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Tahmoor North Longwalls 31to37

Aquatic Ecology Assessment

Prepared for Tahmoor Colliery

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Cover photograph: Cedar Creek

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1. Executive summary

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Tahmoor Coal Pty Ltd (Tahmoor Coal) to undertake an aquatic ecological assessment of the potential subsidence impacts associated with the proposed mining of Longwalls 31 to 37 at Tahmoor Colliery. This document constitutes the aquatic ecological assessment to accompany and inform the Subsidence Management Plan (SMP). This ecological report has been prepared to meet the relevant sections of the NSW Department of Primary Industries (DPI) Guideline for Applications for Subsidence Management Approvals December 2003.

The primary objective of this report is to describe and assess ecological values of the waterways within the SMP Area and surrounds and determine whether the proposal is likely to have a significant impact on threatened aquatic biodiversity. A description of likely impacts from the development and consideration of mitigation measures is also provided.

The approach of this assessment includes the following:

- Review relevant literature, mapping and databases.
- Conduct a field survey using recognised methods **Aus**tralian **Riv**ers **A**ssessment **S**ystem (AUSRIVAS) and Riparian Channel and Environment (RCE) inventory to assess the ecological values of the site.
- Describe the ecological values of the site in regard to flora and fauna aquatic communities.
- Determine the impact of the proposal on threatened biodiversity and aquatic habitat, and undertake formal assessments under relevant legislation where required.
- Provide recommendations and options on how to conserve and enhance the aquatic ecological and biodiversity features of the SMP Area.

The RCE sores showed that stream health was in moderate to good condition; particularly those overlying northern longwalls (Matthews Creek, Cedar Creek and Stonequarry Creek). AUSRIVAS indicated that waterways were not in reference condition, however despite this classification, it is likely that the ecology of some stream reaches overlying northern longwalls are close to natural. No threatened aquatic species were recorded, or are thought to occur in the SMP area.

The predicted ecological impacts from the proposed development include localised reduction in biomass, possible localised loss of sensitive species, and localised change in community composition. The most impacted streams predicted include Redbank Creek and Cedar Creek, while Matthews and Stonequarry Creek are likely to experience less impact from longwall mining. No threatened aquatic species will be impacted.

The report recommends the following remediation and monitoring measures.

Remediation

- The impacts of longwall mining on aquatic ecology should be assessed at the completion of each longwall panel to ensure any remediation (if required) is undertaken in a timely manner. This will also assist in increasing the accuracy of predictions of impacts from future longwall mining in the area.
- Remediation to be conducted in accordance with the SMP and experience from past remediation techniques. Any remediation activities – should they be necessary – should take into consideration previous methods used in the surrounding area for e.g. remediation of fractured rock bars in streams in the Southern Coalfields.
- Consult with NSW DPI regarding any rehabilitation and compensation measures that may be deemed necessary to ensure the longevity and ongoing management of Key Fish Habitat during and post coal extraction of Longwalls 31 to 37.

Monitoring

Conduct a stream health monitoring program that:

- Assesses sample sites that were assessed prior to the commencement of longwall mining to gain further information regarding possible changes to the habitats and ecology due to mining related subsidence.
- Ensures sampling is conducted at appropriate frequencies.
- Includes additional pre-mining baseline data.
- Investigates the use of Leptophlebiidae (*Atelophlebia* sp.) as an indicator species to monitor changes to populations and stream recovery as:
    - They are abundant and common to these ephemeral/semi permanent streams.
    - They are sensitive to changes in water quality including salinity and ferruginous precipitation.
    - Previous studies have suggested that these species have been impacted in the Southern Coalfields.

Further assessment

- No further assessment such as Referral or Species Impact Statements is recommended for any threatened species populations and communities.

2. Glossary and abbreviations

Flora and fauna of conservation significance	Threatened species or populations listed on the schedules of the TSC Act and/or listed as Matters of National Environmental Significance (MNES) under the EPBC Act.
Local population	The population of a particular threatened species that occurs in the locality.
Locality	The area within 10 km of the study area.
Local occurrence	Refers to the distribution of an ecological community within the study area and continuous with it.
MNES	Matters of National Environmental Significance listed on the EPBC Act.
OEH	The NSW Office of Environment and Heritage.
TEC	Threatened Ecological Community listed on the TSC Act and or EPBC Act. TEC is a collective term to describe vulnerable, endangered and critically endangered ecological communities.
Threatened biodiversity	Threatened species, populations and ecological communities as listed on the TSC and or EPBC Acts.
TSC Act	NSW *Threatened Species Conservation Act 1995.*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*
EP&A Act	NSW *Environmental Planning and Assessment Act 1979.*
SEPP	State Environment Planning Policy.
SMP	Subsidence Management Plan.
SIGNAL	Stream Invertebrate Grade Number Average Level.
AUSRIVAS	Australian Rivers Assessment System.
RCE	Riparian Channel and Environment Inventory Assessment.
FM Act	*Fisheries Management Act 1994.*
DPI	The NSW Department of Primary Industries.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Modal Width	The width which appears most often in a specified length of stream channel.

3. Introduction

3.1 Background

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Tahmoor Coal to undertake an assessment of the potential subsidence impacts on aquatic ecological values associated with the proposed mining of Longwalls 31 to 37 at Tahmoor Colliery (Figure 1).

This document constitutes the aquatic ecological assessment to accompany and inform the SMP for the project. This aquatic ecological report has been prepared to meet the relevant sections of the NSW Department of Primary Industries Guideline for Applications for SMP Approvals December 2003.

3.2 Project context

In accordance with SMP Guidelines 2003, Tahmoor Coal will seek approval to extract coal from Longwalls 31 to 37. Extraction of the coal will be undertaken using longwall mining methods which will cause subsidence of the lands surface. The mine is subject to two different development consents and associated leases as follows:

- The majority of the northern section of the mine received development consent in 1994 from the Land and Environment Court (DA57/93). This section is covered by Mining Lease Number 1376.
- Sections beneath urban areas and the railway line that received development consent in 1999 from the Minister for Urban Affairs and Planning (DA67/98) and which is covered by Mining Lease Number 1539.

3.3 Purpose and objectives

The primary objective of this report is to describe and assess ecological values of the waterways within the SMP area and surrounds and determine whether the proposal is likely to have a significant impact on threatened aquatic biodiversity. A description of likely impacts from the development and consideration of mitigation measures is also provided.

The approach of this assessment includes the following:

- Review relevant literature, mapping and databases.
- Conduct a field survey using recognised methods AUSRIVAS and RCE inventory to assess the ecological values of the site.
- Describe the ecological values of the site in regard to flora and fauna aquatic communities.
- Determine the impact of the proposal on threatened biodiversity and aquatic habitat, and undertake formal assessments under relevant legislation where required.
- Provide recommendations to conserve and enhance the aquatic ecological and biodiversity features of the SMP Area.

3.4 Study area

The Study Area includes the SMP Area and the surrounding aquatic environment (Figure 1, Figure 2). The Study Area occurs within the boundaries of Wollondilly Local Government Areas (LGA) and is located approximately 80 kilometres (km) south west of Sydney, in the vicinity of the townships of Picton, Tahmoor and Thirlmere (Figure 1). The Study Area is located in the Southern Coalfield and is encompassed by CCL 747 and CCL 716 and situated on the south western edge of the Sydney Basin.

Most of the area to the east of the Study Area consists of rural residential development, with most of the vegetated land concentrated along the riparian zones of the watercourses. Topography varies within the

Study Area; situated on gently undulating flats, and the far northern and far south-eastern sections comprising of steep incised gullies with exposed Hawkesbury Sandstone.

Redbank Creek, Stone Quarry Creek, Matthews Creek and Cedar creek are the main natural waterway features within the Study Area (Figure 2).

3.4.1 Redbank Creek

Redbank Creek flows above the proposed Longwalls 31 to 32 in the southern portion of the SMP Area. The creek flows towards the north-east, where it joins Stonequarry Creek approximately 830 metres (m) east of proposed Longwall 32, which then drains to the Nepean River. The creek falls approximately 30 metres over a total length of approximately 2300m within the SMP Area, with an inferred average gradient of13mm/m. Redbank Creek flows over predominantly Hawkesbury Sandstone bedrock within the SMP Area. Natural iron seepage flows into the creek, resulting in red colouration of the banks and pools (MSEC 2014).

3.4.2 Cedar Creek

Cedar Creek flows within 50m of the proposed Longwalls 34 and 35 in the northern portion of the SMP Area and directly above the proposed Longwall 33, where it joins Stonequarry Creek. The catchment comprises mainly rural properties. The creek flows towards the north-east in the SMP area. The section of creek within the SMP falls approximately 30m over a total length of approximately 1500m within the SMP Area, with an inferred average gradient of 20mm/m (MSEC 2014).

3.4.3 Matthews Creek

Matthews Creek flows above the proposed Longwalls 35 to 37 in the northern portion of the SMP Area. The catchment comprises mainly rural properties. The creek flows towards the north-east, where it joins Cedar Creek near the northern end of Longwall 35. The creek falls approximately 40 m over a total length of approximately 1600m within the SMP Area, with an inferred average gradient of 25mm/m (MSEC 2014).

3.4.4 Stonequarry Creek

Stonequarry Creek flows directly above the proposed Longwall 33 in the northern portion of the SMP Area. The catchment comprises mainly rural properties. The creek flows towards the south-east in the SMP Area and joins with Matthews Creek, Cedar Creek and Redbank Creek before it drains to the Nepean River. The section of creek within the SMP falls approximately 13m over a total length of approximately 1600m within the SMP Area, with an inferred average gradient of 8mm/m (MSEC 2014).

3.5 Mine subsidence predictions

Subsidence predictions for Longwalls 31 to 37 were investigated and reported by MSEC (2014). The report provides the predicted subsidence parameters for the natural features (including waterways) and items of surface infrastructure within the SMP Area. Impact assessments have been made for each of these features based on the predicted subsidence parameters and on the experience gained from the mining of previous longwalls at Tahmoor Colliery. A summary of the subsidence prediction impacts that the proposed extraction of Longwalls 31 to 37 will have on waterways is provided in Section 6.2. This information was used to address the potential impacts to aquatic ecology.

3.6 Predicted impacts to groundwater/surface water interactions

Predicted impacts for groundwater/surface water interaction for Longwalls 31 to 37 were investigated and reported by GeoTerra (2014). The report provides predicted impacts to surface/groundwater flow and water quality based on predicted subsidence impacts (MSEC 2014) and the experience gained from the

mining of previous longwalls at Tahmoor Colliery. The predicted impacts are provided in Sections 6.2.4 to 6.2.6. This information was used to address the potential impacts to aquatic ecology.

Drawn by: GT Project Manager: MR Project Number: 2276 Date: 2/12/2014

Project Location

Tahmoor North Subsidence Management Plan - Aquatic Assessment

FIGURE 1

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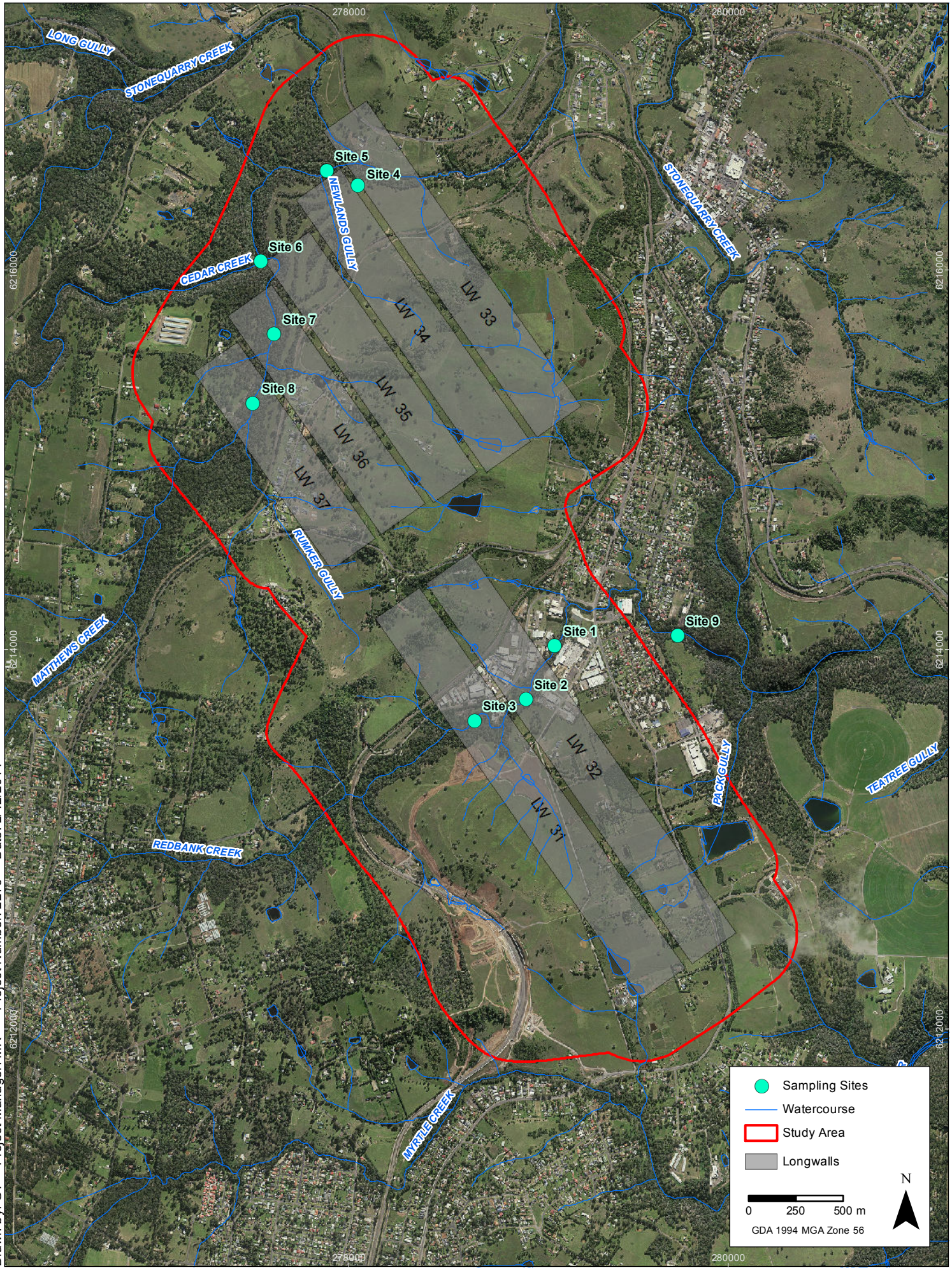

Location of sampling sites

Tahmoor North Subsidence Management Plan - Aquatic Assessment

FIGURE 2

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Imagery: (c) Glencore Coal Pty Ltd

4. Methods

4.1 Legislation

4.1.1 *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*

The *Commonwealth EPBC Act 1999* requires the proposed development to be assessed in terms of potential impact upon Matters of National Environmental Significance (MNES). MNES currently listed under the EPBC Act are:

- World Heritage properties
- Natural heritage places
- Wetlands of international importance
- Threatened species and ecological communities
- Migratory species
- Commonwealth marine areas
- Nuclear actions (including uranium mining).

The EPBC Act applies within the Study Area for commonwealth threatened species and ecological communities. All commonwealth threatened species and ecological communities recorded or predicted to occur within the Study Area require an assessment to be undertaken to determine if a referral is required to the Department of Environment (DOE) who will in turn determine if the proposal is a Controlled Action under the EPBC Act.

4.1.2 *NSW Fisheries Management Act 1994 (FM Act)*

The main objectives of the *NSW Fisheries Management Act 1994* (FM Act) are to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations, and in particular:

- To conserve fish stocks and key fish habitats.
- To conserve threatened species, populations and ecological communities of fish and marine vegetation.
- To promote ecologically sustainable development, including the conservation of biological diversity and, consistently with these objectives.
- To promote viable commercial fishing and aquaculture industries.
- To promote quality recreational fishing opportunities.
- To appropriately share fisheries resources between the users of those resources.
- To provide social and economic benefits for the wider community of NSW.
- To recognise the spiritual, social and customary significance to Aboriginal persons of fisheries resources and to protect, and promote the continuation of, Aboriginal cultural fishing.

To meet the primary objectives, Part 7 of the FM Act deals with the protection of aquatic habitats and Part 7A deals with threatened species conservation. Part 7 commonly applies to “integrated development” proposals as defined by the *Environmental Planning and Assessment Act 1979 (EP&A Act).*

The FM Act applies within the SMP Area for state listed threatened species, populations and ecological communities. Impacts of the proposed development on threatened species, populations and ecological communities known or considered to have suitable habitat in the SMP Area are required to be assessed to determine if significant impacts are likely to occur.

Key fish habitat policy

The waterways within the SMP Area fall within the definition and are mapped as 'key fish habitat' (DPI 2013). NSW DPI recognises that certain types of activities have varying degrees of impact on key fish habitats and, as such, require different levels of control and regulation. As a general principle, NSW DPI requires that proponents should, as a first priority; aim to avoid impacts upon key fish habitats. Where avoidance is impossible or impractical, proponents should then aim to minimise impacts. Any remaining impacts should then be offset with compensatory works.

4.2 Database mapping and literature sources

Databases and mapping reviewed as part of this assessment include:

- DECC (2008) Threatened Species Profiles Database, NSW Office of Environment and Heritage
- OEH Atlas of NSW Wildlife (OEH 2014)
- EPBC Act Protected Matters Search Tool (DoE 2014)
- DPI Records Viewer (2014a)
- DPI Key fish habitat mapping (2014b).

Literature and data sources reviewed included:

- Biosis Research (2009) Aquatic Impact Assessment Longwalls 27 to 30 Tahmoor Colliery
- Niche (2013) Tahmoor South Aquatic monitoring report
- AUSRIVAS sampling guidelines for NSW
- ANZECC guidelines.
- Geoterra (2014) Longwall Panels 31 to 37 Streams, Dams & Groundwater Assessment
- MSEC 2014 Subsidence Predictions and Impact Assessments for Longwalls 31 to 37

4.3 Survey methods

The Study Area was investigated by two ecologists - Luke Baker (Niche - Botanist) and Matthew Russell (Niche – Aquatic Ecologist) on the 15th to 17th of October 2014.The AUSRIVAS and RCE Inventory were the survey methods employed.

4.4 Sampling locations

Sites were sampled in affected waterways within the SMP area. Four sites were located in Redbank Creek, one site in Stonequarry Creek, two sites in Cedar Creek, and two sites in Matthews Creek (Table 1, Figure 2). Effort was made to ensure sites were in proximity to each proposed longwall.

Table 1 Location of sampling sites

Site Number	Location	Stream	Longwall	Easting	Northing
Site 1	Borah Place	Redbank Creek	31	279085	6214023
Site 2	Near rural fire station	Redbank Creek	32	278932	6213735
Site 3	Near culvert	Redbank Creek	100m downstream 32	278661	6213627
Site 4	Confluence of Stonequarry and Cedar	Stonequarry creek	37	278049	6216448

Site Number	Location	Stream	Longwall	Easting	Northing
	creeks				
Site 5	Upstream of Stonequarry Creek confluence	Cedar Creek	36	277883	6216526
Site 6	At confluence of Cedar and Matthews creeks	Cedar Creek	35	277534	6216048
Site 7	Upstream of Cedar Creek confluence	Matthews Creek	34	277606	6215667
Site 8	Most upstream site	Matthews Creek	33	277494	6215298
Site 9	Redbank Creek upstream of Stonequarry confluence	Redbank Creek	1km downstream 32	279734	6214071

4.5 Aquatic habitat assessment

A visual assessment of aquatic habitat was conducted using the AUSRIVAS (Australian River Assessment System) proforma. The survey is a rapid visual assessment to describe the habitat based on the following parameters:

- Geomorphology
- Channel diversity
- Bank stability
- Riparian vegetation and adjacent land use
- Water quality
- Macrophytes
- Local impacts and land use practices.

This was complimented by a Riparian Channel and Environment Inventory assessment to rank the relative health of stream condition. The RCE Inventory (Chessman *et al.* 1997) provides a comparative measure of stream condition by assessing both the stream and its riparian environment in terms of habitat diversity, habitat condition and the degree of human-induced disturbance. Thirteen categories each receive a score between 1 and 4 based their condition, resulting in an accumulated score of between 13 and 52. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) indicates a heavily channelled stream without any riparian vegetation. This assessment provided a score the general condition of the stream and must be interpreted accordingly.

4.6 Water quality sampling

Surface water quality was measured in situ using a Yeokal 611 water quality probe at each site. The following variables were recorded:

- Temperature (°C)
- Conductivity (µS/cm)
- pH
- Oxidation – Reduction Potential (ORP) (mV)
- Dissolved Oxygen (DO)(% saturation and mg/L)
- Turbidity (NTU).

Alkalinity (mg CaCa3/L) was measured with a standard titration kit. Water quality data were compared with the ANZECC (2000) default trigger values to physical and chemical stressors for protection of slightly disturbed lowland aquatic ecosystems in south-eastern Australia.

4.7 Macroinvertebrate survey

The AUSRIVAS methods of sampling both pools and riffles were modified, as no suitable in-stream riffle features were present. Samples were collected from pool edges for a length of 10m either as a continuous line or in disconnected segments. Sampling in segments was undertaken to ensure the sampling of sub-habitats such as macrophyte beds, bank overhangs, submerged branches and root mats. Segmented sampling was also employed where pool length was short and it was logistically difficult to sample in a continuous line (e.g. in-stream logs). A 250 micrometre (µ/m) dip net was drawn through the water with short sweeps towards the bank to dislodge benthic fauna while scraping submerged rocks and debris, sides of the stream bank and the bed substrate. Further sweeps in the water column targeted the suspended fauna.

Each sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps, pipettes and or paint brushes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. The animals collected at each site were placed into a labelled jar containing 70% ethanol.

The chemical and physical variables required for running the AUSRIVAS predictive model were also recorded. Alkalinity, modal depth and width of the stream, percentage bedrock, boulder or cobble and latitude and longitude were recorded. Distance from source, altitude, land-slope and rainfall were also calculated.

4.7.3 Laboratory methods-invertebrate identification

Macroinvertebrate samples were identified to family level with the exception of Oligochaeta (to class), Polychaeta (to class), Ostracoda (to subclass), Nematoda (to phylum), Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Identification keys used include:

- Dean, J., Rosalind, M., St Clair, M., and Cartwright, D. (2004) Identification keys to Australian families and genera of caddis-fly larvae (Trichoptera) Cooperative Research Centre for Freshwater Ecology.
- Gooderham, J. and Tsyrlin, E. (2002). The Waterbug Book: A guide to the Freshwater Macroinvertebrates of Temperate Australia, CSIRO Publishing.
- Hawking and Theischinger (1999) A guide to the identification of larvae of Australian families and to the identification of ecology of larvae from NSW.
- Madden, C. (2010) Key to genera of Australian Chironomidae. Museum Victoria Science Reports 12,1-31.
- Madden, C. (2011) Draft identification key to families of Diptera larvae of Australian inland waters La Trobe University.
- Smith, B. (1996) Identification keys to the families and genera of bivalve and gastropod molluscs found in Australian inland waters Murray Darling Freshwater Research Centre.
- Website - http://www.mdfrc.org.au/bugguide/.

4.7.4 Data analysis

AUSRIVAS

Samples collected using AUSRIVAS protocol were analysed using the predictive models for NSW pool edge habitats. The AUSRIVAS model predicts the aquatic macroinvertebrate fauna expected to occur at a site in the absence of environmental stress, such as pollution or habitat degradation. The AUSRIVAS spring model was used for the data collected. Observed to expected ratio (OE50), SIGNAL (Stream Invertebrate Grade Number Average Level), and number of taxa were the indices used to interpret stream health.

OE50

The Observed to Expected ratio is the ratio of the number of invertebrate families observed at a site (NTC50) to the number of families expected (NTE50) at that site. Only macroinvertebrate families with a greater than 50% predicted probability of occurrences are used by the model. OE50 provides a measure of biological impairment at the test site. Bands derived from the OE50 indicate the level of impairment of the assemblage. The OE50 ratios are divided into bands representing different levels of impairment (Table 2).

Table 2 AUSRIVAS band interpretation

Band	Interpretation
Band X	Represents a more biologically diverse community than reference
Band A	Is considered similar to reference condition
Band B	Represents sites significantly impaired
Band C	Represents sites in a severely impaired condition
Band D	Represents sites that are extremely impaired

SIGNAL (Stream Invertebrate Grade Number Average Level) scores

The revised SIGNAL2 biotic index developed by Chessman (2003) was also used to determine the "environmental quality" of sites. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their response to a range of environmental conditions (Table 3). The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site.

Table 4 provides a broad guide for interpreting the health of the site according to the SIGNAL 2 score of the site.

Table 3 SIGNAL Grade and the Level of Pollution Tolerance

SIGNAL Grade	Pollution Tolerance
10-8	Indicates a greater sensitivity to pollution
7-5	Indicates a sensitivity to pollution
4-3	Indicates a tolerance to pollution
2-1	Indicates a greater tolerance to pollution

Table 4 Guide to interpreting the SIGNAL 2 scores

SIGNAL 2 Score	Habitat quality
Greater than 6	Healthy habitat
Between 5 and 6	Mild pollution
Between 4 and 5	Moderate pollution
Less than 4	Severe pollution

*Note that SIGNAL2 scores are indicative only and that pollution does not refer to just anthropogenic pollution. Environmental stress may result in poor water quality occurring naturally in waterways. Low family richness and the occurrence of pollution tolerant invertebrates can give a low SIGNAL score even though they are natural condition.

4.8 Threatened flora and fauna likelihood of occurrence

A list of subject threatened flora and fauna within the locality was determined from database searches. The literature and database review identified threatened fauna species that could potentially occur in the Study Area. The review used the following databases and search tools:

- DPI Threatened and Protected Species Records Viewer (2014) (searched by Nepean Catchment Management Authority CMA boundary).
- Office of Environment and Heritage Atlas BioNet (2014) (searched by Nepean CMA boundary).
- Commonwealth Department of the Environment (DoE) Protected Matters Search Tool (2014) (search by area defined by the following point with coordinates -34.21257, 150.61575, with 10 km buffer).

The list of potentially impacted (affected) species is determined from consideration of this list. In order to adequately determine the relevant level of assessment to apply to subject species, further analysis of the likelihood of those species occurring within the Study Area was completed.

Five categories for 'likelihood of occurrence' (Table 5) were attributed to species after consideration of criteria such as known records, presence or absence of important habitat features on the subject site, results of the field surveys and professional judgement. This process was completed on an individual species basis.

Species considered further in formal assessments of significance pursuant to relevant legislation were those in the 'Known' to 'Moderate' categories and where impacts for the species could reasonably occur from the development (refer to the outcomes of the affected species analysis in Section 5.4).

Table 5: Likelihood of occurrence criteria

Likelihood rating	Threatened aquatic flora criteria	Threatened aquatic fauna criteria
Known	The species was observed within the Study Area.	The species was observed within the Study Area.
High	It is likely that a species inhabits or utilises habitat within the Study Area.	It is likely that a species inhabits or utilises habitat within the Study Area.
Moderate	Potential habitat for a species occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the Study Area.	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the Study Area.

Likelihood rating	Threatened aquatic flora criteria	Threatened aquatic fauna criteria
Low	It is unlikely that the species inhabits the Study Area.	It is unlikely that the species inhabits the Study Area. If present at the site the species would likely be a transient visitor. The site contains only very common habitat for this species which the species would not rely on for its on-going local existence.
None	The habitat within the Study Area is unsuitable for the species.	The habitat within the Study Area is unsuitable for the species.

4.9 Impact assessment

An overall assessment of the likely impacts to the aquatic ecology was inferred from the results obtained by the spring survey; known or historical impacts to stream processes in the Southern Coal Fields; known impacts to stream habitat, flora and fauna; and specific subsidence/water interaction impacts provided from specialist studies (MSEC 2014, GeoTerra 2014).

Specific impact assessments were carried out on listed species, populations and ecological communities that occur or have a moderate-high likelihood of occurrence within the Study Area (based on the presence of suitable habitat) and where there is potential for subsidence associated with mining of Longwalls 31 to 37 to impact the species or community and/or its habitat.

Where subsidence may impact species, communities or their potential habitat listed on the TSC Act or EPBC Act, Assessments of Significance are required to assess the potential significance of the impact.

Fisheries key threatening processes, fish habitat mapping and legislation by DPI fisheries will also be reviewed to determine their relevance to the development.

4.10 Limitations

The field survey was designed to identify threatened aquatic fauna and/or its habitat utilising the study area, and assess stream health with AUSRIVAS (Australian Rivers Assessment System) (Turak et al. 2004).

The survey was limited temporally, based on one sampling occasion and as such some fauna maybe seasonally absent from the Study Area.

This report has replied upon the results of the MSEC (2014), GeoTerra (2014) and experience in the Southern Coalfields to determine potential impacts to aquatic flora and fauna.

5. Results

5.1 Aquatic habitat

In general the aquatic habitat consists predominately of pools with little to no riffles present, with most sites having moderate to high quality riparian and channel health. The streams were controlled by the sandstone geology with bedrock a common component of the streams morphology. There was very little cobble/boulder habitat and stream benthos was dominated by finer sand/silt sized sediment where bedrock did not occur. Macrophyte occurrence varied between sites. Table 6 shows the RCE inventory scores of each site. An RCE score below 20 indicates that the stream is in very poor condition. RCE Scores of 20-40 indicate a stream is in moderate condition and greater than 40 indicates a stream is considered to be in good condition with potential for higher biodiversity values.

Table 6 RCE inventory scores

Stream	Redbank Creek			Stonequarry Creek	Cedar Creek		Matthews Creek		Redbank Creek
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RCE Score	35	38	39	36	42	51	51	47	44

5.1.1 Site 1 down stream Redbank Creek

The site is located in an urban area of Tahmoor (Figure 2, Plate 1) immediately downstream of Longwall 32. The stream was in moderate condition (RCE score 35) however there were high levels of disturbance including bank erosion, sedimentation and weeds. Canopy vegetation was dominated by weeds including Large Leaf Privet, Small Leaf Privet; however *Eucalyptus tereticornis* was also present. The dominant mid-storey species was Turkey Rhubarb and ground cover dominated by *Tradescantia* spp., *Commelina cyanea*, and *Microleana stipoides*. The vegetation provided moderate shading of the stream.

This stream at the location was mostly shallow (<1m depth) with 2m modal width. The benthic substrate of the stream contained some gravel but was dominated by finer sized sediment including sand and silt. There were few macrophytes present at this site (approximately<3% of the reach contained macrophytes) with the distribution of the macrophytes being confined to the stream edge. There were pools present; however there was little flow at the time of sampling.

Plate 1 Site 1 Redbank Creek (Borah Place)

Site 2 Redbank Creek off Bridge Street near rural fire station

The site is located in the urban area of Picton and overlies the proposed Longwall 32 (Figure 2, Plate 2). The stream was in moderate condition (RCE 38) however showed high levels of disturbance including sedimentation, and dominance of weeds in the riparian vegetation. Canopy vegetation was dominated by weeds Large Leaf Privet and Small Leaf Privet; however *Eucalyptus moluccana* and *Angophora floribunda* also occurred. Weedy shrubs dominated the mid-storey including Large and Small Leaf Privet and Lantana (*Lantana camara*). Ground cover was dominated by weeds Wandering Jew (*Tradescantia* spp.), Panic Veldt Grass (*Erharta erecta*), as well as native species *Microleana stipoides*. The vegetation provided moderate shading of the stream.

Plate 2 Site Redbank Creek near rural fire station

The stream was shallow (<1m depth) with 2m modal width. The stream substrate was dominated by finer sand and silt. There were few macrophytes present at this site, (approximately<3% of the reach) occurred along the stream edge. There were pools present; however there was little flow at the time of sampling.

5.1.2 Site 3 Upstream Redbank Creek near culvert

The site is located in the urban area of Picton with commercial buildings on the left bank; it overlies proposed Longwall 31 (Figure 2, Plate 3). The stream was in moderate condition (RCE 39) however showed high levels of disturbance including rubbish, and dominance of weeds. Canopy vegetation was dominated *Backhousia myrhfolia*, and weeds including Large and Small Leaf Privet. The mid-storey was dominated by *Bursaria spinulosa* and the ground cover by *Lomandra longifolia*, *Microleana stipodes*, *Commelina cyanea* as well as the weed Wandering Jew (*Tradescantia* spp.). The vegetation provided moderate shading of the stream.

Plate 3 Site 3 Redbank Creek near culvert

This stream was shallow (<1m depth) with 2.5m modal width. The stream substrate consisted of bedrock, sand and silt. There were no macrophytes observed at this site. There were pools present; however there was little flow at the time of sampling. There was a red ferrous precipitate in the water.

5.1.3 Site 4 Stonequarry Creek at confluence of Stone Quarry Creek and Cedar Creek

The site is located in the rural area west of Picton and is over lies the proposed Longwall 37 (Figure 2, Plate 4). The site is located at the confluence of Stonequarry and Cedar creek. The overall stream was in moderate condition (RCE 36). Canopy vegetation was dominated *Eucalyptus punctata*. The mid-storey was dominated by *Bursaria spinulosa*, *Acacia parramattensis* and *Acacia floribunda*. Groundcover by dominated by, *Microleana stipodes*, *Perscaria sp.,* and *Viola hederacea*. The vegetation provided moderate shading of the stream.

Plate 4 Stonequarry Creek at confluence with Cedar Creek

The stream was deep (>1m depth) and wider 4.5m modal width. The stream substrate consisted of bedrock, boulder and cobble however the stream was dominated by silt. There were significant macrophytes beds observed at this site consisting mostly of submerged species. Filamentous algae also covered most of the benthos and aquatic vegetation at this location. *Potamogeton sulcatus*, *Myriophyllum salsugineum*, and *Juncus* spp were common macrophtyes. Other submerged macrophytes also occurred. There were pools present; however there was little flow at the time of sampling.

5.1.4 Site 5 Cedar Creek upstream of Stonequarry Creek confluence

The site is located in the rural area west of Picton and overlies the proposed Longwall 36 (Figure 2, Plate 5). Overall the stream was in moderate-good condition (RCE 42). Canopy vegetation was dominated by *Eucalyptus punctata*. The mid-storey was dominated by *Melaluca sp*. and groundcover by, *Microleana stipodes*, *Viola hederacea*, *Lomandra longifolia*, and *Dianella caerulea*. The vegetation provided moderate to high shading of the stream. Macrophytes were present in 10% of the reach, algae was also present.

Plate 5 Site 5 Cedar Creek upstream of Stonequarry Creek confluence

The stream was approximately 1m deep and 2.5m modal width. The stream substrate consisted of a mix of bedrock, boulder, cobble, pebble and sand. There were macrophytes beds observed at this site consisting mostly of submerged species *Potamogeton sulcatus*, *Myriophyllum salsugineum* and *Elantine gratioloides*. Filamentous algae also covered most of the benthos and aquatic vegetation at this location. There were pools present; however there was little flow at the time of sampling.

5.1.5 Site 6 Cedar Creek at confluence with Matthews Creek

The site was located in a steep gorge; in the rural area to the west of Picton and overlies the proposed Longwall 35 (Figure 2, Plate 6). The stream was in good condition (RCE 51). Canopy vegetation was dominated by *Eucalyptus piperita*. The mid-storey was dominated by *Callicoma serratifolia*, *Leucopogon lanceolatus*, *Clematis aristata* and *Triotaniopsis laurina*. The groundcover was dominated by, *Viola hederacea*, *Lomandra longifolia*, and *Pratia purpurascens*. The vegetation provided moderate to high shading of the stream.

Plate 6 Site 6 Cedar Creek at confluence with Matthews Creek

The stream was approximately 1-2mm deep and 4m modal width. The stream substrate consisted of a mix mainly bedrock with some boulders. No macrophytes were present. There were pools present; however there was little flow at the time of sampling.

5.1.6 Site 7 Matthew Creek upstream of Cedar Creek confluence

The site was located in a steep gorge in the rural area to the north of Thirlmere and overlies the proposed Longwall 34 (Figure 2, Plate 7). The stream was in good condition (RCE 51). Canopy vegetation was dominated by *Eucalyptus punctata*. The mid-storey was dominated by *Backhousia myrtifolia*, *Persoonia linearis* and *Triotaniopsis laurina*. The groundcover was dominated by *Lomandra longifolia*, *Schoenus melanostachys, Callicoma serratifolia*, and *Oplismenus aemulus.* The vegetation provided moderate to high shading of the stream.

Plate 7 Site 7 Matthews Creek us Cedar Creek confluence

The stream was approximately 1m deep and 3m modal width. The stream substrate consisted of mostly bedrock, with occasional boulders and pockets of sand and silt. There were no macrophytes present. There were pools present; however there was little flow at the time of sampling.

5.1.7 Site 8 Matthews Creek most upstream site

The site is located in the rural/urban area to the north of Thirlmere and over lies the proposed Longwall 33 (Figure 2, Plate 8). The stream was in good condition (RCE 47). Canopy vegetation was dominated by *Eucalyptus punctate, Ceratopetalum apetalum,* and *Backhousia myrtifoli.* The mid-storey was dominated by *Callicoma serratifolia*, *Clematis aristata* and *Triotaniopsis laurina*. The groundcover was dominated by *Lomandra longifolia*, *Blechnum cartilagineum,* and *Oplismenus aemulus*. The vegetation provided moderate to high shading of the stream.

Plate 8 Site 8 Matthews Creek – most upstream site

The stream was shallow approximately <.5m deep and 1.5m modal width. The stream substrate consisted of bedrock, boulder and silt. There were no macrophytes present. There were pools present; however there was little flow at the time of sampling.

5.1.8 Site 9 Redbank Creek downstream site

The site was located in a very steep gorge (Figure 2, Plate 9). The stream was in good condition (RCE 47) however there was evidence of disturbance including rubbish household and car parts as well as a significant presence of weeds. Canopy vegetation was dominated by *Eucalyptus punctata, Pittosperum undulatum* and *Backhousia myrtifoli.* The mid-storey was dominated by weed species Small and Large leaved Privet as well as native *Pittosperum undulatum.* The groundcover was dominated by, *Lomandra longifolia*, *Geranium solarideri* and weed Wandering Jew. The vegetation provided high shading of the stream.

Plate 9 Redbank Creek upstream of confluence with Stonequarry Creek

The stream was >1m deep and had a 1.5m modal width. The stream substrate consisted of bedrock, boulder, and gravel however was dominated by sand and silt. There were no macrophytes present. There were pools present; however there was little flow at the time of sampling.

5.1.9 Other ephemeral streams

Other lower order tributaries such as Newlands Gully (Plate 10) had no water therefore aquatic habitat could not be sampled.

Plate 10 Newlands Gully

5.2 Water quality

Water quality results for spring 2014 are presented in Table 7. Water sampling results showed that temperature was consistent ranging between 12.1 – 13.4°C, the highest being Site 9 (Redbank Creek). Conductivity ranged between 212-2003 µ/cm. Sites in Redbank Creek particularly had raised electrical conductivity. Turbidity was low however default ANZECC trigger values were exceeded at Site 2 (150 NTU). Considering the sampling was conducted after a moderate rainfall event this result is not considered environmentally significant.

Dissolved oxygen ranged between 61 – 90.1% saturation, with most sites falling outside of ANZECC trigger values. Lower dissolved oxygen however is a characteristic of the non-flowing semi-permanent/ephemeral groundwater baseflow dependent ecosystems in the region so these values are not considered environmentally significant. The pH range was generally low (3.88—7.02) and was exceeded by sites 1-5. Site 3 Redbank Creek and Site 5 Cedar Creek particularly returned a low pH reading; indicating a more acidic environment that could potentially affect river health. Alkalinity was very low ranging from 0-25 mgCaCa3/L. This indicates that the streams have very little buffering capacity (i.e. the capacity of the stream to neutralise acid) and therefore little resistance to pH change. Low alkalinity indicates that river health is potentially sensitive to disturbances.

Table 7 Water quality results

Stream	Redbank Creek			Stonequarry Creek	Cedar Creek		Matthews Creek		Redbank Creek
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Temperature °C	13	13.05	12.34	12.1	12.5	12.4	13.21	12.81	13.4
Electrical conductivity (µS/cm) ANZECC	**1521**	**1478**	**2003**	**354**	**359**	237	222	212	341
Turbidity (NTU)	10	**150**	12	2.6	0	3.7	1.6	0.5	30
Dissolved oxygen (% sat)	**71**	**77.6**	**84.7**	**80**	90.1	**79.8**	**88.3**	**89.8**	**71.1**
pH	**6.4**	**6.14**	**3.88**	**6.35**	**3.62**	6.6	6.81	6.83	7.05
Alkalinity (mg CaCa3/L)	15	15	0	10	10	15	25	20	30
Oxygen reduction potential (mV)	270	146	370	294	301	201	377	363	337

ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

5.3 Macroinvertebrates

AUSRIVAS spring results are presented in Table 8 and raw data is provided in Annex 1. Overall, 39 different taxa were collected from the spring sampling. The number of taxa ranged 9-17 among sites.

AUSRIVAS results showed that, with the exception of Site 4, 8 and 9, sites scored in Band B. This indicates that sites are significantly impaired. Sites 4, 8 and 9 scored in Band C indicating a severely impaired site. Southern sites in Redbank Creek scored low SIGNAL values indicating that sites are severely polluted as they contain pollution tolerant macroinvertebrate families. Northern sites, Cedar Creek and Matthews Creek, returned a SIGNAL score >4. This indicates that there are more pollution sensitive invertebrates at these sites and the presence of these fauna infer that these streams are unlikely to be severely affected by pollution. One family in particular, Leptophlebiidae (SIGNAL 8) was notably absent from all Redbank Creek sites which was relatively abundant (Annex 1) in Cedar Creek and Matthews Creek. The family is common among the ephemeral/semi permanent streams in the area and its absence may show that Redbank Creek is under natural or anthropogenic stress.

Table 8 AUSRIVAS results

Stream	Redbank Creek			Stonequarry Creek	Cedar Creek		Matthews Creek		Redbank Creek
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
No of taxa	9	16	10	12	17	10	12	11	12
OE 50)	0.68	0.78	0.53	0.47	0.72	0.64	0.59	0.41	0.33
SIGNAL	3.44	3.44	4	3.25	4.53	4.1	4.42	4.18	3
Band	B	B	B	C	B	B	B	C	C

5.4 Threatened species, populations and communities

The DPI record viewer showed historical records of Macquarie Perch in the Hawkesbury/Nepean catchment. Macquarie Perch are also listed on the EPBC Act as having species or species habitat likely to occur within area. NSW database searches revealed no Sydney Hawk Dragonfly records in the catchment despite known locations in the Nepean (DPI 2007). Other threatened insects under the FM Act/and or TS Act such as Giant Dragonfly and Adams Emerald dragonfly have no habitat with in the SMP Area.

Table 9 Threatened species likelihood of occurrence

Threatened Species	FM Act	TS Act	EPBC Act	Likelihood of Occurrence
Macquarie Perch (*Macquaria australasica*)	Endangered	-	Endangered	No (Does not occur or have habitat in SMP Area, however there are records downstream in the Nepean River)
Sydney Hawk Dragonfly (*Austrocordulia leonardi*)	Endangered	-	-	No (Does not occur or have habitat in SMP Area however there are records downstream in the Nepean River)
Adams Emerald Dragonfly (*Archaeophya adamsi)*	Endangered	-	-	No (Does not occur or have habitat in SMP area)
Giant Dragonfly (*Petalura gigantean*)	-	Endangered	-	No (Does not occur or have habitat in SMP area)

5.5 Key threatening processes

Table 10 shows key threatening processes that are relevant to the development and the section of the report it is addressed.

Table 10 Key threatening processes

Key Threatening Process	TSC Act/FM Act	EPBC Act	Section
Alteration of habitat following subsidence due to long wall mining	✓		This KTP is addressed by this assessment (Section 6.2)
Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands	✓		This KTP is addressed by this assessment (section 6.2.4)

5.6 Key fish habitat

All creeks are mapped as 'key fish habitat' and are classed as having TYPE 1 highly sensitive and TYPE 2 moderately sensitive aquatic habitat. The waterways are classed as TYPE 2 fish passage and as such have moderate key fish habitat (DPI 2013).

6. Impact Assessment

6.1 Discussion of results

6.1.1 Riparian zone and aquatic habitat

In RCE inventory scores indicated that northern sites have greater stream integrity than southern sites in Redbank Creek. Sites in Matthews Creek, Cedar Creek and Stonequarry Creek returned high RCE scores which are reflective of generally good riparian native vegetation, the absence of weeds, rubbish, or visual pollution, and a healthy channel morphology that provides substantial aquatic habitat. Northern sites have riparian zone and stream morphology in very good condition, containing reaches that could be considered close to natural for an ephemeral stream in the area; where as Redbank Creek is highly disturbed.

6.1.2 Aquatic ecology of ephemeral/semi permanent streams in the Southern Coalfields

Ephemeral/semi-permanent streams undergo natural fluctuations in hydrology, habitat availability, water quality, which ultimately influences faunal composition spatially and temporally. The fauna that use these habitats are thus adapted to the resulting stress of these natural fluctuations. The macroinvertebrate communities in these habitats generally consist of families that are good dispersers; particularly those that aerially disperse; can cope with poor water quality (e.g. low dissolved oxygen, low alkalinity/pH, extremes in temperature); as well as variable flow conditions including extended periods of no flow or complete drying out. Mostly the faunal composition includes those of low SIGNAL scores (Table 8) that indicate pollution tolerance. A low SIGNAL2 score in this instance can be considered natural in drying ephemeral streams.

There are however pollution sensitive invertebrates that inhabit these environments. The mayfly Leptophlebiidae (SIGNAL score 8) and species of this family are most vulnerable to pollution. Studies in the area have found that this family is very common in these ephemeral/semi-permanent streams and are present in streams that are close to reference condition (Niche 2013). This family was previously recorded in Redbank Creek (Biosis 2009) however were not recorded in any of the four sites in Redbank Creek from this survey. This may indicate either natural or anthropogenic stress in this system and is possibly related to the high levels of salinity observed in Redbank Creek. Studies by CSIRO rating the sensitivity of aquatic macroinvertebrates to salt found Leptophlebiidae to be sensitive to saline conditions (Horigan et al. 2005). Local studies on saline mine water discharge in the Georges River have found an absence of this family downstream of saline mine water discharge (Niche 2014). While this potentially deleterious effect of this family in Redbank Creek in this instance requires more study and is complicated by an array of environmental factors, the evidence is clear that this family is sensitive to disturbance. An understanding of sensitive species should be incorporated into future monitoring programs with Leptophlebiidae being utilised as a potential indicator species in monitoring disturbance and the recovery of affected streams in Southern Coalfields.

6.2 Predicted subsidence impacts to streams

Details of the range and intensity of tilts and strains affecting waterways are provided in MSEC 2014. These can lead to direct impacts to the water ways and are discussed below.

6.2.3 Potential for increased levels of ponding, scouring or desiccation due to mining tilt

Mining can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the stream beds in the locations where the mining induced tilts considerably increase the natural stream gradients that exist before mining.

MSEC (2014) predicts that Redbank Creek is unlikely to experience a reversal of grade, as the natural grades are sufficiently large. A reduction in grade is predicted to occur on the downstream edge of Longwall 32 and this may result in localised ponding. Elsewhere, there are no predicted reversals of grade due to the proposed mining.

The natural grade of Stonequarry Creek is predicted to reduce to an almost flat grade at one point on the downstream side of Longwall 33. Hence there is increased potential for ponding upstream of this location. Elsewhere, there are no predicted reversals of grade due to the proposed mining.

It is possible that there could be localised areas along the streams which could experience small increases in the levels of ponding, where the predicted maximum tilts occur in the locations where the natural gradients are low. As the predicted changes in grade are typically less than 1%, however, any localised changes in ponding are expected to be minor and not result in adverse impacts on these streams.

Stream gradients increase where they flow into the predicted subsidence trough near the edges of the proposed longwalls. The streams flow predominantly over Hawkesbury Sandstone, which has a high resilience to scouring. The predicted maximum increases in grade are less than 1%, which are relatively small compared to the natural gradients and, therefore, the potential for increased scouring is not expected to be substantial.

Further discussions on the potential changes in ponding and flooding along the streams and the impacts, consequences and implications of the changes are provided in the report by GeoTerra (2014).

6.2.4 Fracturing, pool holding capacity, surface water flow diversion and flow regime

Where the longwalls mine directly beneath the streams it is considered likely that fracturing could result in surface water flow diversions. Upsidence and compressive strains due to valley closure are expected to be of sufficient magnitude to cause the underlying strata to buckle and induce cracking at the surface at some locations (MSEC 2014).

GeoTerra (2014) states that if substantial fracturing were to occur, partial or complete diversion of surface water and drainage of pools could occur at locations and times where the rate of flow diversion is greater than the rate of incoming surface water. The majority of the streams are ephemeral and so water typically flows during and for a period of time after each rain event. In times of heavy rainfall, the majority of the runoff would flow over the beds of the streams and would not be completely diverted into the dilated strata below the stream beds.

In times of low flow or prolonged periods of dry weather, however, some or all of the water could be diverted into the strata below the stream beds for those sections of the streams that are located over the mined panels (GeoTerra 2014).

While much of the channel beds are exposed bedrock, sediments were also commonly found in the creek beds throughout the SMP Area. Where such loose materials occur, it is possible that fracturing in the bedrock would not be seen at the surface. In the event that fracturing of the bedrock occurs in these locations within the alignments of the streams, the fractures may be filled with soil during subsequent flow events.

Cracking may occur in the creek bed which could lead to loss of overland stream flow into the underlying dilated strata or drainage of ponds, however it is not anticipated to generate a net loss of water from the creek systems since the subterranean flow, if it occurs, would re-emerge downstream (GeoTerra 2014).

After heavy rain, the majority of runoff would flow along the creek bed, with a lesser proportion flowing through the dilated, subsided strata, whilst during low flows; a greater proportion of water would flow in the bedrock (GeoTerra 2014).

Redbank Creek

GeoTerra (2014) states that the due to the predicted stream bed uplift and valley closure associated with the proposal (MSEC 2014), as well as the significant impacts of reduced pool holding capacity and reduced stream flow connectivity observed to date in reaches of Myrtle and Redbank Creek over Longwalls 25 to 28, it is anticipated that similar effects will occur in the 3rd order or higher stream reaches within the Longwall 31 to 37 SMP area.

Further more changes in either the location or discharge rate / longevity of groundwater seeps into the more incised valleys is also anticipated, however there is currently insufficient field data to predict where and by how much this may occur. The reach over Longwalls 31 and 32 is a more likely area to be affected as there is currently groundwater seepage occurring based on the high iron hydroxide precipitation within this reach (GeoTerra 2014).

Matthews Creek

GeoTerra (2014) states that the due to the predicted stream bed uplift and valley closure associated with the proposal (MSEC 2014), as well as the significant impacts of reduced pool holding capacity and reduced stream flow connectivity observed to date in reaches of Myrtle and Redbank Creek over Longwalls 25 to 28, it is anticipated that similar effects will occur in the 3rd order or higher stream reaches within the Longwall 31 to 37 SMP area.

Changes in either the location or discharge rate / longevity of groundwater seeps into the more incised valleys is also anticipated, however there is currently insufficient field data to predict where and by how much this may occur. The junction of Cedar Creek and Matthews Creek is a more likely area to be affected as there is currently groundwater seepage occurring based on the high iron hydroxide precipitation within this reach.

Cedar Creek

GeoTerra (2014) states that the due to the predicted stream bed uplift and valley closure associated with the proposal (MSEC 2014), as well as the significant impacts of reduced pool holding capacity and reduced stream flow connectivity observed to date in reaches of Myrtle and Redbank Creek over Longwalls 25 to 28, it is anticipated that similar effects will occur in the 3rd order or higher stream reaches within the Longwall 31 to 37 SMP area.

Changes in either the location or discharge rate / longevity of groundwater seeps into the more incised valleys is also anticipated, however there is currently insufficient field data to predict where and by how much this may occur. The junction of Cedar Creek and Matthews Creek is a more likely area to be affected as there is currently groundwater seepage occurring based on the high iron hydroxide precipitation within this reach.

Stonequarry Creek

GeoTerra (2014) states that the due to the predicted stream bed uplift and valley closure associated with the proposal (MSEC 2014), as well as the significant impacts of reduced pool holding capacity and reduced stream flow connectivity observed to date in reaches of Myrtle and Redbank Creek over Longwalls 25 to 28,

it is anticipated that similar effects will occur in the 3rd order or higher stream reaches within the Longwall 31 to 37 SMP area.

GeoTerra (2014) states that based on the absence of observed groundwater seepage occurring in Stonequarry Creek, through the lack of iron hydroxide precipitation within the SMP area creek reach, it is not anticipated that significant groundwater seepage change will be observed in Stonequarry Creek.

6.2.5 Subsidence impacts to groundwater and stream base flow

GeoTerra (2014) states that based on the observation of red – orange ferruginous precipitation in the streams, groundwater seeps are located in the 3rd order reach of Redbank Creek over Longwalls 31 and 32 as well as at, and downstream of, the junction between Matthews and Cedar Creeks, adjacent to the western end of Longwall 35. However, no significant change to groundwater inflow or outflow volumes to or from the 3rd order streams is anticipated to occur.

6.2.6 Potential impacts to water quality

Stream water quality can be affected through a reduction in stream flow, increased standing water periods in disconnected pools and / or altered groundwater recharge to a stream.

Redbank Creek

GeoTerra (2014) states that based on the observed chemistry changes in Redbank Creek over Longwalls 22 to 28 and the anticipated subsidence impacts on the stream, it is anticipated that iron, manganese, zinc and nickel could increase in Redbank Creek over and downstream of Longwall 31 associated with increased iron hydroxide precipitation over Longwalls 31 and 32 due to enhanced groundwater seepage into the creek.

Matthews Creek

GeoTerra (2014) states that based on the similarity in the water chemistry of Myrtle Creek and Matthews Creek and the lack of iron hydroxide precipitation indicating limited or no groundwater seepage, as well as the predicted subsidence impacts on the stream, it is anticipated that no significant change in water quality will occur in Matthews Creek.

Cedar Creek

GeoTerra (2014) states that based on its similarity to Redbank Creek water chemistry and the anticipated subsidence impacts on the stream, it is anticipated that iron, manganese, zinc and nickel could increase in Cedar Creek over and downstream of the junction with Matthews Creek, adjacent to Longwall 35 associated with increased iron hydroxide precipitation due to enhanced groundwater seepage into the creek.

Stonequarry Creek

GeoTerra (2014) states that based on the similarity in the water chemistry of Stonequarry Creek and Myrtle Creek and the lack of iron hydroxide precipitation indicating limited or no groundwater seepage, as well as the predicted subsidence impacts on the stream, it is anticipated that no significant change in water quality will occur in Stonequarry Creek.

Potential for gas emissions and changes to water quality

MSEC (2014) states that it is likely that gas emissions will occur as a result of the mining of the longwalls. Gas is often released into rivers and streams as these areas form topographical low points in the landscape. Where these gas releases occur into the water column there is insufficient time for any substantial amount

of gas to dissolve into the water (MSEC 2014). The majority of the gas is released into the atmosphere and is unlikely to have an adverse impact on water quality.

It is possible for substantial gas emissions at the surface to cause localised vegetation die-back. This is a rare event and has only been observed to occur previously on one occasion at Tower Colliery, over small areas in the base of the Cataract Gorge that had been directly mined beneath by Longwalls 10 and 14 (MSEC 2014). These impacts were limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored (MSEC 2014)

6.3 Impacts to aquatic ecology

6.3.7 Ponding and scour

Increased ponding is likely to provide localised increase in available habitat for aquatic macroinvertebrates and if there is stream connectivity in the area of ponding, it may also provide additional habitat for fish and macrophytes. Scouring is not predicted to occur therefore it unlikely that aquatic ecology will be impacted by changes to this stream process.

6.3.8 Flow regime and pool holding capacity

Drainage of pools resulting from mine subsidence will impact aquatic biota inhabiting these pools, including macroinvertebrates and native fish, with high mortalities likely in areas of complete pool drainage

For invertebrates, while there will be loss of habitat in sections of streams, and changes to invertebrate composition, density and family richness where these impacts occur, it is unlikely that at a sub- catchment to catchment scale changes to overall assemblage and family richness will be measurable, however total biomass is likely to be reduced.

The sudden drainage of pools or rapid drop in stream flow due to subsidence are likely to have localised impacts to aquatic biota, particularly on organisms that are unable to move to areas that are damp or submerged. Aquatic plants and sessile animals are particularly vulnerable to desiccation, because of their inability to move elsewhere to other available habitat. The survival of mobile organisms is difficult to predict, as it depends on a number of factors such as their tolerance and response to desiccation and rapid changes in water level, their ability to move, weather conditions, the underlying substratum and duration of exposure (Larned et al. 2010). Streams with soft sediment banks are likely to contain moisture with interstices which may prolong the survival of stranded animals. In the streams with a bedrock substrate where there are few natural refugia, with the exception of cracks and cavities, few organisms may survive complete pool drainage. The majority of freshwater fish species recorded in the Study Area are likely to asphyxiate when exposed to air.

Recovery potential of stream biota

There is capacity for recovery of some stream biota, particularly macroinvertebrate fauna. Temporary rivers function as meta-communities (i.e. part of a larger community), with variable hydrological connectivity and multiple dispersal pathways (water, air, dry river bed) (Larned et al. 2010). Aquatic insects with aerial stages may be the most common migrants to and from disconnected aquatic habits. As well as those invertebrates that can persist for years as cysts, eggs, copodites, cocoons and dehydrated larvae and adults, and crayfish (*Cherax destructor* and *Euastacus spinifer*) which retreat to their burrows or disperse overland. Most taxa identified are able to adapt to drying conditions and have the potential to recruit back to pools once and if pool holding capacity is re-established. Animals with long larval stages and limited distribution, are obligates to a particular habitat, or are poor dispersers will be most impacted. Fish may be limited in their capacity to re-establish if river connectivity is reduced. However surface flow will remain connected in

higher flow periods (GeoTerra 2014) enabling movement of fish. Submerged and floating macrophytes generally require permanent water however they can, in time, recolonise dry areas if and when water levels return.

Although there is potential for recovery, long term impacts may persist. Some pools may not self heal; either being permanently dry; or have a permanently reduced holding capacity (of both volume and retention); and thus contribute to reduced stream connectivity. This could lead to permanent changes to stream biota within the affected pools and restrict recovery of animals that require stream connectivity e.g. fish.

6.4 Water quality

The potential impacts of subsidence on water quality in overlying waterways include the liberation of contaminants from subsidence induced fracturing in watercourses. This causes localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain iron and other minerals. This sort of impact has the potential to affect biota in Redbank Creek and Cedar Creek and downstream watercourses. Changes to chemical characteristics of surface flows can also occur as a result of changes to baseflow. One of the effects of longwall subsidence on watercourses commonly reported is the emergence of ferruginous springs (DoP 2008), often accompanied by iron flocs, staining of the bed, increased turbidity and the build-up of iron rich slimes. This ferruginous deposition occurs within sandstone streams in the Sydney Basin and was particularly prevalent at Redbank Creek and Cedar Creek.

Studies have shown considerable impact to flora and fauna from iron depositional related impacts (Wellnitz et al.1994; Johnson and Ritchie 2003). Invertebrate communities are impacted through a reduction in abundance, richness and changes to community composition (Johnson and Ritchie 2003; Wellnitz et al.1994; Rassmussan and Lindegaard 1988; Peters et al. 2011). It is thought that invertebrates are impacted through a reduction of habitat complexity, interference of holdfast mechanisms, affecting food supply, coating of respiratory surfaces, and inhibiting ion exchange (Johnson and Ritchie 2003; Wellnitz et al. 1994). A commonly affected insect order is mayflies, in particular the family Leptophlebiidae (SIGNAL 8) (Johnson and Ritchie 2003; Wellnitz et al.1994; Rassmussan and Lindegaard 1988; Peters et al 2011). The sensitivity of mayflies is likely to be related to the exposure of gills and the dependence on periphytic algae (Johnson and Richie 2003).

Leptophlebiidae was a common taxa found throughout the ephemeral/semi-permanent streams in the area however they were absent in Redbank Creek. It is possible that increased iron precipitation in anoxic streams can impact macroinvertebrates through decrease in density, richness and changes to community composition.

Iron is known to precipitate on the gills of fish and eggs, prevent oxygen uptake (Peuranen et al. 1994) and also affect the food supply (Wellnitz et al.1994). Scouring of iron flocculent increases turbidity and suspended solids and may inhibit fish feeding (Peuranen et al.1994).

The degree of impact will be related to the alkalinity of the stream. Streams that are acidic (low pH) and have low total alkalinity are likely to be impacted than acidic stream with high total alkalinity (Johnson and Ritchie 2003; Wellnitz et al.1994; Peters et al. 2011) as they have a greater buffering capacity against changes to pH.

The impact of metals (iron, manganese, and zinc) is also expected to be localised and transient (GeoTerra 2014). The impacts to stream fauna similarly are expected to be localised, and fauna are likely be able to

recover from transient spikes in concentration. Localised long term changes to fauna may occur if metal concentration is elevated for extended periods of time.

Increases in electrical conductivity has also been raised as an impact from subsidence that could potentially affect aquatic flora and fauna (DoP 2008); aquatic fauna such as Leptophlebiidae are likely to be affected if increases in electrical conductivity occurs. However it must noted that high salinities can occur naturally in streams in the area.

Gas emissions have been known to occur in the Southern Coalfields (DoP 2008). In areas where gas releases occur into the water column there is insufficient time for any substantial amount of gas to dissolve into the water to change water quality (MSEC 2014). Gas emissions have caused rare and isolated dieback of riparian vegetation in the Southern Coalfields (DoP 2008) however within the Cataract River this vegetation has largely rehabilitated (M Richardson Pers. Obs.). Gas emissions have not been observed in streams or pools above any mining at Tahmoor Colliery (Tahmoor Colliery 2013). Therefore gas emissions from longwall mining in the SMP Area are unlikely to occur and the emission process itself unlikely to affect aquatic ecology.

6.4.9 Cumulative impacts to aquatic ecology

The aquatic ecology is affected by the combined influence of water quality, stream connectivity and habitat loss and is therefore susceptible to cumulative impacts to these environmental variables. The cumulative effects to ecology are difficult to predict and is likely to be spatially and temporally variable. Impacts may be localised (e.g. to a pool), transient (e.g. occur in prolonged low flow condition only), gradational impacts (e.g. down stream from a point source) and maybe triggered when one or more environmental thresholds are met. Impacts to stream and biological processes may alter aquatic communities through: localised reduced abundances of sensitive flora and fauna, increased abundance on tolerant flora and fauna, reduction of abundances of all aquatic flora and fauna, and a reduction of fauna richness. However there is potential for partial recovery of stream fauna with re-establishment of aquatic communities following natural repair of some pool habitat.

6.5 Threatened species, populations and communities under the TSC, FM and EPBC act

No threatened species are likely to be impacted by this development.

No suitable habitat is present for Sydney Hawk dragonfly. This species is often found in habitats of deep and shady riverine pools with cooler water (DPI 2007) and rocky substrate; restricted to larger streams in coastal areas (Theischinger 2013). The Sydney Hawk Dragonfly has no likelihood of occurrence although habitat may occur in the Nepean River which is some distance outside the SMP Area. Macquarie Perch is known to occur in the Nepean River (DPI 2014; 2005a, 2005b) however this well outside the SMP Area and any impacts are likely to be restricted to localised areas with in Redbank, Cedar, Matthews and Stonequarry Creeks. Similarly no suitable habitat for Adams Emerald Dragonfly (2005c) or Giant Dragonfly (OEH 2014) is present; consequently 7-part tests and test of significance are not required for these species.

6.6 Key fish habitat

It is likely that there will be a net reduction in key fish habitat as a result of localised flow diversion and draining of pools. However stream connectivity, hence fish passage will be accessible in periods of higher flow.

6.7 Summary of impacts

The following table summarises the physical, chemical and resulting ecological changes predicted for Longwall panels 31 to 37.

Table 11 Summary of predicted impacts

	Predicated impacts							
Stream	**Grade reversal**	**Ponding**	**Scour**	**Flow**	**Pool holding capacity**	**Water quality changes**	**Aquatic ecology**	**Threatened species**
Redbank Creek	No	Yes localised	No	Yes (localised flow diversion, reduced baseflow and loss of connectivity)	Yes (localised)	Yes (enhanced ground water seepage from springs and flow diversion and associated water quality impacts)	Yes (localised: reduction in biomass, possible loss of sensitive species, and change in community composition) .	No
Matthews Creek	No	Minor	No	Yes (localised flow diversion, reduced baseflow and loss of connectivity)	Yes (localised)	Unlikely	Yes (localised reduction in biomass).	No
Cedar Creek	No	Minor	No	Yes (localised flow diversion, reduced baseflow and loss of connectivity)	Yes (localised)	Yes (enhanced ground water seepage from springs and flow diversion and associated water quality impacts))	Yes (localised reduction in biomass, possible loss of sensitive species and change in community composition) .	No
Stonequarry Creek	No	Yes localised	No	Yes localised (flow diversion, reduced baseflow and loss of connectivity)	Yes (localised)	Unlikely	Yes (localised reduction in biomass).	No

7. Recommendations

This study provides baseline data on aquatic fauna, habitat, and stream conditions prior to the extraction of Longwalls 31 to 37. This information and relevant literature was used to conduct an assessment of the potential impacts of mining related subsidence effects on aquatic ecology and threatened aquatic species, populations and ecological communities. Recommendations from this assessment are listed below.

Remediation

- The impacts of longwall mining on aquatic ecology should be assessed at the completion of each longwall panel to ensure any remediation (if required) is undertaken in a timely manner. This will also assist in increasing the accuracy of predictions of impacts from future longwall mining in the area.
- Remediation to be conducted in accordance with the SMP and experience from past remediation techniques. Any remediation activities – should they be necessary – should take into consideration previous methods used in the surrounding area for e.g. remediation of fractured rock bars in streams in the Southern Coalfields.
- Consult with NSW DPI regarding any rehabilitation and compensation measures that may be deemed necessary to ensure the longevity and ongoing management of Key Fish Habitat during and post extraction of Longwalls 31 to 37.

Monitoring

Conduct a stream health monitoring program that:

- Assesses sample sites that were assessed prior to the commencement of the extraction of Longwalls 31 to 37 to gain further information regarding possible changes to the habitats and ecology due to mining related subsidence.
- Ensures sampling is conducted at appropriate frequencies.
- Includes additional pre-mining baseline data.
- Investigates the use of Leptophlebiidae (*Atelophlebia* sp.) as an indicator species to monitor changes to populations and stream recovery as:
    - They are abundant and common to these ephemeral/semi permanent streams.
    - Are sensitive to changes in water quality including salinity and ferruginous precipitation.
    - Previous studies have suggested that these species have been impacted in the Southern Coalfields.

Further assessment

- No further assessment such as Referral or Species Impact Statements is recommended for any threatened species populations and communities.

8. References

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000). National water quality management strategy and assessment guidelines: Australian and New Zealand guidelines for fresh and marine water quality ANZECC/ARMCANZ. Environment Australia

Biosis Research (2009) Aquatic Impact Assessment Longwalls 27-30. Prepared for Tahmoor Colliery

Chessman, B.C. (1995). Rapid Assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family-level identification and a biotic index. *Australian Journal of Ecology*, **20, 122-9**.

Chessman, B.C., Growns, J.E. and Kotlash, A.R., (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales. *Marine and Freshwater Research* **48, 159-172**.

ChessmanB.C. (2003) Signal 2. A scoring system for macroinvertebrates ('water bugs') in Australian rivers user manual. Department of Environment and Heritage

Department of Environment (DoE) (2012), SPRAT Database and Protected Matters Search Tool , http://www.environment.gov.au/, Department of Environment. Provides access to threatened species profiles, recovery plans and final determinations by the Commonwealth Scientific Committee Accessed November 2014.

Department of Planning (DoP) (2008). Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield: Strategic Review, State of New South Wales through the NSW Department of Planning.

Department of Primary Industries (DPI) (2005a), Prime Fact 9: Threatened Species in NSW – Macquarie Perch – *Macquaria australasica*. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/5102/Primefact_Macquarie_perch.pdf

Department of Primary Industries (DPI) (2005b). Profiles for species, populations & ecological communities Macquarie Perch *Macquaria australasica*. NSW Department of Primary Industries.

Department of Primary Industries (DPI) (2005c). Profiles for species, populations & ecological communities Adam's emerald dragonfly - *Archaeophya adamsi*. NSW Department of Primary Industries. http://pas.dpi.nsw.gov.au/Species/Species_Profile.aspx?SpeciesListingID=10

Department of Primary Industries (DPI) (2007). Prime Fact 184 Threatened species in NSW - Sydney Hawk dragonfly - *Austrocordulia leonardi*. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/144127/sydney-hawk-dragonfly.pdf

Department of Primary Industries (DPI) (2013). Policy and guidelines for fish habitat conservation and management Update 2013 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/468927/Policy-and-guidelines-for-fish-habitat.pdf

Department of Primary Industries (2014) Threatened and protected species records viewer. Accessed November 2014 http://www.dpi.nsw.gov.au/fisheries/species-protection/records/viewer

Department of Primary Industries (DPI 2014b). Key Fish Habitat Maps (local government areas: Wollondilly. http://www.dpi.nsw.gov.au/fisheries/habitat/publications/protection/key-fish-habitat-maps access November 2014.

GeoTerra (2014) Tahmoor Coal Pty Ltd - Tahmoor Colliery Longwall Panels 31 to 37 Streams, Dams & Groundwater Assessment. Prepared by GeoTerra for Tahmoor Colliery

Horigan N., Chot S., Marshall J. and Recknagel F. (2005) Response of stream invertebrates in salinity and the development of a salinity index. *Marine and Freshwater Research* **56 (6) 825-833**.

Johnson, P. T. and Ritchie, E.G (2003). Macroinvertebrate fauna of an iron-rich stream in the Wet Tropics of Australia: a comparative analysis of communities using a rapid bioassessment protocol. *Memoirs of the Queensland Museum* **49 (1) 331-338**. Brisbane.

Larned, S.T., Datry, T., Arscott, D.B. and Tockner K. (2010). *Emerging concepts in temporary-river ecology. Freshwater Biology* **55, 717–38.**

MSEC (2014). *Subsidence predictions and impact assessments for longwalls 31 to 37*. Prepared by Mine Subsidence Engineering Consultants (MSEC) for Tahmoor Coal Tahmoor Mine.

Niche (2012). Tahmoor South Pilot Study, Prepared for Tahmoor Coal

Niche (2014). Tahmoor South Aquatic Monitoring Project Year 2012-2013 prepared for Tahmoor Colliery

Niche (2014). Georges River mine water discharge monitoring 2013 Prepared for West Cliff Colliery BHPBIC

OEH (2013). Atlas of NSW Wildlife (accessed November 2014). online http://www.bionet.nsw.gov.au/

Office of Environment and heritage (OEH) (2012). Giant dragonfly profile http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10600 Accessed November 2014)

Peuranen, S., Vuorinen, P., Vuorinen, M., and Holander, A. (1994) The effects of iron, humic acids and low pH on the gills and physiology of Brown Trout (Salmo trutta) *Finnish Zoological and Publishing Board* **(31) 389-396**

Peters, A., Crane, M. and Adams, W. (2011). Effects of Iron on Benthic Macroinvertebrate Communities in the *Field Bull Environ Contam Toxico* **86, 591–595**

Rassmussen, J. and Lindegaard, C. (1988). Effects of iron compounds on macroinvertebrate communities in a Danish lowland river system *Water Resouces* **22, (9) 1101-1108**

Rosenberg and Resh (Eds) (1993). *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman & Hall, New York, London.

Tahmoor Colliery (2013). Environmental Management Plan- Longwalls 27 to 30 Revision D. Tahmoor Coal Pty Ltd

Theischinger, G., Jacobs, S., and Bush, A. (2013). Significant Range Extensions of Two Iconic Australian Dragonfly Species (Odonata: Anisoptera: Libelluloidea) *Victorian Entomologist* **43(1)**

Turak, E., Waddel, l N., and Johnstone, G. (2004). New South Wales Australian River Assessment System (AUSRIVAS): Sampling and Processing Manual, 2004. Natural Heritage Trust, Department of Environment and Conservation NSW.

Wellnitz, T.A., Kristianne, A., Sheldon, G., and Sheldon S.P. (1994). Response of macroinvertebrates to blooms of iron-depositing bacteria *Hydrobiolgia* **28 1-17**

Annex 1 – Macroinvertebrate results

Macroinvertebrates recorded at survey sites

	Redbank Creek			Stonequarry Creek	Cedar Creek		Matthews Creek		Redbank Creek
Taxonomy	**Site1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**
Turbellaria				1				1	
Sialidae				1		2			
Corydalidae			1						
Lymnaeidae									1
Physidae									2
Corbiculidae				1	2				6
Oligochaeta	8			3				3	15
Acarina									1
Atyidae				23	11	2			
Parastacidae	4	1					2	2	
Dytiscidae	8	9	18	2			1	8	1
Gyrinidae			1		1				
Haliphidae				1					
Hydrophilidae		1							
Hydraenidae							1		
Scirtidae	1				2	1	1		
Tipulidae		1					2		
Dixidae					1		1		
Culicidae		1			1		1		1
Ceratopogonidae			1					1	1

Tanypodinae	2			2		3			
Orthocladiinae		1		3					
Chironominae	15	38	19	31	7	35	2	2	1
Baetidae									
Leptophlebiidae					27	6	28	71	
Caenidae									
Veliidae	2	2	9		1	1	2		
Gelastocoridae								1	
Gerridae		1							
Corixidae				1					
Notonectidae	10	5	2		3	2		1	2
Hydrometridae		1							
Coenagrionidae		2			2				
Isostictidae		2							
Megapodagrionidae		1	9		1				1
Gomphidae					1				
Telephlebiidae					1			1	
Synthemistidae					1				
Hemicorduliidae		7	1	1		1			6
Calamoceratidae					7				
Leptoceridae	1	13	2		16	5	3	2	

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