by the Mt Arthur Coal Mine operations. The Project will further influence the Saddlers Creek alluvium potentially reducing the residual influx of water to zero (AGE 2012).

In the southern reaches of Saddlers Creek near the confluence of the Hunter River, it is predicted that the alluvium will continue to receive groundwater from the underlying Permian aquifer during peak mining activities associated with the Project and the Mt Arthur Coal Mine operations. The alluvium will also be recharged predominantly through rainfall, which may improve the groundwater quality (AGE 2012).

Infiltrating rainfall or water from creeks or rivers often brings with it organic matter and oxygen to fuel aquifer food webs. Changing surface topography can change the timing, location, and intensity of groundwater recharge. The rate of recharge over the Permian bedrock (sandstone/siltstone) is considered to be lower than the alluvial deposits and areas of coal seam sub-crops. This is a result of the low permeability of the bedrock material, which does not typically harvest significant quantities of water (AGE 2012).

A reduction in the seepage flux from the Permian aquifer and the effects of draw down may degrade or diminish the local habitat required for known stygofauna in the Saddlers Creek alluvium. Known stygofauna were identified at MB02_Alluvial at 5 m below ground level from the 2011 sampling program and as a result are expected to be impacted by the draw down.

The groundwater model indicates that the zone of depressurisation extends further to the south of the study area within proximity of the Hunter River but not measurably beneath the alluvium (AGE 2012). Subsequently, there will be very limited, if any, impact to the Hunter River alluvium and associated stygofauna as a result of the Project.

7.3 REMOVAL OF AQUIFER MATERIAL

Declining water tables can exacerbate habitat loss through the removal of the physical part of the aquifer. In cases where the coal seams themselves are habitat to stygofauna, mining poses a direct impact to any animals endemic to the area. Material may also be removed from aquifers overlying or adjacent to target strata during excavation.

Within the study area, mining will impact the Permian aquifers. No stygofauna are known and are unlikely to occur in the Permian strata, therefore no critical habitat will be removed by mining the targeted coal seams. Mining will not remove any material associated with the Saddlers Creek and Hunter River alluvial aquifer.

7.4 CHANGES TO WATER CHEMISTRY

7.4.1 Electrical Conductivity

The main water quality variable likely to impact stygofauna is EC. Hancock and Boulton (2008) observed that, although there are exceptions, most stygofauna taxa occurred when EC was less than 5000 µS/cm. Along the Hunter River alluvial aquifer, groundwater EC is between 644 and 6700 µS/cm with water becoming more saline with distance from the main channel (AGE 2012). As the Project is not expected to draw down on the Hunter River alluvial aquifer, the EC range is not expected to measurably change and therefore stygofauna communities associated with this aquifer are not likely to be impacted.

The EC for the Saddlers Creek alluvial aquifer is between 8530 and 9180 µS/cm. Due to the expected depressurisation of Saddlers Creek alluvial aquifer as a result of the Project and cumulative impacts, there may be a reduction in saline water influx. This change in water quality is likely to have no significant impact on stygofauna.

7.4.2 Overburden and Rejects

Overburden and most coal rejects from mining are likely to be benign, with low sulphur content and negligible acid-generating properties. Runoff and seepage from overburden and rejects emplacement areas will be slightly alkaline and contain low and moderate concentrations of soluble salts, respectively. The salinity of runoff and seepage from these materials is expected to decrease with time (RGS, 2012).

The concentration of total metals in overburden materials is well below applied guideline criteria for soils. The concentration of trace metals in runoff and seepage from most overburden and coal reject material is likely to be low with some minor exceptions (molybdenum and selenium). Overall, the risk of water quality impacts from overburden and coal reject materials is low (RGS, 2012).

Based on the geochemistry of overburden and coal reject material, leachate is unlikely to impact on stygofauna that are known to occur in the area.

8 Conclusions and Recommendations

The desktop assessment of previous stygofauna sampling in the Hunter Valley concluded that stygofauna are known from the Hunter River alluvium. Following the sampling program for the Project stygofauna were also confirmed in the Saddlers Creek alluvial aquifer within the study area. The two taxa collected from the Saddlers Creek alluvial aquifer are not endemic to the aquifer.

Due to the depth of the water table, the low hydraulic conductivity and the isolation of the deeper Permian aquifers, these areas were considered unsuitable for stygofauna habitat. Sampling in September 2011 found no stygofauna in Permian bores, and further sampling of these bores is unlikely to yield any fauna.

The Saddlers Creek alluvial aquifer is the only known stygofauna habitat likely to experience impacts from the Project and other mining operations. Impacts are likely to include reduced input from upwelling Permian water and depressurisation of parts of the Saddlers Creek aquifer as a result of mining activities.

The alluvial aquifer of Saddlers Creek appears to be sparsely populated with stygofauna. All stygofauna collected from the aquifer are known from other locations, and there is no threat posed to any rare or significant stygofauna taxa. There are likely to be species living in the aquifer that have not yet been collected, however the Project is only anticipated to have a minimal impact on the aquifer and will pose no threat to the stygofauna community. As such no further stygofauna sampling or mitigation measures are recommended for the Project.

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