ASHTON COAL
S75W MODIFICATION TO DEVELOPMENT CONSENT DA309-11-2001 MOD 4 - MINING AN ADDITIONAL LONGWALL PANEL

AQUATIC ECOLOGY ASPECTS

REPORT PREPARED FOR
ASHTON COAL OPERATIONS PTY LTD

MARINE POLLUTION RESEARCH PTY LTD
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1 INTRODUCTION

Ashton Coal Operations Pty Ltd (ACOL) currently operates a combined open cut and underground (longwall) mine in the middle reaches of the Hunter River valley at Camberwell, some 14 km north of Singleton. The open cut mine is located on the north eastern side of the New England Highway and the underground mine is located south west of the highway. The underground mine is bounded by Glennies Creek to the east, the New England Highway to the north and Ravensworth open cut mine to the west (see Figure 1 below). Details of the approved mine project plans are contained in the development consent (DA No 309-11-2001-i) dated 11 October 2002 (DoP 2002).

ACOL are seeking approval for the mining of an additional long wall panel located on the western margin of the mine's existing development consent area as indicated in Figure 1. The additional panel (designated LW9) is around 3.25 km long. It is orientated north-south and a portion of the proposed long-wall (about one third) is located under Bowmans Creek. This report address the potential impacts of long-wall mining of this panel on the aquatic ecology of Bowmans Creek.

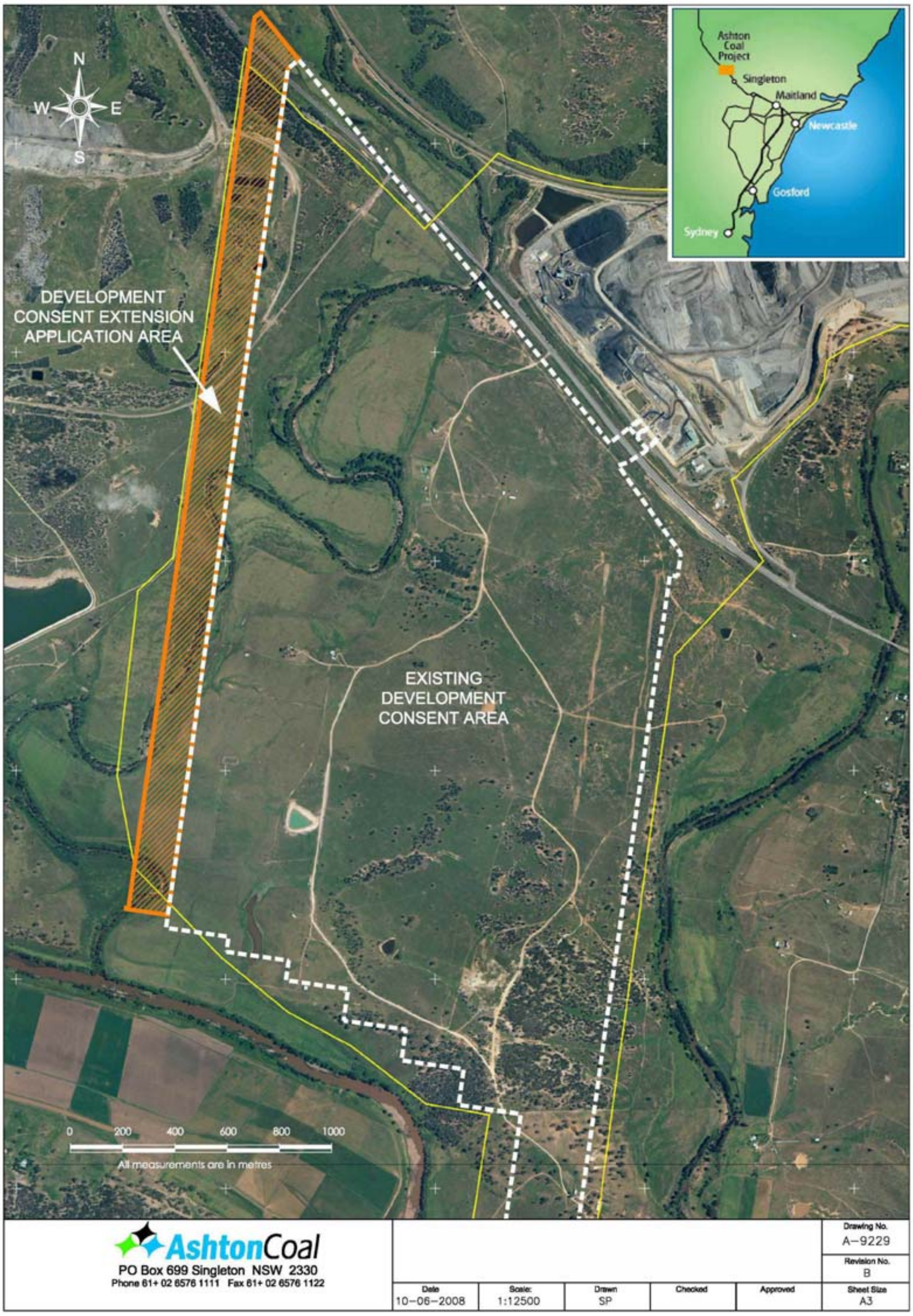
Marine Pollution Research Pty Ltd (MPR) has been commissioned to provide an aquatic ecology assessment report to be submitted as part of the S75W approval process. The report has been prepared against the Director-General's requirements provided by the NSW DoP on 31 July 2008 which identified "Flora and fauna" as a key issue. The main objectives of this report are to:

(i) Assess what possible impacts mining may have on aquatic ecology within Bowmans Creek,

(ii) Assess possible mitigation measures to achieve a "maintain and improve" outcome for the aquatic ecology of Bowmans Creek (as per the DEC & DPI (2005) assessment guidelines).

(iii) Provide details of an aquatic ecology monitoring program to assess possible mining related aquatic ecology impacts.

Fig 1 Ashton Underground Layout Option for LW9
Development Consent Extension Option



1.1 Bowmans Creek Site Attributes

Bowmans Creek is about 35 kilometres (km) long and the headwaters are located in the Little Brothers Range, at an elevation of about 650m Australian Height Datum (AHD). It has a catchment area of approximately 265 km^2. The lower section of Bowmans Creek between the New England Highway and the Hunter River confluence is 6 km long and approximately 4.5km of this section is located within the ACOL Mining Lease. Patterson Britton & Partners (PBP 2001) concluded that Bowmans Creek experiences variable flow and that it is generally perennial, although flow reportedly ceases during severe droughts.

2 STUDY METHODS

In order to assess the possible impact on aquatic ecology of the predicted subsidence, the following tasks were undertaken:

- A review of literature regarding the potential for long-wall related mining impacts on Bowmans Creek structure and function.
- A review of all aquatic ecology monitoring conducted in Bowmans Creek to date to summarise creek aquatic ecology attributes.
- A field walkover inspection of Bowmans Creek and tributaries within the mine lease area, to ascertain aquatic habitat conditions and fish passage attributes post 2006 floods.
- An update literature review of regional aquatic ecology information to assess the potential for threatened and protected species to utilise Bowmans Creek.

The field walk-over investigation was undertaken by MPR staff over two days (1 to 2 July 2008) during a period of high base flow (around 37 ML/day). The study area extended the full length of Bowmans Creek between the New England Highway to the downstream limit of the lease area (just above the Hunter River confluence). Channel morphology maps (ERM 2006a) and subsidence prediction maps (SCT 2008) were used as aids for determining the areas of potential concern for aquatic ecosystems.

It is considered that the present aquatic ecology information available for Bowmans Creek within the present lease area is sufficient to meet the seasonal assessment requirements of the DGRs and that no further field work is required for this impact assessment.

3 RESULTS

3.1 Literature Review

The literature review has been split into two sections. Section 3.1.1 documents the studies undertaken on behalf of Ashton Coal to assess and predict likely impacts on Bowmans Creek structure and function arising from proposed underground mining, and Section 3.1.2 documents the aquatic ecology and water quality studies that have been undertaken in Bowmans Creek.

3.1.1 Bowmans Creek Longwall Mining Impact Studies

The Ashton Coal Project Environmental Impact Statement (EIS) prepared by HLA-Envirosciences Pty Ltd (HLA 2001) included a proposal to divert Bowmans Creek from immediately below the New England Highway, around proposed underground mining operations. As part of that proposal, a geomorphology and hydraulic assessment of Bowmans Creek was prepared by Patterson Britton and Partners Pty Ltd (PBP 2001) as a basis for the proposed creek rehabilitation works. This report provided a detailed description of creek structure and function and summarised the relationship between surface water attributes and local alluvial and Permian groundwater resources. A summary of the main finding of the PBP (2001) report was included in ERM (2006a) as discussed below.

Following DPI approval of the final modified mining plan (which no longer included Bowmans Creek diversion), conditional approval for the mining under Bowmans Creek was granted. Conditions of consent included additional subsidence and groundwater monitoring studies, to be used to develop a mine plan which would meet minimum subsidence and groundwater connectivity requirements (to be determined in consultation with relevant government departments). To that end there have been a number of studies commissioned by ACOL to address these questions and to develop the SMP:

- Environmental Resources Management Australia Pty Ltd (ERM) provided a detailed geomorphology report for Bowmans Creek (ERM 2006a) based on survey and field work undertaken in the first half of 2006. The report was commissioned to address relevant consent conditions, namely to establish a geomorphology baseline for ongoing monitoring during and after the potential mining beneath Bowmans Creek. This report provides a baseline of creek geomorphology against which the impacts of the 2007 floods can be assessed and is currently being reviewed and updated to identify any major morphology changes following flooding in June 2007.

- ERM (2006b) prepared a baseline flora and fauna report for Bowmans Creek which provides a pre-mining assessment of the riparian and aquatic habitat along Bowmans Creek, prepared in accordance with the Ashton Coal Flora and Fauna Management Plan (Part 2 prepared in August, 2005). It provides the results of riparian flora and fauna habitat studies undertaken in Autumn 2005 and 2006 and the results of aquatic ecology surveys undertaken in December 2005 and May/June 2006 (see Section 3.1.2 below for more details of the aquatic ecology surveys). As for the geomorphology study, the riparian flora study provides a baseline against which the impacts of the 2007 floods can be assessed.
- SCT Operations Pty Ltd (SCT) modelled and prepared initial subsidence estimates for the adopted mine plan, using (*inter alia*) the results of subsidence monitoring for LW1 and LW2. SCT (2008) concluded that a partial miniwall design for long-wall 9 would reduce subsidence to sufficiently low levels (between 200 and 350 mm of vertical subsidence) under Bowmans Creek (see Table 1) and that a substantially intact barrier of sound rock would remain between the base of the alluvium and underground goaf so as to prevent significant loss of water from the creek and saturated alluvium. The proposal also includes a mid-width panel which is located under rehabilitated land previously mined by open-cut.

Table 1
Predicted Subsidence Impacts

Longwall	Panel Width (m)	Overburden Depth (m)	Maximum Subsidence (mm)
MW9	92	160-190	200
LW9	158	140-180	1200

Data from STC (2008)

- Aquaterra (2008) provided the results of groundwater modelling and monitoring studies undertaken for the Ashton underground mine. The report summarises data collected for the original EIS, monitoring data collected for LW1 and LW2 and additional Bowmans Creek alluvium data collected in 2007. The main aquifers in the Mining Lease are the coal seams (with permeability developed in cleat fractures), and unconsolidated aquifers within the alluvium associated with the Hunter River and Bowmans Creek. Glennies Creek and its alluvial floodplain are located to the east of the underground mine, and do not overlap the mining area. Groundwater studies undertaken for the project show that creek flow is governed by upstream rainfall with minimal contribution from surrounding saline alluvium.
- The Bowmans Creek alluvium merges with colluvium along the flanks of its floodplain, and has an abrupt boundary with Hunter River alluvium at the southern end of the valley. The bed of Bowmans Creek is incised directly into bedrock

(Permian coal measures) in a small number of locations, and is overlain by at least 4 metres of saturated alluvium in other places.

- There are three outcrops of Permian coal measures in the creek-bed of Bowmans Creek. Two of these (the upper and lower rock bars) are located outside the area of longwall mining and the middle rock bar section is located just within the present western lease boundary and just outside the LW9 extension area (see Figure 1), coinciding with the weir pool for the DWE stream gauging station. The upper outcrop is associated with elevated saline groundwater seepage sustained by seepage from the Permian rock outcropping beside and/or beneath the pool (see also Section 3.3.1 below).

3.1.2 Bowmans Creek Aquatic Ecology and Water Quality Studies

With respect to aquatic ecological assessments within the Bowmans Creek study area and locality, a number of studies have been conducted to date. These studies are summarised below and the results of the studies in terms of summarising the aquatic ecology of the study area are provided where appropriate in the remaining sub-sections of Section 3:

- In 2001 Marine Pollution Research Pty Ltd (MPR) undertook a qualitative assessment of aquatic ecology (fish habitat) aspects for the Ashton Coal Project EIS (HLA 2001). The study incorporated a review of existing literature and field studies of fish passage potential in Bowmans and Glennies Creeks.
- ACOL has been undertaking monthly 'whole of mine' water quality monitoring of sites in Bowmans Creek, Bettys Creek, Glennies Creek and the Hunter River since September 2004. Water quality parameters include pH, electrical conductivity (EC), alkalinity (total hardness as mg/L CaCO3), total dissolved solids (TDS), total suspended solids (TSS) and oil & grease.
- ERM (2006b) summarised initial aquatic ecology monitoring results for Ashton Mine for the spring 2005 to autumn 2006 period. The monitoring was undertaken by The Ecology Lab (TEL) and the full monitoring reports are contained as appendices to the ERM (2006) report (TEL 2006a, 2006b). Monitoring included macroinvertebrate, fish (using electro-fishing) and water quality sampling. The TEL reports also provided an updated literature review for aquatic ecosystems in Bowmans Creek and confirmed that Bowmans Creek supported native fish populations (see Section 3.4.2 below).

- MPR undertook aquatic ecology monitoring as part of the EMP for Liddell Open Cut mine over the same survey period as the TEL studies (MPR 2005, 2007). Monitoring studies included macroinvertebrate, fish and water quality sampling from three sites located upstream of the Ashton lease area on Bowmans Creek. This study confirmed both the intermittent nature of surface flow and the persistence of shallow sub-surface seepage flow in Bowmans Creek.
- MPR have been undertaking bi-annual aquatic ecology monitoring studies within Bowmans Creek on behalf of ACOL, from 2007 onwards. To date there have been three ‘during mining’ aquatic ecology monitoring surveys conducted; in autumn and spring 2007 and autumn 2008 (MPR 2007, 2008a, 2008b).
- Walkover surveys of Bowmans Creek and tributaries within the study area were undertaken in July 2008 for the present study. For the July 2008 field inspections surface flow was present throughout the whole creek length within the study area (stream flow 37ML/day).

3.2 Aquatic Habitat Assessment

3.2.1 Bowmans Creek Geomorphology

The elevation of the Bowmans Creek channel bed at the upper limit of the lease boundary is about 62m and the elevation at the confluence with the Hunter River is about 49m. PBP (2001) noted that downstream bed-load transport of gravels and cobbles occurs upstream of the New England Highway bridge and that for 5 of the 6 km between the bridge and the confluence with the Hunter River, the creek expands into a much wider valley formed by Pleistocene alluvial terraces and coarse gravel/cobble riffles. Contemporary gravels thin out and become sandier towards the downstream limit of present day progradation of gravels, occurring near a bedrock control point about 1 km upstream of the confluence. Beyond this point a steep scour ramp has been created within the southern-most 300 to 400 metres, in response to the much lower bed level of the Hunter River relative to Bowmans Creek.

Overall, with downstream progression, the channel bed grades from cobble lining with a gravely silty substrate, to a silty sand substrate. Bed slope varies between 0.01% to 0.8% with a mean slope of 0.23% and the Bowmans Creek floodplain width varies from 700 to 1300 metres (ERM 2006a).

Within the study area, the channel of Bowmans Creek is generally incised up to eight metres below the surrounding alluvial flats and up to twelve metres below the bank of the Hunter River (ERM 2006a). The channel banks are alternately steep, gently sloping and terraced, with no clear pattern to channel form evident within the study area.

Whilst the three small billabong formations some 1 to 1.5 km downstream of the Highway are indicative of channel migration in the past, ERM (2006a) concluded that there had been very little channel migration since 1983 based on a review of historical aerial photography. The 2006 geomorphology study indicated that there may have been some recent lateral migration in some reaches although most reach profiles appeared to be constrained on one bank and therefore only exhibited terracing on the opposite bank.

3.2.2 Bowmans Creek Riparian Corridor

The riparian vegetation corridor is characterised by *Casuarina* woodland with small sections of River Red Gum (*Eucalyptus camaldulensis*) open forest (ERM 2006b). The River Red Gum population in the Hunter Catchment is listed as an endangered population under the *Threatened Species Conservation Act 1995* (TSC Act), and is confined to the riparian corridor outside of the mining lease area approximately 1km upstream from the Hunter River confluence.

The area adjoining the riparian vegetation is characterised by continually grazed pasture and relatively isolated patches of open woodland. Surrounding land uses consist of agriculture with mining activities occurring immediately to the north of the New England Highway and to the west of Bowmans Creek.

All studies, including the July 2008 walkover, noted that cattle have access to the creek along most of the study area creek banks, and riparian cattle tracks (parallel to the creek-line) were present along many sections, contributing to minor terracing on steep riparian slopes and facilitating active erosion of the banks.

Some steep sided banks were noted to be unstable, as they are typically in areas with limited riparian vegetation with coverage often consisting of grasses, weeds, or well spaced riparian trees. Whilst active bank erosion was visible in some areas, annual erosion rates appear to be relatively low to moderate (Amanda Kerr *pers com*, September 2008). Submerged bank undercutting at the base of steep sided banks was common along most of the study area creek length.

Riparian trees, where present, generally comprised a single line running parallel to the creek within 5m of the water edge. The most common riparian trees were River She-Oak (*Casuarina cunninghamia*) and the introduced Willow (*Salix babylonica*).

3.2.3 June 2007 Flood Impacts

With regard to impacts on creek geomorphology arising from the June 2007 flood, recent bank erosion was evident at all four survey sites following the June 2007 floods (photos 1, 2 & 3).

During the autumn 2007 sampling survey (two weeks after the flood), MPR noted peak flood levels (by observations of debris deposition in trees) to be approximately 5m above dry weather creek levels at upstream sites and 10-15m higher at downstream sites near the Hunter River confluence.

At all sampling sites, riparian environments had been subjected to deposition by sediment and areas of minor bank collapse were common along most creek sections inspected. Groundcover had been severely scoured at the downstream sites (see photo 1). Fallen riparian trees were present all along the study area bank and at locations where they had fallen in, there was obvious bank collapse (photo 2). Instream logs from fallen riparian trees were present throughout the whole creek length, though not overly abundant.

Photo 1: Riparian and in-stream scouring at the downstream

aquatic ecology monitoring site on Bowmans Creek.

Photo 2: Flood impacts at the mid-stream aquatic ecology monitoring site, autumn 2007

3.2.4 Bowmans Creek Aquatic Habitats

The number of pools in the Bowmans Creek study area varies with flow conditions. In the 2006 geomorphology study, undertaken during low flow conditions, there were 44 separate pools identified (ERM 2006a). For the June 2008 walkover inspection there was moderate surface flow and there were around 24 pools within the study area, ranging in length from 10m to 500m. Most pools are wide (10m) and shallow (to 1m deep) with some deeper pools (to 2.5m deep). Several pools (the top pool and the weir pool) are located within exposed basement rock, although neither are rock-bar constrained. Most of the pools are connected by cobble riffle zones and the remaining pools are structured as "chain-of-ponds" type (see Rutherford et al 2000), with more or less permanent pools (dependent on depth) separated by bars of sediment stabilised with vegetation. Many riffle or narrow pool sections are bordered by exposed cobble beds on one side with steep sided banks on the other. Pools at the lower end of the study area are steep sided on both sides as the creek erodes down to the level of the Hunter River.

MPR (2001) concluded that 'no major barriers to fish migration were found within the Bowmans Creek study area'. The small DLWC gauging weir (located approximately 2.6km downstream from the New England Highway) was deemed to potentially inhibit fish passage during drought conditions, and there were some minor impoundments noted upstream of New England Highway behind road crossings, however all structures were considered suitable for fish passage during most flow conditions. Subsequent surveys confirm that this still remains the case (see for example MPR 2008a.b).

Observations of water availability during 2006 drought periods noted minimal or zero surface water available in the upper reaches of the study area (i.e., for about 2.5km of creek immediately downstream of the New England Highway). From this point (at around Pool 21 in ERM 2006a), the surface water flow then resumed downstream to the Hunter River.

The combined TEL and MPR 2005 to 2008 monitoring studies indicate that during dry times when pool water levels are low, the Bowmans Creek exposed channel is colonised by terrestrial species, such as spike rushes (*Juncus sp*), and Casuarinas. Grasses and weeds rapidly colonise previously wet bank areas or newly settled sediment deposits. The newly established in-stream vegetated areas have the potential to form islands or extended terrestrial banks, if flow conditions remain low for sufficient time for trees to develop to a mature enough stage, and can influence the localised formations of flow channels during and following subsequent high flow periods.

For the July 2008 walkover inspection and for most of the earlier monitoring studies, Cumbungi (*Typha sp*) stands were the most commonly encountered emergent macrophytes, with Curly Pondweed (*Potamogeton crispus*) and Watermilfoil (*Myriophyllum sp*) the most common submerged macrophytes. An additional six submerged and emergent macrophyte species have been recorded over all Bowmans Creek surveys, they are; Clasped Pondweed (*Potamogeton perfoliatus*), Sago Pondweed (*Stuckenia pectinata*), Slender Knotweed (*Persicaria decipens*), Maundia (*Maundia triglochinoides*), Common Reed (*Phragmites australis*) and the introduced Watercress (*Nasturtium officinale*).

Lower sections of Bowmans Creek between the ox-bow and the Hunter River including sections that will be potentially impacted by mining under the proposed lease extension long-wall are described as follows:

- Upstream of the lease extension, at the lower part of the ox bow, the creek is narrow with short pool sections (to 1.5m deep) all connected by shallow, constricted cobble-riffle zones that alternate flow routes within the channel between consecutive pool sequences. The banks bordering the channel on the western bank are steep with riparian trees abutting the bank edge, some of which are in the process of falling into the stream.

- In July 2008 there was a single narrow, straight pool extended for a distance of approximately 500m from the ox-bow to the bend just upstream from the DWE stream gauge and weir. Banks on both sides of the creek are relatively similar and vary between 2 and 3m height, with sections of bank showing signs of recent slumping. Average pool depth along the pool section is around 1m, with maximum depths to 1.5-2m.
- There is a short cobble riffle section on the bend of the creek bordered by large concrete blocks and a retaining fence on the western bank. The riffle coincides with the start of the creek section overlying LW9, which turns due south and extends into a 1m deep pool (pond 22 in ERM 2006a) which terminates at the weir. There are a number of bedrock outcrops through this creek section that could act as fish passage barriers during periods of low flows.
- The creek channel immediately below the weir contains a number of boulders, with bedrock present in-stream and on the western bank. The pool extends for around 150m, near the downstream limit overlying LW9 and has a depth of 1.5 to 2m (pond 24 in ERM 2006a).
- The next 700 m section of creek is narrow (to 5m width) and relatively deep (to 2m), with very steep banks, mostly along the eastern edges. This section includes the MPR aquatic ecology monitoring site BCLW7 and the ACOL water quality monitoring site SM5 (see Figure 1) plus the long section overlaying the proposed longwall extension. Seven ponds (ponds 24 to 30) were noted in March 2006 in this creek section (ERM 2006a). In July 2008 there were two pools separated by a riffle section, with the lower pool widening and the bank becoming steep along the western side.
- The southernmost limit of the proposed LW9 underlying Bowmans Creek is located around 400m upstream from the Hunter River confluence. The creek channel throughout the potential impact area is uniform, consisting of a deeply incised channel 10-15m below the surrounding floodplain. The channel basin is relatively flat averaging 0.8 to 1m deep throughout the section, with an exposed cobble bar on

the inside corner of the creek bend. Riparian banks are steep (~45º) and vegetated by grasses and weeds, with scattered riparian Casuarinas, Eucalypts and Willows. Bank undercutting is present along the outside edge.

3.3 Seasonal Water Quality

The ecological value of the Bowmans Creek study area aquatic habitats is linked to both habitat availability and condition (summarised in Sections 3.1 and 3.2 above) and to the water quality attributes of the ponded waters. In this section, available water quality data is reviewed. Section 3.3.1 considers the 'whole of mine' monthly water quality collected by ACOL over the mining period and Section 3.3.2 considers the water quality data collected by the aquatic ecology teams over the period of aquatic ecology sampling (2005 onwards). TEL and MPR sampled water quality in spring 2005, autumn 2006, and autumn 2007 to autumn 2008 at four sites in the study area.

3.3.1 ACOL Water Quality Data

With regard to understanding the various contributions of natural and human contributions to water quality in Bowmans Creek, ACOL have established a network of water quality monitoring stations (see Figure 1) most of which have been sampled since September 2004. In terms of Bowmans Creek inputs and outputs the following monitoring sites are relevant:

- Water quality monitoring sites above New England Highway are located on Bettys Creek (SM1 above all Ashton mining activities and SM2 above the confluence with Bowmans Creek) and in Bowmans Creek (SM3 upstream and SM4A downstream of the Bettys Creek Confluence).
- There are three sites in Bowmans Creek below the New England Highway (SM4 to SM6). SM4 and SM6 are located upstream and downstream of the proposed underground mining footprint and SM5 is located about mid way at the weir pool.
- There are two sites in the Hunter River, SM9 upstream and SM10 downstream of the Bowmans Creek confluence.

Full results of this water quality monitoring are provided in the ACOL Annual Environmental Monitoring Reports (AEMRs) and are not reproduced for this report. However, Table 2 provides summary statistics for five of the six ACOL water quality parameters from all the relevant Bowmans/Bettys Creek/Hunter River sites. The sixth parameter (oil and grease) was excluded as all data were reported as "less than detection limit".

Table 2
ACOL Life of Mine Monthly Water Quality Data
Summary Statistics Sept 04 to Feb/Mar 08

Statistic / Site	BCk Up SM1	BCk Conf SM2	Bow Up SM 3	BowB Conf SM4A	Rock Pool SM 4	Weir Pool SM 5	Bow Conf SM 6	Hunt Up SM 9	Hunt Dwn SM 10
Alkalinity (mg/L CaCO3)									
N	3	3	38	12	42	42	42	42	42
Min	39	71	102	106	97	105	107	131	112
Max	283	303	383	344	1590	363	371	358	356
Mean	147	159	301	251	683	291	241	218	221
SE of Mean	72	72	10	22	64	8	10	8	9
Total Suspended Solids (TSS mg/L)									
N	3	3	38	12	42	42	42	42	42
Min	8	18	2	2	2	2	2	1	2
Max	504	98	160	103	278	31	36	204	160
Mean	175	48	23	24	49	11	15	26	26
SE of Mean	165	25	5	9	8	1	1	5	4
Acidity (pH)									
N	3	3	39	13	43	43	43	42	42
Min	7.2	6.6	6.9	7.5	7.4	6.9	6.9	7.8	7.9
Max	7.9	7.6	7.9	7.9	9.1	8.1	8.3	8.5	8.5
Mean	7.6	7.1	7.5	7.7	8.0	7.7	8.0	8.1	8.2
SE of Mean	0.20	0.29	0.04	0.04	0.06	0.03	0.04	0.02	0.02
Conductivity (µS/cm)									
N	3	4	39	12	43	43	42	42	42
Min	277	574	421	434	428	432	453	304	319
Max	1800	1950	1750	1980	14400	2040	1850	1270	1290
Mean	951	1032	1375	1263	4574	1486	1001	740	767
SE of Mean	448	313	46	139	590	48	53	32	33
Total Dissolved Solids (TDS mg/L)									
N	3	3	38	12	42	42	42	42	42
Min	578	586	294	300	286	296	308	236	255
Max	1190	1120	976	1130	8820	1160	1080	658	672
Mean	919	791	818	734	2833	870	539	385	401
SE of Mean	180	166	25	76	364	27	31	18	18

Over the 42 months of sampling, the two up-stream Bettys Creek sites SM1 and SM2 were predominantly dry and only showed sufficient water levels for sampling following the June 2007 flood. Since then they have only been sampled three times, also when there was sufficient water for sampling. The additional Bowmans Creek site SM4A was established in March 2007 to aid in determining the cause/source of the water quality anomalies at Site SM4 (see below). The upstream Bowmans Creek site SM3 was sampled over the complete sampling period, but was dry over the period 13 March to 7 June 2007.

Inspection of the statistical summary results indicate that variations in mean electrical conductivity (EC), Total Dissolved Solids (TDS), alkalinity, and pH between sites were similar, with the exception of Site SM4. SM4 has had significantly higher mean values recorded for all parameters than all other sites. Aquaterra (2008) found that salinity in the upper Permian coal measures ranged from 1100 to 9390 µS/cm EC and that some Bowmans Creek baseflow is derived locally from the Permian at site SM4. Thus, the increase in salinity within the SM4 pool would be expected to be inversely related to overall flow in Bowmans Creek (as was the case). That is, when upstream surface contributed inflow rates are low, the contribution of Permian derived baseflow to the SM4 pool becomes more significant and conductivity in pool SM4 rises, with the rate of rise dependent on the preceding flow history. Further, when there is a long dry period with little to no surface water in-flow, conductivity in pool SM4 can be expected to become highly elevated (as observed).

The monthly ACOL EC data for sites downstream from the SM4 pool and the daily EC data from the weir pool do not show any significant increases over the periods when the SM4 pool salinity is elevated and it is concluded that the elevated EC in pool SM4 is generally confined to that pool by virtue of the correlation with low to no flow periods.

3.3.2 Aquatic Survey Water Quality Data

Field water quality measurements were made at all aquatic ecology sites in Bowmans Creek sites during each of the five aquatic ecology sampling programs (spring 2005 to autumn 2008) and results are provided in the various monitoring reports). Water quality results obtained during these studies may be summarised as follows:

- For All Bowmans Creek monitoring sites, salinity and pH values were within the range set for Lowland Rivers by ANZECC (2000) guidelines.
- On three of the five surveys, mean dissolved oxygen (DO) values (measured as % saturation) were below the range set by ANZECC Guidelines for Lowland Rivers of 85 to 110% saturation; TEL recorded mean DO values of 68.3 and 74.4% saturation in the low flow and drought periods (spring 2005 and autumn 2006 respectively). During high flow conditions (autumn 2007), MPR recorded a mean DO value of 59 %. Higher values were encountered in spring 2007 and autumn 2008 by MPR (mean DO % saturation values of 91.4 % and 91 % respectively).

From the consideration of the combined ACOL water quality monitoring program and the aquatic ecology field water quality measurements it is concluded that for all the sites where measurements were made (with the exception of site SM4), water quality was generally reasonable and acceptable for the maintenance of aquatic ecological function. Water quality and thus aquatic ecology, deteriorated during low flow and flood flow periods with the main aquatic stress arising from low dissolved oxygen concentrations. Site SM4 is highly stressed by elevated conductivity during low to no flow periods and this is likely to have had a significant (i.e. measurable) impact on the biotic assemblages of this pool.

3.4 Macroinvertebrate and Fish Communities

Over the period spring 2001 to autumn 2008, there have been eight aquatic ecology surveys in Bowmans Creek, incorporating sampling for macroinvertebrates and fish, and including two surveys that used electro-fishing techniques. Surface stream flow conditions varied between surveys, and even between sites within surveys. For references to flow condition in the following paragraphs the following flow descriptors have been adopted:

- ‘dry’ represents no surface flows during time of sampling in the majority of site pools,
- ‘low flow’ represents surface flow conditions encountered at all sites, with generally only trickle flow through riffle zones in the shallow cobble and boulder beds in between pools.
- ‘Normal flow’ conditions are more representative of mean flow rates for Bowmans Creek, and
- ‘Wet flow’ includes periods with higher than mean flows following rainfall through to floodwaters (i.e., where normally exposed banks are submerged).

3.4.1 Macroinvertebrate Fauna

A total of 28 edge and 2 riffle habitat sites have been sampled over 8 surveys between spring 2001 and autumn 2008. Seasonal summary statistics for the edge habitats sampled between 2001 and 2008 are presented in Table 2 below. Unless otherwise stated, the following summary applies to edge habitat data only.

To date, a total of 70 aquatic macroinvertebrate taxa (taken to AusRivAS required family level) have been identified from the combined studies. Four of the taxa were recorded from riffle habitats only; riffle beetles (family Elmidae), water pennies (family Psephenidae), fly larvae (family Dolichopodidae) and dobsonflies (family Cordyalidae). The majority of the taxa are insects (67%), with the remainder being molluscs (12%), crustaceans (9%). Arachnids, flatworms, annelid worms, leeches, roundworms and springtails were all <3%.

Table 3
Macroinvertebrate Summary Statistics for Bowmans Creek

Flow Condition	Dry	Dry	Dry	Low flow	Low flow	Normal Flow	Wet	Wet
Flow rate (ML/D)	N/A	0.4	0.4	0.7-0.8	1.7	27.7-24.8	123-129	840-158
Sampler	MPR	TEL	MPR	TEL	MPR	MPR	MPR	MPR
No of Sites	N=2	N=4	N=2	N=4	N=3	N=4	N=4	N=4
Season and Year	Sp01	Au06	Au06*	Sp05	Sp05*	Au08	Au07	Sp07
Total number of invertebrate taxa:	8	31	31	33	33	32	25	30
Mean number of taxa per site:	5.0	15.5	16.3	20.5	23.0	18.8	14.0	17.0
SE:	0.0	1.8	4.7	1.9	3.0	1.1	2.5	1.9
Creek SIGNAL scores:	3.88	3.83	4.59	4.06	4.43	4.97	3.80	4.43
Site SIGNAL low	3.00	3.14	4.33	3.09	3.67	4.79	3.00	4.33
Site SIGNAL high	4.80	3.90	4.80	3.50	4.86	5.19	4.00	5.25
Mean	3.90	3.59	4.49	3.31	4.34	5.00	3.67	4.59
SE	0.90	0.16	0.16	0.11	0.35	0.09	0.23	0.22

*Represents aquatic ecology surveys undertaken from upstream Bowmans Creek locations

There were thirteen taxa which were found in Bowmans Creek on six or more of the eight surveys, and six of those taxa were also common throughout the creek (i.e. occurring at over 75% of total sites sampled); midge fly larvae (sub-family Chironominae), freshwater shrimp (family Atyidae), damselflies (family Coenagrionidae), mayflies (family Caenidae), water boatmen (family Corixidae) and caddis flies (family Leptoceridae).

Individual site diversity ranged between 5 taxa (spring 2001 drought) to 26 taxa (spring 2005 dry with some flow). Comparisons of the seasonal mean number of taxa per site show reduced taxa diversity during wet and dry periods when compared to low flow and normal flow conditions. Despite this, seasonal total number of creek taxa figures during wet and dry flow periods are almost as high as those in periods of low flow to normal flow. That is, even though individual sites may not support as diverse an assemblage of aquatic macroinvertebrates under drought or flood conditions, the aquatic drought and flood refuges in the creek as a whole continue to support similar taxa diversities.

In terms of SIGNAL grades, the study area pools support diverse fauna with a full range of pollution tolerances, from the most sensitive taxa, Mayfly family Leptophlebiidae (grade 10) to the pollution tolerant snail family Physidae, Dragonfly family Lestidae and Springtails (grade 1).

In general, the Bowmans Creek monitoring sites support a pollution tolerant macroinvertebrate fauna, as indicated by the AusRivAS model and validated by the SIGNAL index scores over consecutive surveys. From analysis of taxa present in Bowmans

Creek on a seasonal basis, SIGNAL values all indicate a range of severe to moderate impairment under drought and flood conditions, and moderate impairment during normal flow conditions. There were no real trends in overall creek SIGNAL scores relating to different flow conditions. Individual site SIGNAL values range between 3.00 and 5.25 for wet conditions, between 3.00 and 4.80 for dry conditions, and between 3.09 and 5.19 for low flow to normal flow conditions.

3.4.2 Fish and other Fauna

To date there have been 14 fish species recorded from the Bowmans Creek catchment, 2 of which are introduced species (see Table 4 below). MPR (2001) listed two species recorded in Glennies Creek that could also be expected to occur within Bowmans Creek; bullrout (*Notesthes robusta*) and the introduced goldfish (*Carassius auratus*).

Although Australian smelt are listed as potadromous, recent studies of populations in coastal drainages of south-eastern Australia showed that a majority of the fish analysed inhabited the sea or estuaries during early life stages (Crook *et al* 2008).

Table 4
Fish Species Recorded from Bowmans Creek

Family	Species	Common name/s	Life cycle*	Recorded	Native/ Introduced
Anguillidae	*Anguilla australis*	Short-finned Eel	C	X	N
Anguillidae	*Anguilla reinhardtii*	Long-finned Eel	C	X	N
Atherinidae	*Craterocephalus amniculus*	Darling Hardyhead	U	X	N (species of concern)
Cyprinidae	*Cyprinus carpio*	Common Carp	L	X	I
Eleotridae	*Gobiomorphus australis*	Striped Gudgeon	A	X	N
Eleotridae	*Gobiomorphus coxii*	Cox's Gudgeon	P	X	N
Eleotridae	*Hypseleotris compressa*	Empire Gudgeon	U	X	N
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	U	X	N
Eleotridae	*Philypnodon macrostomus*	Dwarf Flathead Gudgeon	U	X	N
Mugilidae	*Mugil cephalus*	Sea Mullet	A	X	N
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	C	X	N stocked
Plotosidae	*Tandanus tandanus*	Freshwater Catfish	L	X	N (species of concern)
Poeciliidae	*Gambusia holbrooki*	Plague Minnow	L	X	I
Retropinnidae	*Retropinna semoni*	Australian Smelt	P	X	N

Key:
A- Amphidromous (fish that migrate between the estuary and the sea, but not for breeding purposes).
C- Catadromous (fish that spend most of their lives in freshwater but migrate to the sea to breed).
P- Potadromous (fish that migrate wholly within freshwater).
L- Local (species that require fish passage only in their immediate environment).

U- Unknown
Note*: Life cycle characteristics referenced from Thorncraft & Harris 2000.

No species of fish or aquatic invertebrates, as currently listed under the NSW Fisheries Management Act 1994 (FMA), or under the Commonwealth Environment Protection & Biodiversity Conservation Act 1999 (EPBC Act), were recorded or expected in any of the monitoring conducted to date, and no protected fish, as listed under the FMA, have been found or observed in Bowmans Creek. Two species are listed a species of concern in Morris *et al* 2001; The Darling hardyhead and the Freshwater catfish.

- The Darling hardyhead (*Craterocephalus amniculus*) is listed due to its taxonomic uncertainty. The Darling hardyhead is endemic to streams in the upper Darling River system. Specimens tentatively identified as *Craterocephalus amniculus* were collected from upper Bowmans Creek in 1976 and 1980, though no further individuals have since been collected (cited in Morris *et al* 2001). This species has not been observed or caught in any of the surveys conducted on behalf of ACOL (from 2005 onwards) and was not caught during the TEL electro-fishing survey of the creek in (2005-2006).
- Morris *et al* 2001 note that whilst the freshwater catfish (*Tandanus tandanus*) is not currently listed as threatened in NSW, its distribution and abundance has been significantly reduced throughout the southern parts of its known range. Freshwater catfish are generally found close to sand or gravel bottoms in slow moving streams, lakes and ponds with fringing vegetation (Allen *et al* 2002), habitat features consistent with that encountered in Bowmans Creek. This species has been recorded from refuge pools in the study area during the autumn 2006 drought.

The introduced pest species, plague minnow (*Gambusia holbrooki*), has been the most commonly encountered fish during all aquatic ecology monitoring surveys. They have been recorded at every monitoring site sampled in Bowmans Creek between spring 2005 and autumn 2008, with the exception two sites in post flood conditions during autumn 2007. carp have also been commonly observed over all surveys, with the exception of high flow periods encountered during autumn and spring 2007.

With regard to other possible fauna associated with the Bowmans Creek aquatic habitats, the various studies have reported amphibians , water birds and lizards. Whilst platypus are known from the locality (in Glennies Creek) there have been no records or sightings in the

Bowmans Creek study area. Also, although possible feeding stations for Australian native water rat have been observed previously, no animals have been observed or recorded.

3.4.3 Groundwater Dependent Ecosystems (GDEs)

Both the flora and fauna report (ERM 2008) and this aquatic report considered the occurrence of GDEs in the study area. Potential GDEs were identified using the eight-step rapid assessment (DLWC 2002) and it was concluded that there are no known or likely wetland, terrestrial or aquifer/cave ecosystem GDEs in the study area. Assessment of riparian vegetation did not indicate any specific riparian plant communities, which could be considered groundwater dependent.

Aquaterra (2008) report that there is a small saline baseflow component from the saturated alluvials of Bowmans Creek to the creek, thus it is assumed that there is a hyporheic zone between the saturated alluvials and the creek bed. Given the lateral extent of saturated alluvials (as indicted on Aquaterra 2008, Fig 19), it is also concluded that there are probably some parafluvial zones in the creek.

With regard to the degree of dependency of possible aquatic or hyporheic GDEs to baseflow in the Bowmans Creek study area the following factors are relevant:

- The creek is perennial with sub-surface creek sediment saturation controlled for the majority of the time by surface water rather than upwelling groundwater.
- Due to there being some surface flow most of the time, riparian and edge emergent vegetation plus riffle zone fauna are more dependent on fluctuating surface water levels than on groundwater upwelling, and there is insufficient groundwater upwelling to make any significant impact on surface water levels except under prolonged drought periods.
- When there is no surface water during prolonged drought conditions such that the baseflow starts to become significant, there are no riffles, there are only small disconnected pools remaining and the pool edge vegetation will have died off. At that time salinity of the baseflow also becomes significant, thus limiting the remaining aquatic macroinvertebrate assemblages that could reside in the pools and limiting the microinvertebrate fauna that could reside in the hyporheic zone.

It is concluded that possible aquatic and hyporheic GDEs in Bowmans Creek within the study area would not be considered significantly dependent on baseflow groundwater.

4 IMPACT ASSESSMENT

4.1 Potential Impacts

The main potential impacts which can arise from long-wall mining below a creek are related to subsidence, with the following potential results:

- Lowering of sections of creek resulting in deeper pools or new pools or steeper riffle sections between pools depending on the location of longwalls with respect to overlaying pool morphology.
- Destabilisation of steep unconsolidated banks with resultant accelerated bank erosion and increased sedimentation within the creek bed.
- Cracking of rock bar or rock bank constrained pools with possible draining or leakage of pools.
- Fracturing of aquclades below the creek alluvium resulting in increased leakage from the creek pools to the fractured rock and possibly leakage to the mine itself.
- Altered water quality arising from increased leakage water percolating laterally through fractured rock or alluvium and re-emerging further downstream.

With regard to aquatic ecology impacts arising from these subsidence related effects, the main consequences are potential increased isolation of pools, increases in barriers to fish passage, a reduced availability of drought refuge pools and changes to water quality, particularly during low flow events.

Barriers to fish passage can cause local extinctions or greatly reduce fish abundance and diversity (Thorncraft & Harris 2000), and, if there are longer prolonged periods of no or intermittent surface flow in Bowmans Creek over the proposed mining area, the resultant increased barrier to fish migration between the Hunter River and upstream Bowmans Creek pool sites could affect the five diadromous species that have been previously recorded in Bowmans Creek (short and long-finned eel, striped gudgeon, sea mullet and Australian Bass).

Isolation of pools can also favour introduced species like Plague Minnow, which are capable of rapid reproduction, spawn many times within a year and can tolerate a wide range of environmental conditions. These factors, combined with a well documented aggression towards native species, can then impact upon native fish and amphibian populations in refuge pool environments.

Both MPR (2007) and TEL (2006b) documented the isolation of in-stream macrophyte beds from reduced-size Bowmans Creek pool sites during the autumn 2006 drought period. More generally, aquatic habitats become impacted by exposure of physical structures such as logs, undercut banks, boulders, bank vegetation, and tree roots that would otherwise serve as habitats for fish and macroinvertebrates.

Aquatic biota can also be impacted by the decline in water quality due to the reduction in pool water volume and the lack of pool water replenishment when flow ceases. For example, there can be increases in the amount of filamentous green algae, there can be high turbidity caused by Carp disturbing the reduced pool bottom sediments and there can be decreased oxygen concentrations in the water due to the oxygen demand from the concentrated populations of aquatic biota.

4.2 Aquatic Ecology Impact Conclusions

Based on the assessment of predicted subsidence induced changes to creek morphology plus to water quantity and quality provided above, the impacts of longwall mining on aquatic biota and habitats in Bowmans Creek above and in the vicinity of the proposed lease extension using conventional full-width panels could be expected to be severe as full-width mining under the creek could be expected to result in subsidence of up to 1.6 m and there could be significant changes to surface and groundwater quality and quantity due to changes in alluvium conductivity plus possible drainage from the creek to the mine. This could have significant impacts on the aquatic ecology of the Creek.

5 MITIGATION AND MONITORING OF POSSIBLE IMPACTS

DEC & DPI (2005) outlines a broad five-step process for assessing flora and fauna impacts and Step 4 addresses the question of mitigation. Where there is a potential for impact, this should be addressed through, firstly, avoiding the impact; this may mean making some changes to the proposed development. If avoidance is not possible, then some form of mitigation may be required. Finally, if neither avoidance nor mitigation is possible, then some form of offset or compensation will be required. This could entail the rehabilitation of similar habitat nearby.

5.1 Avoidance Measures

From the combined longwall mining impacts studies undertaken to date (SCT 2008, Aquaterra 2008, ACOL 2008 and ACOL *pers. comm*.), subsidence over full width longwall panels within the present lease area could be expected to reach up to 1.6m. Based on the assessment provided in Section 4 above it is concluded that full-width long-wall panel mining in the sections of mine below Bowmans Creek and its associated saturated alluvials would have unacceptable impacts on the aquatic ecology of Bowmans Creek, could affect the passage of fish between the Hunter River and upstream habitats in Bowmans Creek and consequently could lead to the local extinction of several fish species from the upper creek habitats. Accordingly the main mitigation measure proposed is to avoid full-width long-wall mining under Bowmans Creek.

5.2 Mitigation and Offset Measures

ACOL (2008), Aquaterra (2008) and SCT (2008) have modelled possible mini-wall mining for the longwall sections under Bowmans Creek, and it is predicted that the main impacts can be minimised to an acceptable degree such that there would be no significant impacts on the aquatic ecology of Bowmans Creek, no significant impact on fish passage and consequently no significant impact on the aquatic ecology of Bowmans Creek above the proposed mine extension.

The main recommended mitigation measure is that mini-wall mining be used for the sections of the proposed longwall panel below Bowmans Creek. The basis for this recommendation is summarised as follows:

- Mining induced subsidence could be kept to a low range of between 200 and 350mm.

- Miniwall mining would be expected to have a minimal impact on the base-flow contribution from Permian (saline) aquifers to Bowmans Creek surface flows, with a during and post-mining decrease limited to around 1 L/s and long term post mining groundwater quality, and contribution to stream flows expected to be similar to pre-mining conditions.
- There would not be a direct hydraulic connection between the saturated alluvium and mine workings.
- Changes to creek channel morphology (e.g., redistribution of sediments within pools, changes to pool riffle sequences) would be minor and it would be unlikely that the overall channel shape would change as a result of subsidence.

Currently, baseflow from the Permian is a source of elevated salinity waters in Bowmans Creek at the SM4 water quality point, located just below the New England Highway. Seepage rates are considered to be relatively low as salinity increases only become significant in this pool when there is no (or very little) contributing surface flows (see Section 3.3.1). For the other water quality sampling sites within the proposed mining area, conductivity is similar to that of Bowman Creek waters upstream of the New England Highway, indicating little baseflow contribution to Bowmans Creek from either the alluvials or Permian measures groundwater in the area. This is confirmed by the Aquaterra (2008) groundwater study; "Bowmans Creek alluvium contributes some baseflow to Bowmans Creek although the contribution from the planned mining area is very small".

It is also predicted (Aquaterra 2008) that baseflow contribution from saline groundwater to Bowmans Creek using miniwall mining techniques would be reduced during mining and for a period after the completion of mining until groundwater aquifers recover. Loss from alluvium would be in the order of 1L/s. Accordingly, there would be negligible lowering of the alluvial water table and it is expected that water quality in Bowmans Creek would not be adversely impacted by mining and could even improve during low and no flow conditions. There would be long-term recovery following cessation of mining. That is, miniwall mining is not expected to have any significant impact on water availability or water quality for creek biota (although water quality could show an incremental improvement under very low flow conditions during mining due to the lower salt load being introduced to the creek from baseflow).

As noted in Section 3.3.4, and as is typical for a meandering stream, a significant proportion of the creek sections overlying the proposed mining areas are subject to non-mining related bank erosion with consequent increased sedimentation, alteration of stream bed character from cobble/sand to sediment plus shallowing of pools, all of which affect the aquatic ecology of the stream. Whilst subsidence could be expected to exacerbate this instability on a local scale in the vicinity of miniwall subsidence zones, the net effect is not expected to be significant, particularly given the scale of present impact.

Notwithstanding this conclusion it is noted that riparian rehabilitation works undertaken pre-mining would decrease any potential for subsidence related creek morphology change. To this end ACOL has initiated riparian rehabilitation works, and the riparian stabilisation works currently being instigated on Bowmans Creek are designed to minimise non-mining related bank instability and would consequently ensure that there are no significant impacts of subsidence on bank stability.

Accordingly, impact on aquatic habitats and biota plus impacts on the hyporheic zone could be expected to be negligible, with no significant impact on the availability of drought refuge pools within the section of Bowmans Creek in the proposed mining area. It is also concluded that there would be no significant impact on fish passage through the section of Bowmans Creek in the proposed mining area and no significant impact on fish passage between the Hunter River and Bowmans Creek above the proposed mining area.

Given the predictions of no significant impacts on the aquatic ecology of the creek if miniwall mining is used for the proposed longwall sections under the creek plus given that one of the recommended mitigation measures (riparian habitat rehabilitation) has already been instigated it is concluded that the main aim of the DEC & DPI (2005) guidelines; to achieve a "maintain and improve" outcome for the ecology of the proposal site can be met with respect to the aquatic ecology of the site and accordingly there would not be any necessity for an offset strategy for the protection of the aquatic ecology of the site.

5.3 Suggested Monitoring Program

Continued monitoring of stream-health plus of water quality and availability in Bowmans Creek is recommended to detect any possible mining impact and to determine the need for any specific mitigation measures as a consequence. For example, monitoring could determine if there is a noticeable increase in saline water contribution to Bowmans Creek stream flows at any location within the study area, or if there is a detectable decrease in stream flows that could be linked to mine workings.

Monitoring would require a guiding set of criteria or protocols developed to establish the circumstances under which mitigation measures would be required. These would be specified in Site Management Plans and Trigger Action Response Plans (TARP). As a general guide, where perceptible impacts are noted through site monitoring activities, the following general procedure would be applied:

- Undertake additional investigations to ascertain the actual cause (mine-related or other cause) of deteriorating aquatic conditions;
- If mining related, notify relevant government authorities;
- Develop and implement a specific response plan to prevent further impacts, and
- Undertake remediation as required.

The response plan would need to be prepared on a case by case basis. For instance, should water quality monitoring indicate adverse localised or stream-wide water quality deterioration which may be attributed to mining impacts, a suggested mitigation measure to prevent water quality/quantity induced impacts on the aquatic ecology of Bowmans Creek could be to make provision for the addition of good quality (low conductivity) water to enhance environmental flows at the upstream end of the lease area, until such time as the loss of water could be addressed.

5.2.1 Water Quality and Quantity Monitoring

With regard to water quality monitoring, recommended groundwater monitoring is described in the specialist groundwater report (Aquaterra 2008). With regard to surface water quality it is recommended that the existing water quality monitoring programs plus some additional site specific monitoring be undertaken:

- The combined monthly water quality monitoring program at the present 'whole of mine' ACOL Bowmans Creek, Bettys Creek and Hunter River sites should be continued.
- Field water quality monitoring during the biannual aquatic ecology monitoring program should be continued and extended to include depth profile monitoring of field water quality parameters where possible or practicable.

With regard to creek surface water quantity monitoring for stream health purposes, it is considered that the present weir gauge monitoring data are important (and sufficient) for enabling the interpretation of Bowmans Creek water quantity change. Accordingly it is recommended that this gauging station (or a replacement gauging station, if required) be maintained and re-calibrated as necessary, at least over the period of proposed mining.

5.2.2 Aquatic Ecology Monitoring

With regard to aquatic ecology monitoring, there are currently four aquatic ecology monitoring sites sampled bi-annually in Bowmans Creek (see Figure 1 in Section 1 above). Long-term monitoring for impacts to include the additional proposed longwall panel may require moving one of the original sites and introducing several additional sites, for a net long-term monitoring set of six sites. The following modifications to the existing long term aquatic ecology monitoring program are recommended:

- The upstream and downstream reference sites (BCUp, BCLW5, BCLW7 and BCDown) remain as designated reference sites above and below the mining impact area.
- Establish a new long term aquatic ecology monitoring site (BC1) at the ACOL water quality monitoring site SM4, as pre-mining monitoring of this site will provide a measure of the impacts of naturally elevated conductivity on macroinvertebrate and fish communities during low to no flow periods.

Short-term miniwall monitoring sites are recommended to be incorporated into sections of Bowmans Creek overlying specific miniwall sections when these are established. In addition to the long-term monitoring sites, these sites would be introduced into the aquatic ecology monitoring program on a staged basis, that is, relative to the progression of the respective miniwall mining. It is recommended that sampling of each of these sites would be scheduled into the regular bi-annual sampling program to incorporate a before, and at least two after samples from each site according to the scheduled mining program. This will enable the direct assessment of mining impacts on individual pools as mining proceeds and will also facilitate the interpretation of long-term monitoring results. For each of the short-term sites any decision to continue monitoring beyond the two post-mining studies would be made on a site by site basis, and only if there was evidence of localised mining impact arising from the before/after comparisons.

6 SUMMARY

This assessment of the present aquatic ecology of Bowmans Creek within the study area (i.e., downstream of New England Highway) indicates that Bowmans Creek provides valuable fish passage conditions linking the Hunter River to upstream Bowmans Creek fish habitats. Bowmans Creek provides valuable localised fish and aquatic habitat within the study area. Whilst Bowmans Creek is perennial, there can be long periods of limited fish passage due to the disconnection of pools during periods of low flow, when the flow is confined to sub-surface sediments.

The study area aquatic habitats (and fish passage potential) have been compromised by the combined effects of historical regional plus local riparian vegetation clearing, continued stock access to the riparian habitats, and the consequential destabilising of riparian banks, the deposition of mobile sediments into the creek, the shallowing of ponds and the alteration of pool water quality, particularly during low to no flow periods.

Based on the assessment of predicted subsidence induced changes to creek morphology plus to water quantity and quality, the impacts of longwall mining on aquatic biota and habitats in Bowmans Creek above and in the vicinity of the proposed lease extension using conventional full-width panels could be expected to be severe as full-width mining under the creek could be expected to result in subsidence of up to 1.6 m and there could be significant changes to surface and groundwater quality and quantity due to changes in alluvium conductivity plus possible drainage from the creek to the mine.

This would have unacceptable impacts on the aquatic ecology of Bowmans Creek, could affect the passage of fish between the Hunter River and upstream habitats in Bowmans Creek and consequently could lead to the local extinction of several fish species from the upper creek habitats. Accordingly the main recommendation with regard to aquatic ecological impacts is to avoid full-width long-wall mining under Bowmans Creek.

With regard to possible mitigation measures. subsidence plus groundwater and surface water impacts can be mitigated to insignificance if mini-wall mining is used for the longwall sections under Bowmans Creek, and it is predicted that the biological impacts can be minimised to an acceptable degree such that there would be no significant impacts on the aquatic ecology of Bowmans Creek, no significant impact on fish passage and consequently no significant impact on the aquatic ecology of Bowmans Creek above the proposed mine extension.

ACOL are presently instigating riparian rehabilitation measures to address and reverse present riparian bank deterioration within their lease area and, whilst minwall mining contributions to geomorphic instability is predicted to be insignificant, it is considered that the riparian rehabilitation works being undertaken pre-mining, would provide an additional buffer against potential mining impacts, mainly by stabilising riparian banks.

Long-term stream health monitoring currently utilises a network of water quality monitoring sites sampled monthly and four Bowmans Creek aquatic ecology sites, sampled twice a year in spring and autumn. In order to monitor for the possible impacts of mining from the proposed mine plan it is recommended that:

- The same water quality monitoring program be continued with provision for additional field (i.e., metered) conductivity monitoring in the section of creek between sites SM4 and SM5 when there is elevated conductivity found at site SM4 (i.e., under low or no flow conditions).
- An additional aquatic ecology monitoring site be introduced (at SM4).
- Short-term 'during mining' aquatic ecology monitoring sites above miniwalls be included, with each of these sites monitored seasonally once before mining proceeds under the site and at least twice after mining has passed under the site.

It is concluded that with the recommended mitigation measures (and including the creek riparian rehabilitation works currently being instigated), long-wall mining in the proposed LW9 area as shown in Fig 1, could be undertaken in a manner such that the main aim of the DEC & DPI (2005) guidelines; to achieve a "maintain and improve" outcome for the ecology of the proposal site, can be met with respect to the aquatic ecology of the site and accordingly there would not be any necessity for an offset strategy for the protection of the aquatic ecology of the site.

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