LIDDELL COAL OPERATIONS

APPENDIX J

Liddell Coal Mine Extension Aquatic Ecology and Groundwater Dependent Ecosystem Assessment (Eco Logical Australia 2013)

APPENDICES

Liddell Coal Mine Modification 5 - Aquatic Ecology and Groundwater Dependent Ecosystem Assessment

Prepared for
Liddell Coal Operations Pty Ltd

July 2013

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Executive Summary

Eco Logical Australia (ELA) has been commissioned by Liddell Coal Operations (LCO) to provide an assessment of types of groundwater dependent ecosystems and the current aquatic communities and habitats on-site. This assessment included:

- A desktop review of databases and existing reports to determine whether any threatened aquatic species occur on-site, and the likelihood of there being groundwater dependent ecosystems (GDEs) present.
- Field surveys of macroinvertebrates, fish, creek habitat, riparian zone, and aquifer fauna (stygofauna) communities to establish baseline condition. This is needed to determine what measures are required to maintain or improve aquatic biodiversity values.
- An indication of whether the proposed operations are likely to impact on key aquatic or groundwater dependent ecosystems or processes.
- Recommendations for monitoring aquatic and groundwater dependent communities.

In July 2012, two sites on Bayswater Creek, three sites on Bowmans Creek, and five bores in the Bowmans Creek alluvial aquifer were sampled.

No threatened aquatic species or ecological communities were previously known from the study area, and none were collected during these surveys. Three species of fish were collected from both Bowmans and Bayswater Creeks. These were the pest species Mosquitofish (*Gambusia holbrooki*), Marbled Eels (*Anguilla reinhardtii*), and Flathead Gudgeons (*Philypnodon grandiceps*). A female platypus (*Ornithorhyncus anatinus*) was captured at the downstream site in Bowmans Creek.

The ecological condition of Bayswater Creek is poor, with the invertebrate community dominated by pollution-tolerant taxa. The riparian zone was dominated by a single species, *Casuarina cunninghamiana*, and at the downstream site dissolved oxygen was just 47 % saturation, well below ANZECC Guidelines. Electrical conductivity at the two Bayswater Creek sites was greater than 4,100 μS/cm, so also exceeded the ANZECC Guidelines

In contrast, Bowmans Creek was in a moderate ecological condition, with a mix of tolerant and sensitive invertebrate taxa. Electrical conductivity was 771 μS/cm at the upstream site and increased to 997 μS/cm at the downstream site. Turbidity was only 1.65 NTU at the upstream site, and increased to 6.47 NTU at the middle site, BC3. This may be a result of surrounding agricultural activity.

The main GDE in the study area is the alluvial aquifer of Bowmans Creek. Sampling of five bores collected 10 invertebrate taxa. This is likely to be only a small part of a larger stygofauna community. Although none of the taxa collected were endemic to the Bowmans Creek aquifer, a single round of sampling is unlikely to be sufficient to collect all taxa present. Further sampling may collect endemic species.

The proposed modification is anticipated to result in drawdown of a maximum of 1.4 m for a relatively small section of aquifer, with drawdown of 0.5 to 1 m extending for a length of approximately 3 km. This is unlikely to have a significant impact on stygofauna communities, as there will still be more than 8 m of saturated sediments over most of the aquifer.

The estimated loss in groundwater flow is not expected to significantly alter the flow regime of Bowmans Creek. The creek currently experiences periods of no flow, so as long as periodic flow is occurs, there will be no long-term impacts on aquatic communities since most species have strategies that allow them to migrate to refuge areas or persist in desiccation-resistant life stages.

Following this assessment, three steps are recommended to monitor the ecological conditions of groundwater dependent and riverine ecosystems:

- Seasonal monitoring of in-stream and riparian ecological condition to ensure that aquatic communities and processes are not adversely impacted by dewatering or other activities. These surveys should conform to NSW Australian Rivers Assessment Scheme (AUSRIVAS) and should also include monitoring at reference sites.
- Prior to dewatering, at least one more round of stygofauna sampling should be conducted in the Bowmans Creek alluvial aquifer to establish baseline composition of the stygofauna community. Surveys should be conducted in spring/summer and include a re-sampling of the July bores.
- Once dewatering begins to affect the alluvial aquifer, stygofauna populations should be monitored every six months to ensure populations are stable. Monitoring should occur at bores inside the proposed area of aquifer dewatering, as well as in reference sites outside of it.

1 Background

1.1 PROJECT BACKGROUND

The Liddell Coal Operation is an open cut coal mine located approximately 25 kilometres northwest of Singleton, NSW, on the boundary of the Muswellbrook and Singleton Local Government Areas (LGAs) in the Hunter Central Rivers Catchment Management Authority (CMA) area.

1.2 PROPOSED MODIFICATION

LCO currently has approval to conduct mining operations until the end of 2023 within the approved mining footprint illustrated in Figure 1. Coal reserves have been identified outside of this footprint and within the development consent boundary. LCO therefore propose to extend the existing open cut mining operations to enable continuity of mining and maximise recovery of coal resources in the existing development consent boundary.

LCO are therefore seeking approval to modify DA 305-11-01 to allow for this extension of mining activities, with the primary objectives of the Project to:

- Develop the on-going open cut mining operations with a focus on maximising resource recovery within the existing development consent and mining lease boundaries;
- Maintain continuity of coal production, and subsequently secure on-going employment opportunities and socio-economic flow-on benefits; and
- Continue to conduct mining at Liddell in an environmentally responsible manner to ensure the potential for adverse impact is minimised.

The key components of the Project, as illustrated in Figure 1, include the following:

- **Expansion of the open cut mining -** Extension of the South and Entrance Pits to the south east, and, upon completion of mining in these pits, the mining of coal resources under the Mine Infrastructure Area (MIA). LCO currently has approval to conduct open cut mining operations in a number of pit areas. The proposed modification involves an expansion of the approved mining.

- **Extension to the Life of Mine** – The extension of open cut mining activities will lead to an associated extension of the life of mine at LCO from 2023 to 2028.

- **Additional Tailings Emplacement Areas** – A tailings emplacement area will be constructed within the final void of the South Pit to dispose of the additional tailings associated with the extension of open cut mining activities. Temporary tailings evaporation cells will be established in the overburden dumps of the South Pit to improve dewatering of the tailings for rehandle and final co-disposal within the overburden dumps.

- **Coal Processing** – Coal will continue to be processed at the LCO CHPP at the approved rate of up to 8 Mtpa. Coal will however no longer be received from, or sent to, the Cumnock CHPP for processing as currently approved under DA 305-11-01, as this CHPP has been demolished following the cessation of mining operations at Cumnock No. 1 Colliery. LCO seek to maintain a contingency for coal processing in the event of downtime at the LCO CHPP, and therefore instead propose delivery of up to 1.5 Mtpa of ROM coal to Ravensworth Central Coal Processing facility (RCPP) for washing and despatch via rail from the Ravensworth Coal Terminal (RCT). In addition, up to 2 Mtpa may be received from Mt Owen for processing.

- **Minor additional infrastructure**:
  - Construction and commissioning of a transfer point and conveyor connected to the existing Mt Owen/Glendell/Macquarie Generation conveyor is proposed, enabling LCO receive material from Mt Owen via the existing conveyor system. The new conveyor will deliver/take ROM coal to/from a new 50,000 tonne stockpile; and
  - Infrastructure and auxiliary surface disturbance to support the new mining areas will be required, including but not limited to, powerlines, water management infrastructure and haul roads.

The proposed works lie wholly within both the existing development consent boundary and the mining lease ML 1597 boundary. No changes are proposed to the approved operating hours, mining method, or mining equipment, which will remain as approved under DA 305-11-01, as modified.

1.3 OVERVIEW OF FLOW IN BOWMANS AND BAYSWATER CREEKS

Bayswater Creek flows south-east through the Liddell Coal Operations, from Lake Liddell to its confluence with Bowmans Creek. Bayswater Creek flows continuously, but has a low flow rate due to the influence of Lake Liddell, which intercepts water in the upper two thirds of the Bayswater Creek catchment (SKM 2013). The bed of the creek is generally composed of soft sand and silt sediments.

Bowmans Creek is the other major surface water system at Liddell. Bowmans Creek is a small gravel and cobble bed stream that flows from north to south along the eastern edge of Liddell. Downstream of Liddell, Bowmans Creek joins with Bowmans Creek and then flows into the Hunter River. Bowmans Creek is hydrologically connected to the underlying alluvial and receives approximately 20 to 25 % of its flow from groundwater (SKM 2013). Although permanent in the lower reaches near the Hunter River, Bowmans Creek near Liddell has no measurable surface flow approximately 35 % of the time (SKM 2013).

Historical underground mining in the LCO area has already had some impact on Bowmans Creek. Impacts have included leakage from the creek into depressurised seams, and leakage in areas damaged by subsidence (SKM 2013).

1.4 SUMMARY OF THE GROUNDWATER ENVIRONMENT AT LIDDELL

Groundwater occurs on-site in two aquifer types: the alluvial sediments associated with Bowmans Creek, and the deeper coal seam aquifers. The alluvial aquifer is the most suitable habitat for stygofauna (groundwater animals) because of the shallow water table, high hydraulic conductivity, and low electrical conductivity.

The alluvium associated with Bowmans Creek is approximately 500 to 700 m wide at Liddell and 18 m thick (SKM 2013). Sediments comprise of highly porous sand, loam, and coarse gravels with varying permeability. The alluvial deposits generally occur in three layers, with coarser sand and cobble material at the base overlain by finer grained levee deposits and, floodplain deposits (SKM 2013). In places, the finer material at the top of the strata can act as a confining layer.

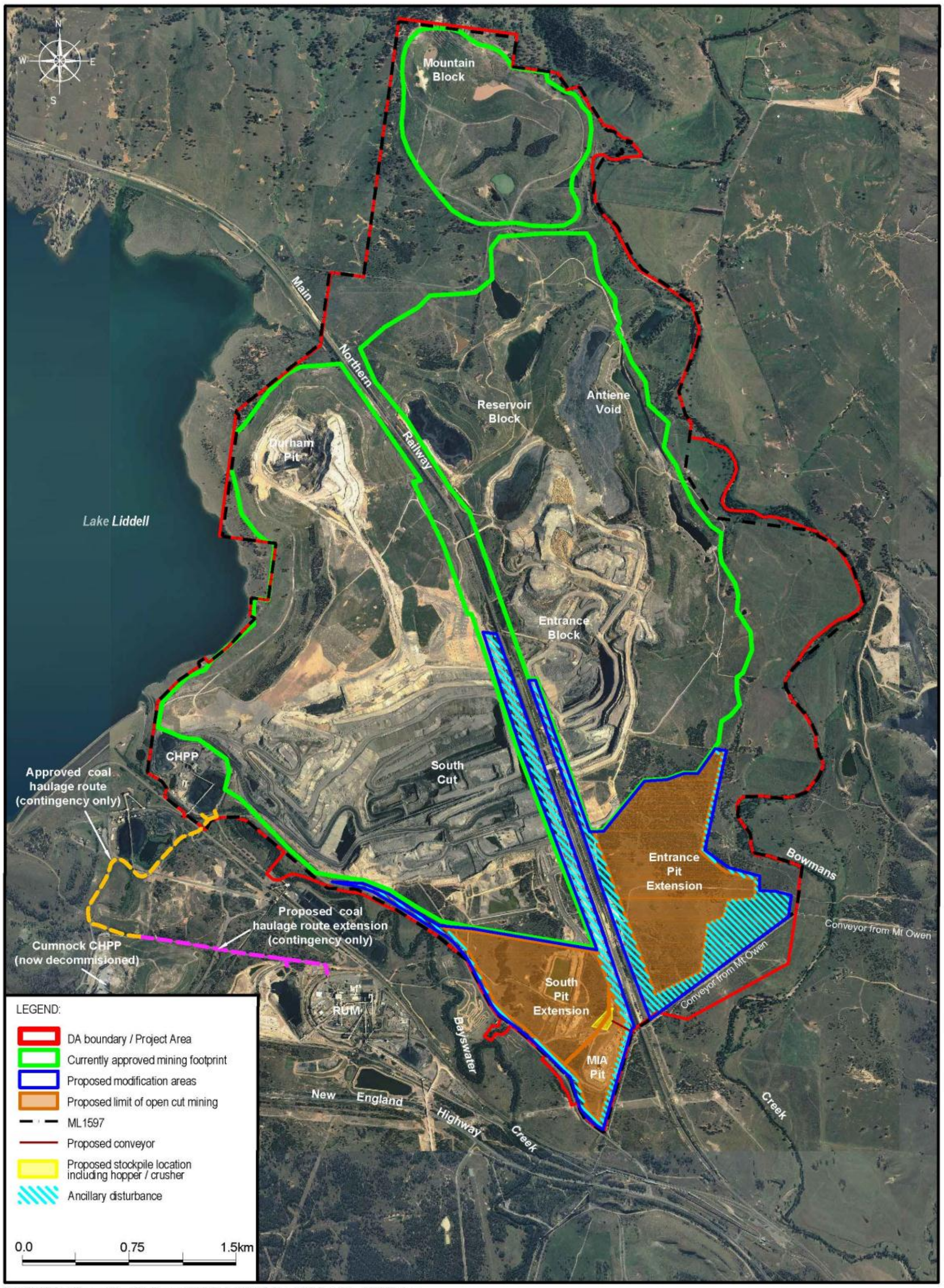
Generally the alluvial aquifer is recharged from rainfall, with water level rising several metres during rain periods, and has a shallow hydraulic gradient towards the creek and in a downstream direction (Mackie

Environmental Research 2001). There is a strong hydraulic connection between the aquifer and the creek, and aquifer water levels respond rapidly (within a day) to rises in creek level.

Water in the alluvium of Bowmans Creek has a low electrical conductivity, with localised increases at points of potential leakage from the underlying coal measures (Mackie Environmental Research 2001).

Permian sediments underlie the alluvial aquifer and consist of coal measures as the primary water storage areas. Hydraulic conductivity of the coal measures is very limiting, with little fracturing or jointing. Hydraulic conductivity is generally between $<1 \times 10^{-5}$ and 1.2×10^{-2} m/day (Mackie Environmental Research 2001). Water in the coal seams is generally brackish to saline with electrical conductivities in most areas exceeding 5000 μS/cm.

Figure 1. Site layout and proposed extensions at Liddell Mine.



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GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Project Area
FIGURE 2

1.5 DIRECTOR GENERALS REQUIREMENTS

The Director Generals Requirements for the Liddell Mine Extension (DA 305-11-01 Mod 5) were released on 15 February 2012. Among the key biodiversity requirements are the needs to assess potential impacts of the project on any aquatic threatened species, populations, or their habitats; the riparian vegetation; and groundwater dependent ecosystems. Liddell Coal Operations also need to provide a description of measures to maintain or improve the biodiversity values of the surrounding region.

Groundwater Dependent Ecosystems (GDE) are described in the NSW GDE Policy (DLWC, 2002) and can include terrestrial vegetation, base flow in streams, aquifer and cave ecosystems and wetlands. While most GDE assessments for mining projects over the past five years have focussed on wetlands and base flow in streams, the last 12 months has seen the NSW Office of Water (NOW) increasingly seeking assessment of aquifer ecosystems..

ELA has been asked to provide an assessment of the current aquatic communities and habitats on-site, and will make an assessment of the types of groundwater dependent ecosystems present. This assessment will include:

- A desktop review of databases and existing reports to determine whether any threatened aquatic species occur on-site, and the likelihood of there being groundwater dependent ecosystems present.
- Field surveys of macroinvertebrates, fish, creek habitat, riparian zone, and aquifer fauna (stygofauna) communities to establish baseline condition. This is needed to determine what measures are required to maintain or improve aquatic biodiversity values.
- An indication of whether the proposed operations are likely to impact on key aquatic or groundwater dependent ecosystems or processes.
- Recommendations for monitoring aquatic and groundwater dependent communities.

1.6 POLICY BACKGROUND

1.6.1 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.

The EA for the Project must be prepared in accordance with the Director-General’s Environmental Assessment Requirements (EARs). This assessment forms a component of the EA that is required to enable the Project to be assessed under Part 3A of the EP&A Act. The EARs outline that LCO is to provide:

- A detailed assessment of the potential impacts to aquatic threatened species or populations and their habitats, endangered ecological communities, riparian vegetation, or groundwater dependent ecosystems; and
- A detailed description of the measures that would be implemented to maintain or improve biodiversity values of the surrounding region in the medium to long term.

1.6.2 NSW State Groundwater Policy 2002

The *NSW State Groundwater Policy 2002* has three parts. Of relevance to GDEs are:

- *Groundwater quality protection management principles (related to ecology):*
  - *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;*
  - *GDEs will be afforded protection;*
  - *Cumulative impacts should be recognised; and*
  - *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.*
- *The ecological processes and biodiversity of GDEs must be maintained or restored using the following principles:*
  - *Threats should be identified and action taken to protect them;*
  - *Groundwater extractions should be managed within the sustainable yield of aquifers;*
  - *Priority should be given to providing sufficient groundwater for identified GDEs;*
  - *Where information is lacking, the precautionary principle should be applied; and*
  - *Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality, and rehabilitating degraded groundwater ecosystems.*
- *Groundwater quantity protection should ensure the:*
  - *Efficient, equitable and sustainable use of the State's groundwater;*
  - *Prevent, halt and reverse degradation of the State's groundwater and their dependent ecosystems; and*
  - *Provide opportunities for development which generate the most cultural, social and economic benefits, within the context of environmental sustainability.*

1.6.3 NSW Groundwater Dependent Ecosystems Policy 2002

The NSW GDE 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 for managing GDEs:

- *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 GDEs.*
- *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 GDEs 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 GDEs. 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 GDEs 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.*

1.6.4 Guidelines for the management of stream/aquifer systems in coal mining developments – Hunter Region

These guidelines were developed in accordance with the *Water Management Act* 2000 and the *EP&A Act 1979,* to reduce the risk of mining-induced impacts to streams and alluvial aquifers (DIPNR 2005). The objectives of these guidelines include:

- The protection of riverine integrity, which involves retention of environmental and use values, maintenance of the river system within its geomorphic boundaries and of its geomorphic character, and protection of dependent ecosystem values.
- Ensuring minimal adverse impact on stream flows, and groundwater availability due to mining activities.
- Maintaining water quality within acceptable limits. This includes maintaining groundwater quality within its current beneficial use class, and surface water quality within its background limits of variability. This includes salinity, pH, and trace metals.
- Ensuring the integrity of the landform and barrier land to alluvial floodplains and river systems remains into the post-mining period.

2 Desktop assessment

2.1 AQUIFER ECOSYSTEMS IN THE HUNTER VALLEY

No stygofauna are currently known from the project area, but there are many species widespread throughout the Hunter River alluvial aquifer and its tributary aquifers. The alluvial aquifer of Bowmans Creek has similar water quality and sediment characteristics to other aquifers in the region with stygofauna, so it is suitable habitat for groundwater fauna and is likely to be a groundwater dependent ecosystem.

2.1.1 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 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 (**Figure 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, 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. 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 1**.

Table 1: 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	✓	✓			✓	✓		✓	✓	✓

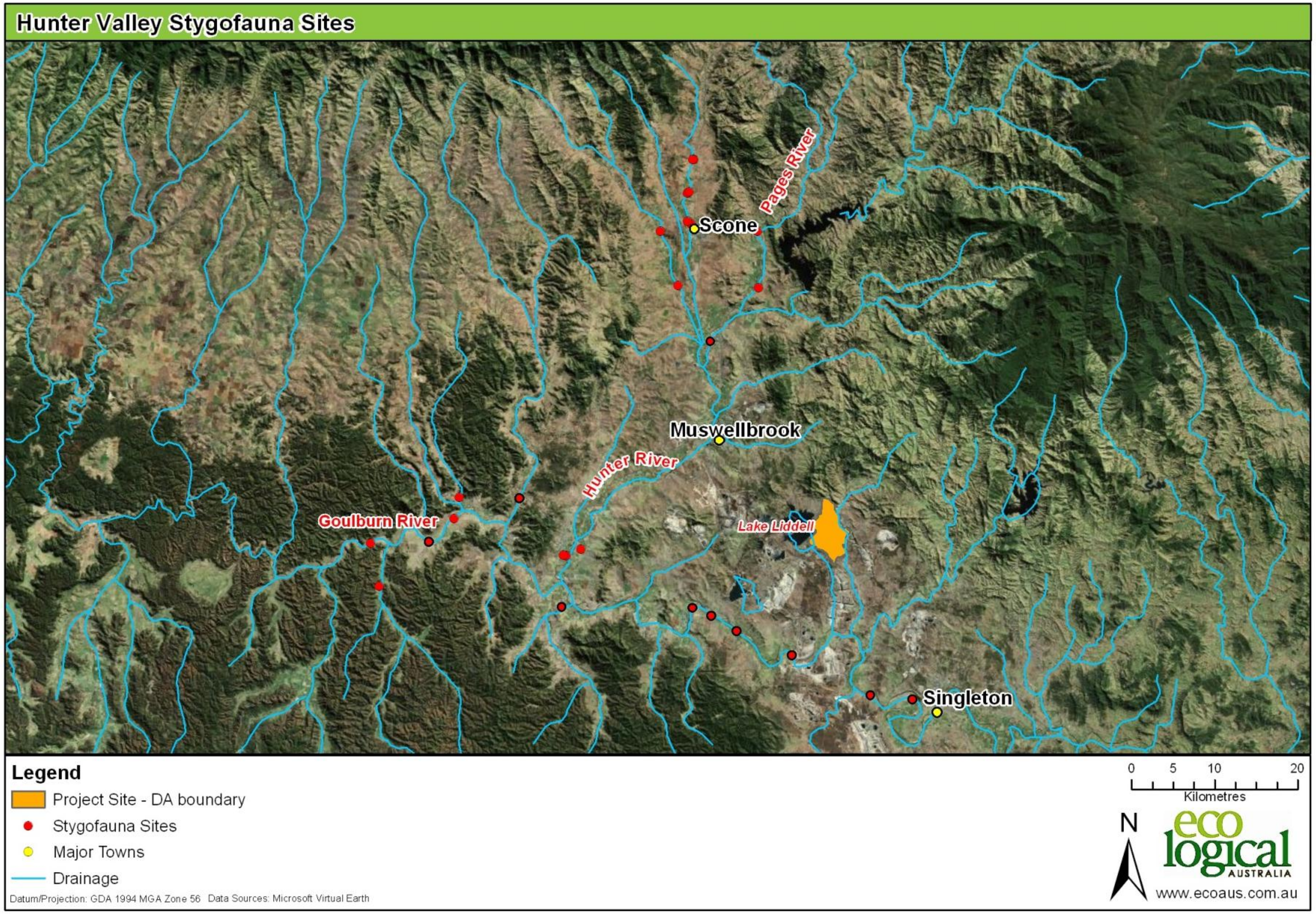

Figure 2: Location of past stygofauna survey points in the Hunter Valley.

2.1.2 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 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 2**.

Table 2. 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.

2.1.3 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.

2.2 OTHER GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater dependent River Redgum (*Eucalyptus camaldulensis*) communities are known from two locations along Bowmans Creek downstream of the New England Highway (MPR 2009). No Red gum communities are known from the Project Area (Umwelt 2006).

Generally the alluvial aquifer is recharged from rainfall, rising several meters during rain periods, and has a shallow hydraulic gradient towards the creek and in a downstream direction (Mackie Environmental Research 2001). There is a strong hydraulic connection between the aquifer and the creek, and aquifer water levels respond rapidly (within a day) to rises in creek level. Bowmans Creek is therefore a 'river baseflows' type of groundwater dependent ecosystem under the NSW GDE Policy (2002).

2.3 THREATENED AQUATIC SPECIES

No threatened freshwater fish species were identified as occurring in the region of the Hunter Valley surrounding the project area (Howell and Creese 2010). There are no species of fish listed under either the *NSW Fisheries Management Act 1994* (FMA) or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) that occur in the project area.

MPR (2009) suggested that suitable habitat for the Southern Purple Spotted Gudgeon (*Mogurnda adspersa*) may occur in the upper reaches of Bowmans Creek. MPR conducted surveys in the lower reaches of Bowmans Creek between Spring 2005 and Autumn 2009 and did not collect this species (MPR 2009). No surveys were conducted of the upper reaches during this period.

Two other species, listed of concern in Morris *et al*. (2001), may also occur in the study area. The Darling hardyhead (*Craterocephalus amniculus*) was collected from upper Bowmans Creek in 1976 and 1980, but has not been collected since. Eel-tailed catfish (*Tandanus tandanus*) have been observed and collected from Bowmans Creek downstream of the New England Highway (MPR 2009) and may occur in the creek adjacent to Liddell Mine. The Murray-Darling Basin population of the Eel-tailed catfish is listed as an endangered population, although populations outside of this are not considered at risk.

3 Methods

3.1 MACROINVERTEBRATE SAMPLING

Macroinvertebrate samples were collected from three sites along Bowmans Creek and two sites on Bayswater Creek (**Figure 3**). Bayswater Creek was sampled on 20 July 2012, and Bowmans Creek was sampled on the 21 July 2012. Site photos are included in Appendix A. All field work was conducted by Rebecca McCue and Dr Peter Hancock.

Macroinvertebrate communities were sampled using the AUSRIVAS sampling protocol for edge habitats at all sites. Riffles did not occur at all study sites, so have been omitted to allow between-site comparisons. Suitable edge habitats for sampling include alcoves or backwaters with abundant benthic leaf-litter, fine organic/silt deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al*. 2004). Habitats were sampled along a total stretch of 10 m at each site. The net was first swept through the water to dislodge benthic animals, and then swept through the water column again to catch suspended animals.

Macroinvertebrates were picked live from each sample for at least 40 minutes or until no more animals were found. Animals were stored in 70 % ethanol until identified in the laboratory. Invertebrates were identified to family, with the exception of the orders Acarina and Oligochaeta. SIGNAL2 scores were calculated to provide an indicator of stream health.

SIGNAL2 scores were used for each site to grade the level of disturbance. Each site was classified as either Healthy Unimpaired (SIGNAL Score >6), Mildly Impacted (SIGNAL Score 5-6), Moderately Impacted (4-5) or Severely Impacted (<4) by the grading of Chessman *et al.* (1997).

A YSI-556 multiparameter meter was used to measure temperature, dissolved oxygen (DO), pH and electrical conductivity (EC) at each site. Turbidity was measured with a Hach Q2100 Turbidity meter. Both meters were calibrated prior to field work.

3.2 FISH SAMPLING

Fish samples were collected using bait traps and fyke nets left overnight at the upstream and downstream sites at each creek (**Figure 5**). No nets were set at the middle site along Bowmans Creek. Fish collected as by-catch during macroinvertebrate sampling were also identified.

Three bait traps with 25 mm diameter entrance holes were baited with cat food and placed at each site. Traps were placed in habitat likely to be favourable to small fish and left overnight. Native fish were identified on site and released alive immediately afterwards. It is illegal to release the exotic fish species *Gambusia holbrooki* once captured, so all members of this species were euthanised humanely and buried on-site.

One fyke net was placed at each site. Fyke nets had a single 5 m wing and a maximum diameter of 60 cm. Nets were set overnight with the tail end of the net suspended above water level to allow air-breathing by-catch to survive (**Figure 5**).

3.3 RIPARIAN CONDITION

Riparian condition assessment was undertaken using a version of the Riparian Channel and Environmental (RCE) inventory (Peterson 1992) that was modified for Australian conditions (Chessman et al. 1997). The modified RCE has 13 descriptors, each with a score from 1 to 4. The total score for each site was then derived by summing the score for each descriptor and calculating the result as a percent of the highest possible score. Sites with a high RCE score (up to 52, or 100%) indicate that the riparian zone is unmodified by human activity, while those with a low score have undergone substantial modification.

3.4 STYGOFAUNA SAMPLING

Stygofauna sampling from four bores in the alluvial aquifer of Bowmans Creek occurred on 22 July 2012. A fifth bore, PGW5, which measures water level in the old Pikes Gully underground workings, was also sampled. Bores were selected on the likelihood that they contained suitable habitat. Bores with shallow water table and relatively low electrical conductivity were favoured over other bores. The spread of bores along the aquifer in the mining lease was also considered.

A weighted sampling net with 50 μm mesh was lowered to the bottom of each bore (**Figure 4**). The net was raised and dropped over approximately 50 cm three to five times to dislodge resting fauna, then retrieved slowly to the surface. 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, were retrieved. Sieve contents were washed into a sample jar containing ethanol and labelled for later identification upon return to the laboratory.

Figure 3: Overview of mine showing the location of river and bore sampling points.

Figure 5: Fyke net set at BCK5 displaying emergent end to allow for survival of air-breathing bycatch.

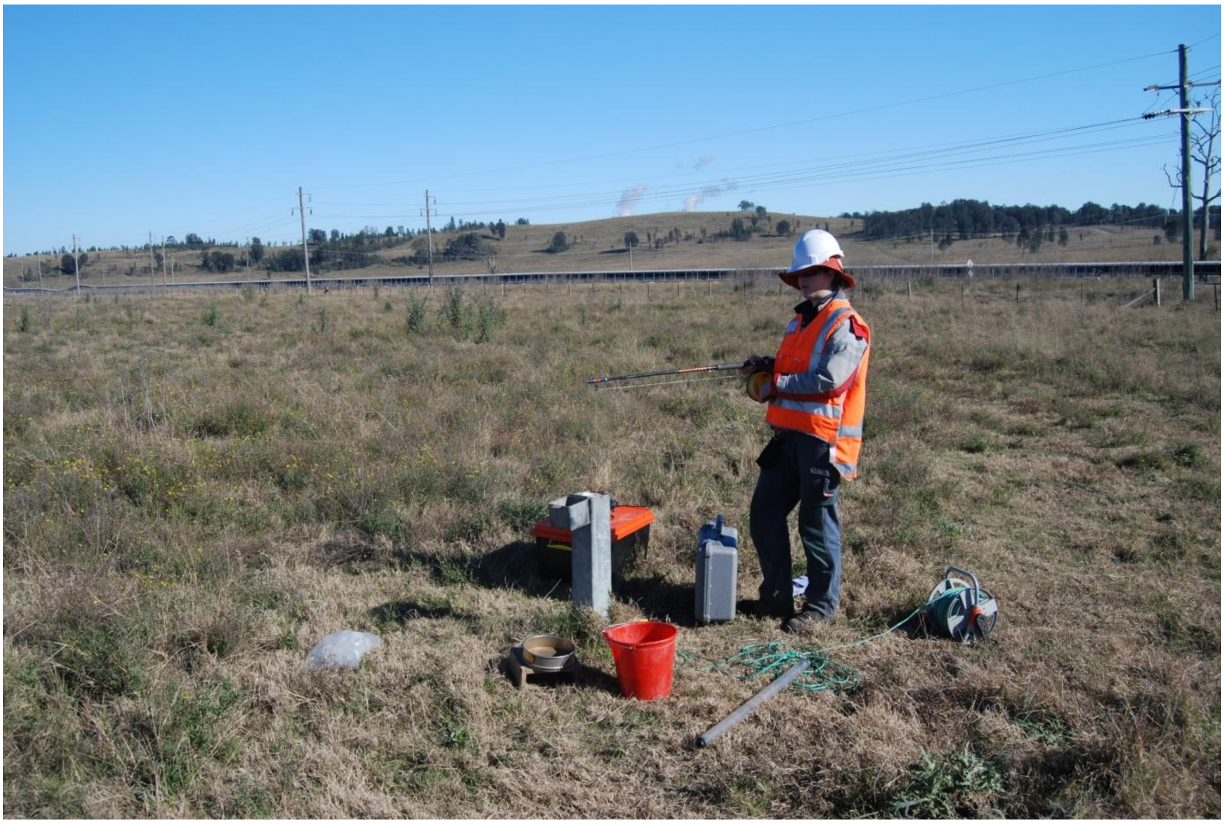

Figure 4: Sampling for stygofauna in ALV7.

4 Results

4.1 WATER CHEMISTRY

Water temperature at both creeks was between 10.13 and 12.27 °C (**Table 3**). Water in Bowmans Creek alluvial aquifer was warmer, measuring between 17.35 and 18.58 °C (**Table 4**).

Bayswater Creek had a higher electrical conductivity than Bowmans Creek (**Table 3**). EC of the alluvial groundwater ranged from 874 to 2,592 µS/cm, but was 4,893 µS/cm in the old Pikes Gully workings measured at PGW5 (Table 4).

Dissolved oxygen concentration was highest in Bowmans Creek, ranging from 97.6 to 114.4 % saturation at the three sites. At the two sites on Bayswater Creek, DO was 47.4 and 83.1 % saturation. Groundwater concentrations were typically low, ranging from 12.1 to 37 % saturation.

The pH of Bowmans Creek (8.13-8.22, **Table 3**) was higher than that of Bayswater Creek (7.55, 7.61) and the alluvial groundwater (6.92-7.45, **Table 4**).

Turbidity in Bayswater Creek was lower than the middle and downstream sites of Bowmans Creek (**Table 3**). Bowmans Creek Upstream had the lowest turbidity of all sites, with water measuring 1.65 NTU.

Groundwater table was less than 6 m below ground level for all of the alluvial bores. The water table was deepest in PGW5, but was still only 10 m deep.

Table 3. Physico-chemistry of creek sites at Liddell.

CREEK	SITE	TEMP (°C)	EC (µS/cm)	DO (% sat.)	DO (mg/L)	pH	TURB (NTU)
ANZECC Trigger	Lowland rivers		125-2000	85-110		6.5-8.5	6-50
Bayswater	Downstream	10.13	4175	47.4	5.27	7.55	3.30
Bayswater	Upstream	12.06	4265	83.1	8.82	7.61	2.33
Bowmans	BC5	10.98	997	104.6	11.5	8.22	5.26
Bowmans	BCK3	10.66	893	97.6	10.8	8.21	6.47
Bowmans	Upstream	12.27	771	114.4	12.23	8.13	1.65

Table 4: Groundwater physico-chemical data.

SITE	WATER TABLE (m bgl)	TEMP (°C)	EC (µS/cm)	DO (% sat.)	DO (mg/L)	pH
ALV7	5.65	17.35	1593	20.9	2.04	7.45
ALV3	4.18	18.89	874	23.4	2.14	7.16
ALV4	4.38	18.58	2592	13.4	1.24	6.92
ALV2	3.77	17.88	2118	37.0	3.52	7.25
PGW5	9.97	18.72	4893	12.1	1.12	7.32

4.2 RIPARIAN CONDITION ASSESSMENT

Riparian Channel and Environmental (RCE) Assessment scores at all three sites on Bowmans Creek were 34 (Table 5). These sites had sparsely vegetated riparian zones with a mix of native and exotic species. Bank undercutting was less pronounced at BCK5 site than at the other two sites. Evidence of cattle access to the creek was present at all sites along Bowmans Creek, though less damage was visible at the upstream site. Sediment on Bowmans Creek was a mix of cobble, gravel, and sand with moderate silt loads at the downstream sites. Aquatic vegetation at BC3 had scattered patches of Broadleaf Cumbungi (*Typha orientalis*). The upstream site had the highest number of aquatic plants, with six species (Table 6). Water Couch was the most abundant species at this site.

The two sites on Bayswater Creek had RCE scores of 30 and 37 for the downstream and upstream sites respectively. The upstream site at Bayswater Creek scored 30 for the RCE assessment. This site had a wide pool with steep banks on both sides and a concrete weir crossing the creek immediately upstream. River margins were vegetated with Common Reed (*Phragmites australis*) and Spiny Rush (*Juncus acutus*), while the riparian zone had low numbers of scattered River Oak.

Bayswater Creek Downstream had an RCE score of 34, the highest of all sites. The riparian zone here was dominated by River Oak (*Casuarina cunninghamiana*) with Spiny Rush (*Juncus acutus*) sparsely populating the creek edges. This site had a moderate amount of accumulated woody debris in the creek and on the bank. The bottom sediments were loosely consolidated with silt and fine coal particles covering the bed.

Riparian vegetation at all sites was dominated by River Oak (*Casuarina cunninghamiana*). River Oak was the only tree species present in the riparian zone at both sites along Bayswater Creek (**Table 7**). The Bowmans Creek sites also had scattered Willows (*Salix* sp.), a Weed of National Significance, and Brazilian Pepper Trees (*Schinus terebinthifolius*), a Noxious Weed. The shrub layer was sparsely vegetated at all sites, with the exotic Paddy's Lucerne (*Sida rhombifolia*) at Bayswater Creek Downstream, and Castor Oil Plants (*Ricinus communis*) at BCK3 and Bayswater Creek Upstream. BCK5 had Broughton Willow (*Acacia salicina*) occurred at BCK5.

Table 5: Riparian Channel and Environmental condition score for surface sites along Bayswater and Bowmans Creeks.

Descriptor	Creek:	Bayswater Ck	Bayswater Ck	Bowmans Ck	Bowmans Ck	Bowmans Ck
	Site:	Downstream	Upstream	BCK5	BCK3	Upstream
1. Land-use pattern beyond immediate riparian zone		2	3	3	3	3
2. Width of riparian strip of woody vegetation		3	3	2	2	2
3. Completeness of riparian strip of woody vegetation		1	2	2	2	2
4. Vegetation of riparian zone within 10 m of the channel		4	4	3	3	3
5. Stream bank structure		4	2	3	3	3
6. Bank undercutting		4	3	2	3	2
7. Channel form		3	4	2	2	2
8. Riffle/Pool sequence		3	1	3	3	3
9. Retention devices in stream		1	1	3	2	3
10. Channel sediment accumulations		2	2	2	4	2
11. Stream bottom		1	1	3	3	3
12. Stream detritus		3	2	3	2	3
13. Aquatic vegetation		3	2	3	2	3
TOTAL		**34**	**30**	**34**	**34**	**34**

Table 6: Macrophytes at sites on Bowmans and Bayswater Creeks.

SPECIES	COMMON NAME	STATUS	SITE				
			BOWMANS CREEK UPSTREAM	BCK5	BCK3	BAYSWATER CREEK UPSTREAM	BAYSWATER CREEK DOWNSTREAM
			Cover (%)				
Emergent Macrophytes							
Cyperus sp.			2				
Juncus acutus	Spiny Rush	Exotic	8	2.5	5	15	5
Myrophyllum sp.			2	1			
Paspalum distichum	Water Couch	Native	20				
Persicaria decipiens	Slender Knotweed	Native	2				
Phragmites australis	Common Reed	Native				30	
Typha orientalis	Broadleaf Cumbungi	Native		2.5	10		
Submerged Macrophytes							
Potamogeton sp.	Pond Weed	Native					2
Rorippa nasturtium aquaticum	Watercress	Exotic	10				
Triglochin sp.	Water Ribbon	Native					2

Table 7. Riparian vegetation at sites on Bowmans and Bayswater Creeks. WONS = Weed of National Significance.

SPECIES	COMMON NAME	STATUS	OTHER	SITE				
				BOWMANS CREEK UPSTREAM	BCK5	BCK3	BAYSWATER CREEK UPSTREAM	BAYSWATER CREEK DOWNSTREAM
				Cover (%)				
Trees (>10 m in height)								
Casuarina cunninghamiana	River Oak	Native		10	15	7.5	5	35
Schinus terebinthifolius	Brazilian Pepper Tree	Exotic	Noxious Weed	10				
Salix sp.	Willow	Exotic	WONS			7.5		
Trees (<10 m in height)								
Casuarina cunninghamiana	River Oak	Native		2.5	2.5	5	10	15
Salix sp.	Willow	Exotic	WONS		2.5			
Schinus terebinthifolius	Brazilian Pepper Tree	Exotic	Noxious Weed	2.5				
Shrubs								
Sida rhombifolia	Paddy's Lucerne	Exotic						10
Acacia salicina	Broughton Willow				2			
Ricinus communis	Castor Oil Plant	Weed				5	5	

4.3 SURFACE WATER MACROINVERTEBRATES

Thirty-two invertebrate taxa were collected across all sites during the survey. Bayswater Creek Downstream and BCK5 (the downstream site on Bowmans Creek) had the highest diversity, with 17 taxa collected at each site (**Table 8)**. Bayswater Creek Upstream had the lowest diversity of all sites, with just 6 invertebrate taxa collected (**Figure 6**). This site was dominated by crustacea, with chironimids (Diptera) and nepids (Hemiptera) being the only insects present (**Table 8**).

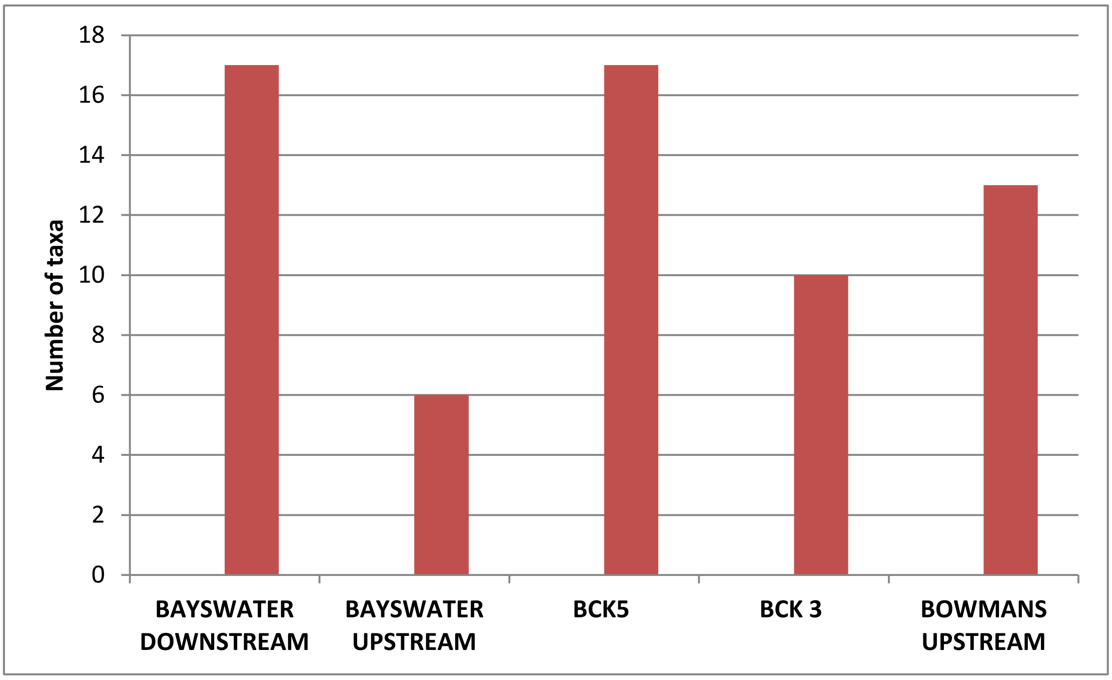

Figure 6: Number of invertebrate taxa per site at Bayswater and Bowmans Creek.

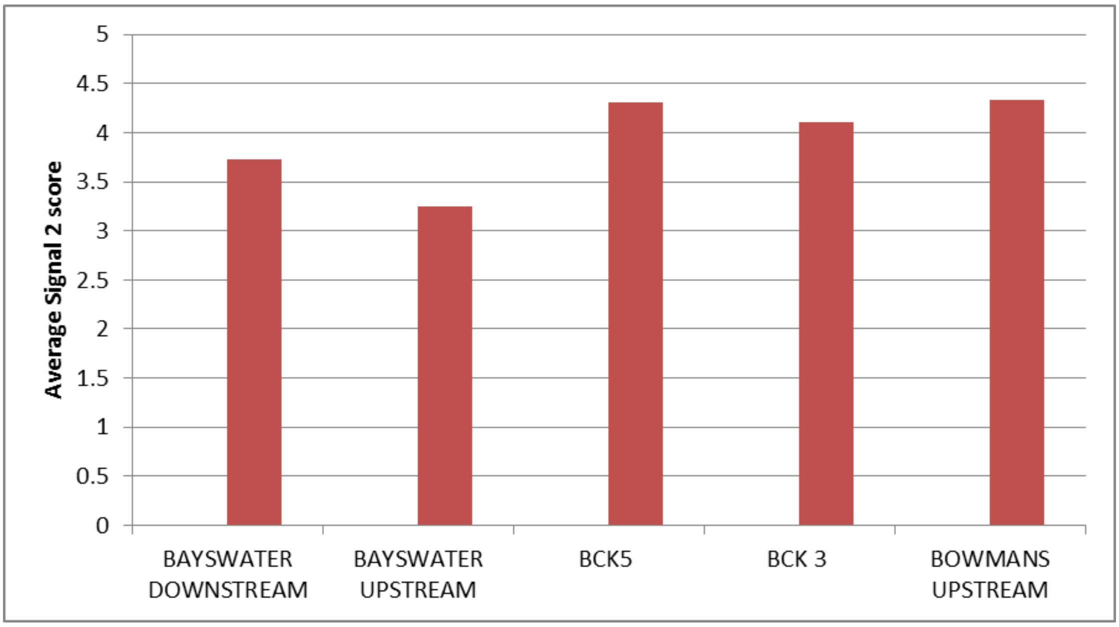

Figure 7: Average SIGNAL 2 Score for sites on Bayswater and Bowmans Creeks

Table 8: Macroinvertebrate taxa collected from Bayswater and Bowmans Creek.

ORDER	FAMILY	SIGNAL 2 SCORE	BAYSWATER DOWNSTREAM	BAYSWATER UPSTREAM	BCK5	BCK 3	BOWMANS UPSTREAM
Ostracoda		n/a	1	6			
Copepoda		n/a	311	55	125	19	2
Oligochaeta		2	2		1		6
Hirunidae		1	2		2		1
Gastropoda	Planorbidae	2	10				
Gastropoda	Lymnaeidae	1	6				
Gastropoda	Physidae	1				3	
Acarina		6	3				
Decapoda	Atyid	3	9	2	4		3
Decapoda	Palaemonidae	4		1			
Diptera	Chironimidae	3	5	2	6		5
Diptera	Dixidae	7	2		1		
Diptera	Ceratopogonidae	4	1				
Hemiptera	Corixidae	2			13	27	47
Hemiptera	Notonectidae	1				1	
Hemiptera	Nepidae	3		1			
Hemiptera	Gerridae	4					5
Coleoptera	Dytiscid	2	1		1		1
Coleoptera	Scirtidae	6				1	
Coleoptera	Hydranidae	3				2	
Coleoptera	Elmidae	7			2		
Ephemoptera	Leptophlebidae	8			5	3	5
Ephemoptera	Baetidae	8			21	7	16
Ephemoptera	Caenidae	4			4		2
Ephemoptera	Unidentified	9					1
Trichoptera	Leptoceridae	6	1		17	13	6
Trichoptera	Hydroptilidae	4			1		
Trichoptera	Conosucidae	7			1		
Odonata	Zygoptera	3	1		1		
Odonata	Coenagrionidae	2	2		1	4	
Odonata	Austrocordulidae	10	3				
Odonata	Aeshnidae	4	3				
AVERAGE SIGNAL 2			**3.73**	**3.25**	**4.31**	**4.11**	**4.33**
NUMBER OF TAXA			**17**	**6**	**17**	**10**	**13**

No Ephemeroptera were collected from Bayswater Creek, despite being relatively abundant in Bowmans Creek. Hemiptera, Coleoptera, and Trichoptera occurred at all three sites in Bowmans Creek, but were represented by single specimens in Bayswater Creek. Bayswater Creek had higher diversities of Gastropoda and Odonata than Bowmans Creek (**Table 8**).

Average SIGNAL scores were lowest for the two Bayswater Creek sites. The Bayswater Upstream site scored 3.25 and the downstream site scored 3.73 (**Figure 7**). Scores of less than 4 generally indicate that the ecological habitat is severely degraded (Gooderham and Tsyrlin 2002). The three Bowmans Creek sites all had scores between 4 and 5, so were only moderately degraded. The upstream and downstream sites were least disturbed, with a score of 4.33 and 4.32 respectively (**Figure 7**).

4.4 FISH

Three fish species were collected during the survey (**Table 9**). The pest species Mosquitofish (*Gambusia holbrooki*), was present at all sites except Bayswater Creek Upstream, Marbled Eels (*Anguilla reinhardtii*) were captured at Bayswater Creek Upstream and BCK5, and Flathead Gudgeons (*Philypnodon grandiceps*, **Figure 8**) were collected at Bayswater Creek Upstream and BCK5.

Figure 8. Flathead Gudgeon (*Philypnodon grandiceps*) collected from Bayswater Creek Upstream.

Table 9: Fish species collected at Liddell.

SPECIES	COMMON NAME	BAYSWATER DOWNSTREAM	BAYSWATER UPSTREAM	BCK5	BOWMANS UPSTREAM
Gambusia holbrooki	Mosquitofish	3	2	1	
Anguilla reinhardtii	Marbled Eel		1	1	
Philypnodon grandiceps	Flathead Gudgeon		1	1	

4.5 STYGOFAUNA

Ten stygofauna taxa were collected from the six bores along Bowmans Creek alluvial aquifer. ALV4 was the only bore that did not have fauna (**Table 10**). Cyclopoid copepods were the most abundant taxa, occurring in four bores spread along approximately 3 km of the aquifer. ALV2 had the highest taxonomic diversity, with nine taxa including the Paramelitid amphipods (Figure 9: A Paramelitidae amphipod from ALV2. This was the only bore to have stygofaunal insects, with the stygofauna community at all other bores consisting only of crustaceans (**Table 10**).

Figure 9: A Paramelitidae amphipod from ALV2.

Table 10: Stygofauna collected from the Bayswater Creek alluvial aquifer

CLASS	ORDER	FAMILY	SPECIES	ALV3	ALV4	PGW5	ALV7	ALV2
Crustacea	Copepoda	Cyclopidae		4		1	1	25
Crustacea	Ostracoda							3
Crustacea	Bathynellacea	Notobathynellidae	*Notobathynella* sp.					1
Crustacea	Bathynellacea	Bathynellidae	*Bathynella* sp.	2				
Crustacea	Anaspidacea	Psammaspidae						1
Crustacea	Isopoda	Janiridae	*Heterias* sp.			1		16
Crustacea	Amphipoda	Paramelitidae	*Chillagoe* sp.	5				3
Insecta	Coleoptera	Dytiscidae	*Carabhydrus stephanieae*					1
Insecta	Coleoptera	Elmidae	*Austrolimnius* sp.					6
Arachnida	Acari	Aturidae						3

4.6 INCIDENTALS

A female platypus (*Ornithorhynchus anatinus*, **Figure 10**) was captured in the fyke net at BCK5. The platypus showed no sign of injury or major distress and was released unharmed at the point of capture.

A single specimen of a troglofaunal Zygentoma (subterranean silverfish) was collected from ALV3 (**Figure 11**). This is possibly a member of the genus *Trinemura,* known from subterranean habitats in Western Australia.

Figure 10: Platypus (Ornithorhynchus anatinus) captured in a fyke net at BCK5.

Figure 11. Troglofaunal Zygentoma from bore ALV3. Total length approximately 12 mm

5 Discussion

5.1 ECOLOGICAL CONDITION OF BAYSWATER CREEK

The two sites at Bayswater Creek were in poor condition, with heavy loads of fine sediment on the bottom, and evidence of erosion along the banks. The main factor influencing the ecological condition at both sites appeared to be the control of flow from Lake Liddell.

Electrical conductivity at both sites was greater than 4,000 µS/cm, exceeding the maximum ANZECC guidelines for lowland rivers of 2,200 µS/cm (ANZECC 2000). However, EC was within the range of previously measured EC for this creek, which was 2370 to 6080 µS/cm in 2010/2011 (AECOM 2012). The high electrical conductivity is probably due to releases of water from Lake Liddell with a moderate salt content. Fine black dust was also present in the bed sediments of the creek.

The riparian zone of Bayswater Creek was dominated by dense growths of *Casuarina cunninghamiana*. Overall, the riparian zone was in moderate condition, with RCE scores of 30 and 34. Both sites contained the exotic species *Sida rhombifolia* and *Ricinus communis* in the understorey. Almost no groundcover was present at the downstream site.

Dissolved oxygen concentration in Bayswater Creek was outside the recommended trigger values for aquatic ecosystems of 85 to 110 % saturation (ANZECC 2000). DO concentration was just 47 % saturation at the downstream site. This was probably due to the large volume of fine anaerobic sediments and fine black dust at the bottom of the pool, and the large amount of organic matter in the stream.

Both the upstream and downstream sites on Bayswater Creek had SIGNAL 2 scores less than 4, indicating by the macroinvertebrate community, that the ecological community is in poor condition. The Downstream site had the highest biological diversity, with 17 invertebrate taxa. Most families had SIGNAL 2 scores of 4 or less, although the dragonfly family Austrocorduliidae, which has a score of 10, were present at the downstream site.

The fish community of Bayswater Creek was dominated by the exotic *Gambusia holbrooki* (Mosquitofish), which was present at both sites. Two native species, *Anguilla reinhardtii* (Marbled Eel) and *Philypnodon grandiceps* (Flathead Gudgeon) were also collected from the upstream site. All three species are tolerant of relatively poor conditions and are known from similar streams throughout the Hunter Valley.

5.2 ECOLOGICAL CONDITION OF BOWMANS CREEK

Bowmans Creek was in relatively good condition, with all physico-chemical variables falling within ANZECC guidelines for lowland rivers in NSW. Turbidity in the upstream site was below the limit for lowland rivers and the water was clearer than the ANZECC guidelines for upland rivers. The highest turbidity was 6.47 NTU at BCK3, where there was evidence of cattle access to the water.

The main impacts on the stream appeared to be from cattle access to the banks and creek. Evidence of erosion was present at all three sites, although this was less visible upstream.

The average SIGNAL 2 scores for the three sites were all between 4 and 5, indicating moderate ecological condition. BCK3 had the lowest SIGNAL 2 score, and the fewest invertebrate taxa, with the invertebrate community dominated by tolerant the taxa Corixidae water boatmen and Copepoda. BCK5 had the most diverse invertebrate community, with high numbers of Baetidae mayflies and Leptoceridae caddisflies. Both of these families are moderately sensitive to pollution, with SIGNAL 2 scores of 6 and 8 respectively.

Bowmans Creek Upstream had the highest SIGNAL 2 score, indicating that the site was in good ecological condition. The dominant invertebrate taxa collected from this site were water boatmen, Baetidae mayflies, and Leptoceridae caddisflies. The low electrical conductivity, low turbidity, high dissolved oxygen concentration, and complexity of habitat at the site made conditions suitable to the diverse macroinvertebrate community present. The upstream site appeared in good physical condition, with an emergent cobble bar immediately downstream of the bridge, and clearly defined riffle, pool and edge habitats. A pool downstream of the main riffle contained a variety of structure for macroinvertebrates, including fallen logs, steep banks with root structure, and gently sloping beds.

The three fish species collected at Bowmans Creek were the same as those from Bayswater Creek, and all were collected only from BCK5. An additional species, Carp (*Cyprinus carpio*) is also regularly observed at BCK3 and other reaches of the creek. Howell and Creese (2010) collected 19 fish species from the lowlands and slopes of the Hunter Valley, and 14 species are known from the Bowmans Creek catchment (MPR 2009) so it is likely that surveys in warmer months will yield more species than the three collected.

5.3 THREATENED AQUATIC SPECIES

No threatened aquatic species were collected during this survey, and none are known from the reach of Bowmans Creek. In 2009, Southern Purple Spotted Gudgeon (*Mogurnda adspersa*) was reported from Goorangoola Creek, in the Glennies Creek Catchment east of Bowmans Creek (MPR 2009). This species in listed as endangered under the *Fisheries Management Act 1994*. Southern Purple Spotted Gudgeons occur in slow flowing water with weed and suitable hard substrates for spawning (McDowell 1996). Bowmans Creek has suitable habitat in its upstream reaches, but no Southern Purple Spotted Gudgeons are known from this creek from this or previous studies.

Although not a threatened species, Platypus (*Ornithorhyncus anatinus*) are a protected species in NSW. One platypus was collected at the downstream site at BCK5. No other platypus were observed in Bowmans Creek, but suitable habitat was present at the Bowmans Creek Upstream site and at BCK3.

5.4 GROUNDWATER COMMUNITIES OF BOWMANS CREEK ALLUVIAL AQUIFER

Alluvial aquifers along the Hunter River and some of its tributaries are known habitat for stygofauna (Hancock and Boulton 2009). The current survey was the first to collect stygofauna from the Bowmans Creek alluvial aquifer. The ten taxa collected demonstrate that a diverse ecological community is present, and indicates that other species are probably present. With just one round of sampling, the Bowmans Creek alluvial aquifer already has a higher diversity than the Goulburn River alluvial aquifer (5 taxa) and in the Hunter River alluvial aquifer near Muswellbrook, but is lower than other alluvial aquifers in the Hunter Valley, which have up to 20 species (Section 2).

None of the stygofauna taxa collected in the Bowmans Creek alluvial aquifer are endemic. *Notobathynella* sp. and *Bathynella* sp. occur along the Hunter River alluvial aquifer, and in the aquifers associated with many tributary stream. The amphipod *Chillagoe* sp. is also distributed widely in alluvial aquifers of the Hunter Valley, as are *Heterias* sp. isopods.

The two beetles collected in ALV2 represent range extensions for both taxa. The subterranean elmid *Austrolimnius* sp. was previously known only from the alluvial aquifers of the Pages River and Dart Brook. The occurrence of this genus in the Bowmans Creek alluvial aquifer, indicate that groundwater elmids occur in much of the Hunter alluvial aquifer and have migrated successfully into tributary aquifers. The dytiscid *Carabhydrus stephanieae* is known from the Dart Brook, Pages and Kingdon Ponds alluvial aquifers, as well as from the Hunter River aquifer near Denman.

The section the Bowmans Creek alluvial aquifer where stygofauna were collected, extends from ALV7 north to ALV3. It is likely that most of the alluvial aquifer of Bowmans Creek contains stygofauna, and so is a groundwater dependent ecosystem.

5.5 OTHER GROUNDWATER DEPENDENT ECOSYSTEMS

Stands of *Eucalyptus camaldulensis* (river red gum) occur downstream of the site (MPR 2009). This species generally occurs on river floodplains and has some dependence on alluvial groundwater. However, no stands of river red gum or other groundwater-dependent vegetation communities were located on-site (Umwelt 2006).

Apart from aquifer ecosystems, the only other GDE occurring on-site is the river baseflow system and associated hyporheic zone of Bowmans Creek. There are strong hydrological links between Bowmans Creek and the surrounding aquifer, which is likely to be important in moderating stream nutrient concentrations, thermal patterns, and water chemistry (Boulton et al. 1998).

The degree of dependence of Bowmans Creek on groundwater will vary through distance and time, as will the direction and magnitude of exchange between surface and groundwater. When there is a large volume of surface water in the creek, water will flow through the stream bed and recharge the aquifer. Conversely, during periods of low surface runoff, a large proportion of water in Bowmans Creek will come from the aquifer. During these periods, all aquatic flora and fauna become groundwater dependent.

6 Impact Assessment

This section assesses the likelihood that the proposed development will impact on GDEs and threatened aquatic species. This assessment of the potential impacts that development poses to stygofauna and groundwater dependent ecosystems is based on **Figure 12** and **Figure 13** provided by SKM (19 February 2013).

6.1 EXPECTED CHANGES TO THE GROUNDWATER REGIME RESULTING FROM THE EXTENSION

Expected drawdown along the alluvial aquifer of Bowmans Creek has been modelled by SKM (2013) for three time periods: half way through mining (approximately 2019), at the period of peak drawdown (approximately 2022), and the post-mining equilibrium, which will be achieved some time following the cessation of mining (SKM 2013). Drawdown with the extension has been modelled against what the drawdown would be if the extension did not go ahead.

In 2019, mining in the extension area is predominantly in the South Pit and will have just started in the Entrance Pit. This marks the half-way point of mining, when there is likely to be negligible extra drawdown that is attributable to the extension.

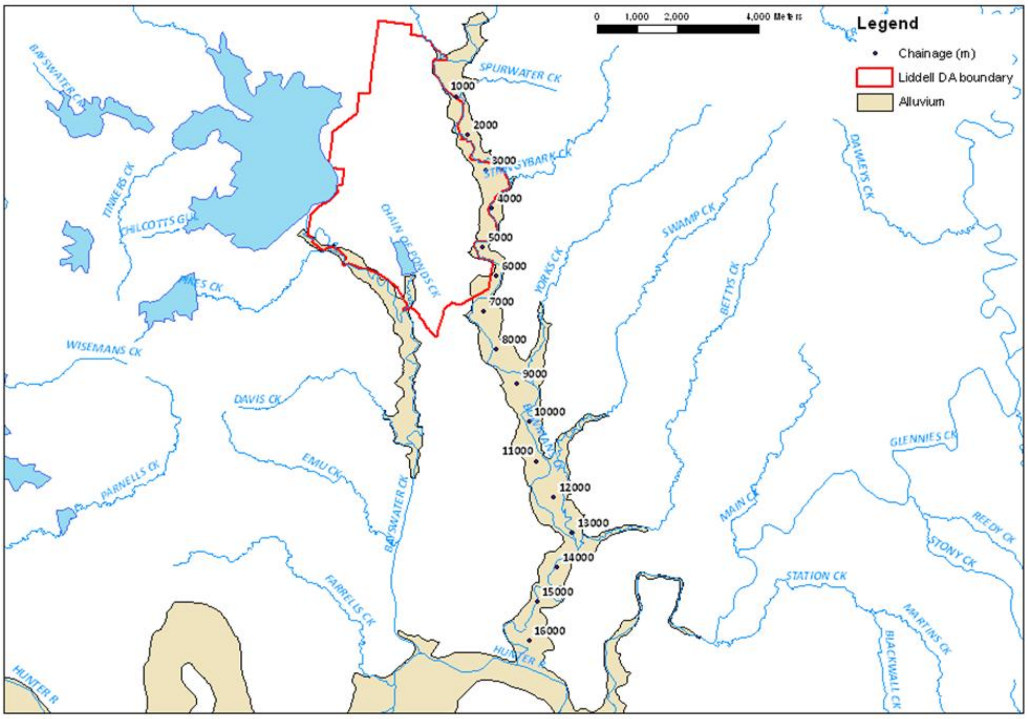

Figure 12. Overview map of the Bowmans Creek alluvium with chainage indicated in metres (SKM, February 2013)

Drawdown is expected to peak in approximately 2022. At this time, the modelled water table with the extension will be approximately 1.4 m below the steady state water level (**Figure 13**). Drawdown due to the extension will be greatest at a chainage distance of 6800 m (SKM 2013).

In Figure 13, the green line representing the “With extension water level 2022” is almost entirely hidden by the “Without extension water level 2022” there-by representing very little change as a result of the project. When drawdown is at its peak, there is at least 7 m of saturated sediments at the base of the aquifer, which should leave a sufficient volume of aquifer for the stygofauna community provided the deeper parts of the aquifer have a suitable physico-chemistry and porosity. Further modelling indicated that aquifer water level will return to the ‘no extension’ equivalent within approximately 50 years following cessation of mining (SKM 2013).

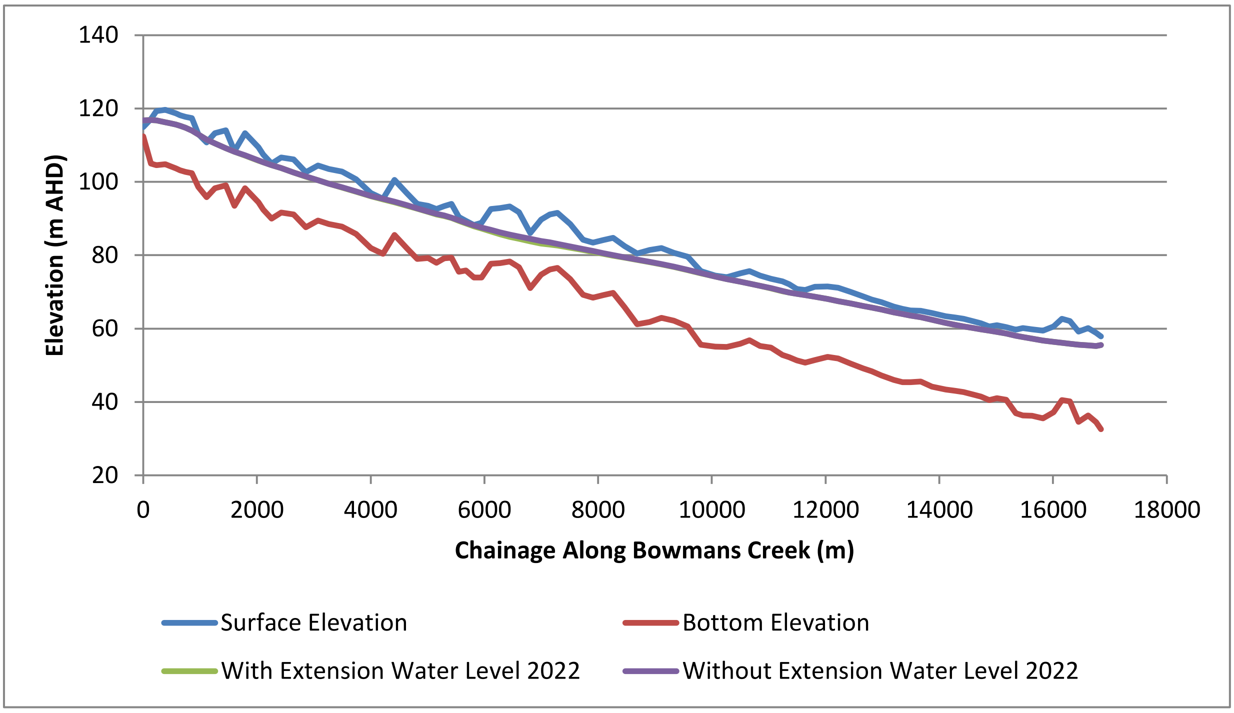

Figure 13. Expected drawdown along the Bowmans Creek alluvium (provided by SKM 2013)

6.2 LIKELY IMPACTS ON BOWMANS CREEK AQUIFER ECOSYSTEM

Groundwater models indicate that the maximum drawdown of 1.4 m will occur in the Bowmans Creek alluvium, and there will be a minimum of 7 m of saturated sediments remaining. The deeper section of the alluvium is likely to be most suitable stygofauna habitat because the coarse sand and cobble sediments will have more interstitial space for the fauna to move through. Therefore, a reduction in water level of 1.4 m in the upper part of the aquifer is unlikely to impact the main stygofauna habitat. Stygofauna occurring in the upper parts of the aquifer should have little trouble migrating downwards as the water table descends.

ALV7 is the only bore sampled for stygofauna that occurs in the section of aquifer modelled to experience drawdown. This bore occurs in the aquifer near chainage distance 6000 m, where the aquifer will experience a 0.9 m drop in water level as a result of the extension. This drop is unlikely to have a significant impact on stygofauna communities, as there will still be more than 12 m of saturated aquifer remaining.

At all other bores, there is likely to be very little change in the water level caused by mining the extension, so the communities here should remain unaffected. Although only ten taxa were collected during this survey, it is likely that there are more species that were not, and this may include species endemic to the aquifer.

Stygofauna are vulnerable to changes in pH and electrical conductivity. However, previous monitoring of the Bowmans Creek alluvium suggest that historical mining has caused little change to water chemistry, and modelled data suggest that no change is likely to occur with the proposed development (SKM 2013).

6.3 LIKELY IMPACTS ON SURFACE ECOLOGY

6.3.1 Bowmans Creek

Historical records from Bowmans Creek indicate that it is punctuated by periods of no flow when dry conditions prevail (Mackie 2001). Each of the eight gauging stations between the Bowmans Creek Upstream site and the confluence with the Hunter River have recorded dry periods of varying duration (SKM memo 17 Oct 2012).

At periods when the alluvial groundwater table is near or above the creek bed, there is good connectivity between the surface channel and groundwater (Mackie 2001). In dry periods, as the creek water level recedes and the contribution of rainfall and runoff declines, the proportion of groundwater contribution to surface flow increases. Recent monitoring data and predictive modelling indicate that estimated losses in groundwater flow at LCO will have negligible impact on surface flow in Bowmans Creek.

The ecological consequences of dry periods on the creek are not likely to be major, as the creek regularly goes dry. The biological community have life history strategies that have allowed them to adapt to periods of drying and the need to disperse when flow events occur. Most aquatic invertebrates have either winged adult stages that allow them to disperse from nearby water bodies (e.g. Ephemeroptera, Odonata) or desiccation-resistant stages (e.g. Ostracoda, Cyclopoida). The fish species collected during our survey are also able to disperse readily so that once flow returns to Bowmans Creek they will migrate upstream from the Hunter River, or downstream from the headwater refugia.

Platypus migration generally occurs along waterways, where the platypus are able to feed. During periods of receding flow they seek refuge in large pools, provided these are able to meet the requirements of the platypus (Grant and Bishop 1998). As pools dry out, platypus follow the drying channel upstream or downstream until suitable pools are located. However, this places them at great risk from predation by foxes, dogs and cats.

6.3.2 Bayswater Creek

Bayswater Creek is already in a poor ecological condition. As flow in the creek is controlled by releases from Lake Liddell, drawdown in the underlying aquifer will have negligible impact on flow volumes and is unlikely to affect the in-stream ecology.

7 Conclusions and recommendations

7.1 CONCLUSIONS

This report assesses the extent of groundwater dependent ecosystems present in the area likely to be impacted by the expansion of Liddell Coal Operations. The types of GDE present, as categorised by the NSW GDE Policy (2002) are:

- the aquifer ecosystem of the Bowmans Creek Alluvial Aquifer, and
- the river baseflow system of Bowmans Creek.

The alluvial aquifer of Bowmans Creek contains at least ten species of stygofauna. Although none of the taxa appear endemic to the Bowmans Creek aquifer, this confirms that the aquifer is an ecosystem with a diverse invertebrate community. Surveys for stygofauna generally need to be carried out over multiple seasons to get an indication of biodiversity (WA EPA 2003, Hancock and Boulton 2008, 2009) and it is likely that additional surveys will uncover more species in the Bowmans Creek alluvial aquifer, some of which may be endemic to the aquifer.

Water table drawdown poses little threat to the stygofauna community, since there is still at least 7 m of saturated sediment available at maximal drawdown over most of the aquifer.

No threatened aquatic species, as listed under the Fisheries Management Act (1994) were observed or collected on-site.

7.2 RECOMMENDATIONS

Following this assessment, three steps are recommended to monitor the ecological conditions of groundwater dependent and riverine ecosystems:

- Seasonal monitoring of in-stream and riparian ecological condition to ensure that aquatic communities and processes are not adversely impacted by dewatering or other activities. These surveys should also include monitoring at reference sites.
- Prior to the anticipated drawdown of the alluvium as a result of mining activities, at least one more round of stygofauna sampling should be conducted in the Bowmans Creek alluvial aquifer to establish baseline composition of the stygofauna community. Surveys should be conducted in spring/summer and include a re-sampling of the July bores.
- Once dewatering begins to affect the alluvial aquifer, stygofauna populations should be monitored every six months to ensure populations are stable. Monitoring should occur at bores inside the proposed area of aquifer dewatering, as well as in reference sites outside of it.

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Appendix A:

Site Photos

Figure 14: Bayswater Creek Downstream, looking upstream.

Figure 15: Bayswater Creek Downstream, looking downstream.

Figure 16: Bayswater Creek Upstream, looking downstream.

Figure 17: Bayswater Creek Upstream, looking upstream.

Figure 18. Bowmans Creek at BCK5, looking downstream.

Figure 19. Bowmans Creek at BCK5, looking upstream.

Figure 20. Bowmans Creek, BCK3, looking upstream.

Figure 21. Bowmans Creek, BCK3, looking downstream.

Figure 22. Bowmans Creek Upstream, looking downstream.

Figure 23. Bowmans Creek Upstream, looking upstream.

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