Tasman Extension Project

Environmental Impact Statement

APPENDIX E

AQUATIC ECOLOGY ASSESSMENT

Resource Strategies

DONALDSON COAL
Part of Gloucester Coal

Tasman Extension Project:
Aquatic Ecology Assessment

Prepared for:

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Summary

This report has been prepared for Donaldson Coal Pty Ltd. It provides an assessment of the potential impacts of the proposed extension of the Tasman Underground Mine (the Project) on aquatic ecology.

The scope of the study included an assessment of aquatic habitat, flora and fauna (including targeted sampling for aquatic species and communities listed in the New South Wales (NSW) *Fisheries Management Act 1994*, NSW *Threatened Species Conservation Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*), and the likely impacts to these by the proposed mine extension, including within, and downstream of, the Project area.

Study Area and Survey Details

The Project is located in the Hunter River Catchment, approximately 20 kilometres (km) west of the Port of Newcastle and 8 km south-east of Kurri Kurri, on the central coast of NSW. The Project is situated in the Sugarloaf Range, which is characterised by several natural drainage gullies. The majority of the Project area is within the ephemeral headwaters of the Surveyors and Wallis Creek catchments, which merge downstream and the north of the survey area and then flow approximately 20 km to the confluence with the Hunter River near Maitland. The Hunter River flows east to the sea and empties into Stockton Bight at Newcastle.

The survey area for the aquatic ecology assessment included tributaries within the Project area and immediately upstream and downstream of the Project area.

Aquatic habitat condition (including water quality), aquatic flora, aquatic macroinvertebrates and fish (including targeted surveys for listed threatened species and ecological communities) were surveyed at eight sites from 9 to 11 June 2011.

Habitat for Aquatic Fauna

The natural drainage gullies in the survey area are generally limited to pooled water following medium to high rain events, and so do not provide significant habitat for aquatic fauna. A small section of stream located downstream of the Project area provides more permanent habitat for aquatic fauna. However, most sites surveyed had good habitat bioassessment scores, due to the availability of diverse habitat, riparian vegetation cover and stable banks and channels.

Water quality results were generally not within the Hunter River Water Quality Objective (WQO) values for most parameters. Turbidity was above the WQO high trigger value for lowlands at four sites. The pH was below the WQO low trigger value for lowlands and uplands at four sites. Electrical conductivity was above the WQO high trigger value for upland sites at two sites, and above the WQO low trigger value for lowland sites at three sites. Dissolved oxygen was below the WQO low trigger value for all sites surveyed; two sites fell below the WQO low trigger value for upland sites and four sites fell below the WQO trigger value for lowland sites.

No endangered ecological communities were recorded in the Project area or surrounds.

Aquatic Flora

A total of 23 species of macrophytes were identified by the surveys. The number of macrophytes found in the 100 metre reach at each site ranged from three to nine species. With the exception of the wet site downstream of the extent of the proposed West Borehole Seam workings, the number of species at sites within and downstream of the proposed West Borehole Seam workings was lower than the number of species at the upstream sites. No threatened species were recorded in the survey.

Aquatic Macroinvertebrate Communities

Non-biting midge larvae (sub-families Chironominae and Tanypodinae) were the most common and abundant taxa. Seed shrimp (class Ostracoda) were also found in high numbers at most sites, and marsh beetle larvae (family Scirtidae) were abundant at one site. Typically, these families are tolerant of a wide range of environmental conditions and are often found in moderately disturbed ecosystems. Taxonomic richness ranged from 11 to 21 taxa and was lowest in bed habitat and highest in edge habitat. Pollution-sensitive Ephemeroptera, Plectoptera and Trichoptera taxa were recorded at five sites. In general, taxonomic richness was similar but lower in the current survey than for previous surveys undertaken from 2000 to 2010. Three species of macrocrustacean were caught, including freshwater prawns, orange-fingered crayfish and common yabbies. No threatened species were recorded in the survey.

Fish Communities

Three species of fish (the eastern gambusia [*Gambusia holbrooki*], the empire gudgeon [*Hypseleotris compressa*] and the firetail gudgeon [*Hypseleotris galii*]) were caught in the survey, out of 41 freshwater fish known in the Hunter-Central Rivers Catchment. Fish were only caught at the wetter site downstream of the extent of the proposed West Borehole Seam workings. The most abundant species caught was the eastern gambusia, which is declared as noxious under the *Fisheries Management Act 1994*, and is considered a pest by the NSW Department of Primary Industries. No threatened species were caught in the survey.

Potential Impacts and Mitigation Measures

The aquatic ecology of the study area has the potential to be impacted by management of surface water (such as stormwater), the effects of subsidence on stream geomorphology and flows, and construction of surface infrastructure. The proposed mitigation measures for surface water management and the implementation of Subsidence Control Zones are expected to minimise the impacts of the Project on aquatic ecology to the extent that no significant impacts are expected.

The Project is not expected to impact on any endangered aquatic ecological communities or listed threatened aquatic species.

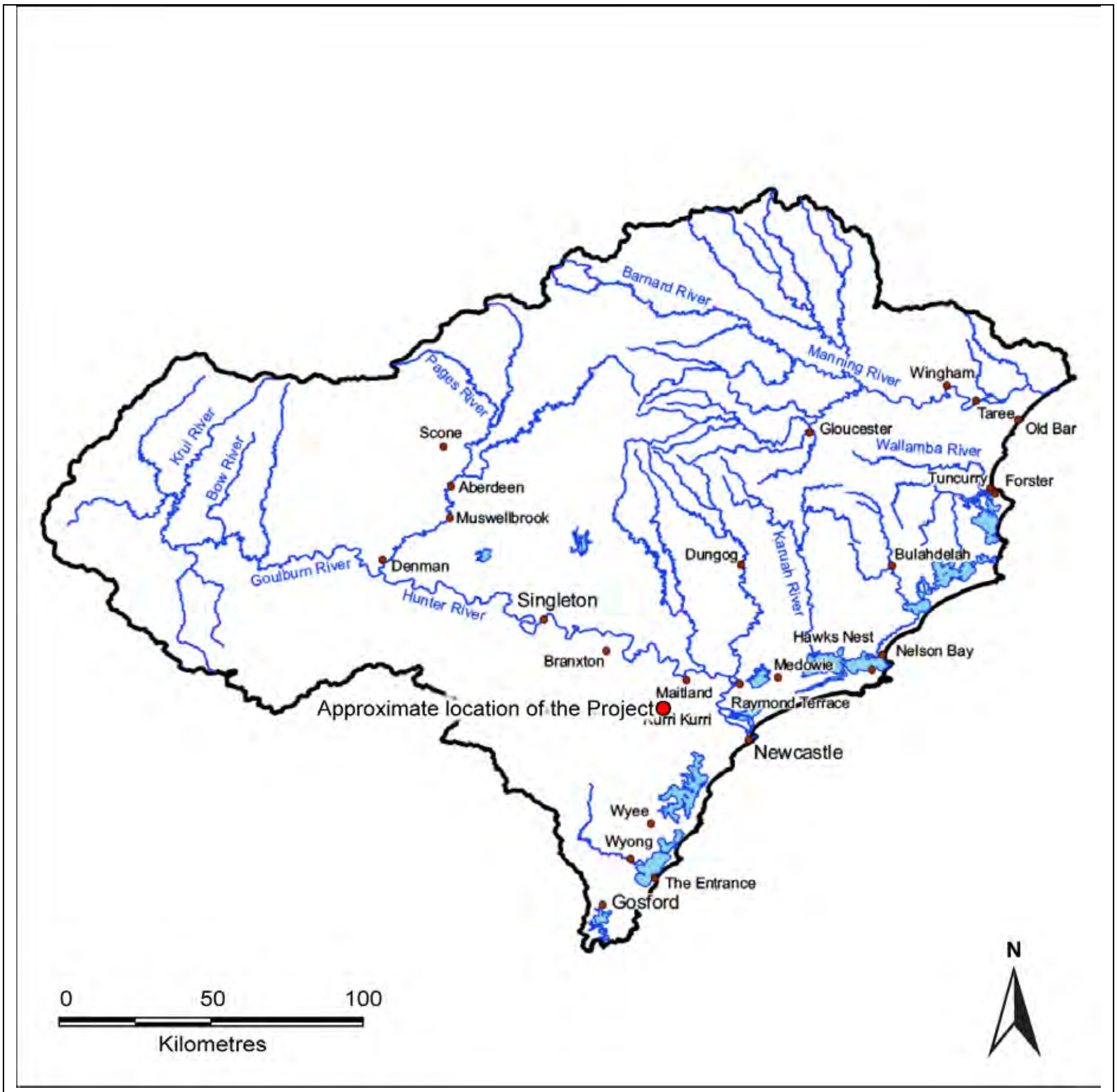
1 Introduction

This report has been prepared for Donaldson Coal Pty Ltd (Donaldson Coal). It provides an assessment of the potential impacts of the proposed extension of the Tasman Underground Mine (the Project) on aquatic ecology. The Project would involve an extension of underground mining into the West Borehole Seam (the West Borehole Seam workings). The scope of works for this report included:

- collecting baseline data on the assemblages of macroinvertebrates, fish and aquatic plants in the survey area
- providing an assessment of the characteristics and condition of aquatic habitats, including water quality
- undertaking targeting sampling for aquatic threatened species and communities listed in the Schedules of the New South Wales (NSW) *Fisheries Management Act 1994* (FM Act), NSW *Threatened Species Conservation Act 1995* (TSC Act) and / or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which are known or considered possible occurrences in the survey area
- assessing the potential impacts of the Project on aquatic ecology including relevant key threatened processes listed under the TSC Act, FM Act and EPBC Act, groundwater dependant aquatic and riparian ecosystems, as well as cumulative impacts, and
- proposing practical measures to avoid, manage, mitigate and offset potential impacts.

1.1 Description of the Survey Area

The Project comprises an underground coal mine located approximately 20 kilometres (km) west of the Port of Newcastle and approximately 8 km south-east of Kurri Kurri, on the central coast of NSW (Figure 1.1). The Project is located in the Hunter River Catchment, which covers approximately 22,000 square kilometres. The Project area includes portions of the Sugarloaf State Conservation Area and Heaton State Forest in the Sugarloaf Range, at an elevation of 40 to 370 metres (m) Australian Height Datum. The terrain in these areas is characterised by several natural drainage gullies. The Project area also includes private land holdings in the north and west.



frc environmental AQUATIC ECOLOGISTS deep thinking.science.	110409	Tasman Aquatic Ecology
	Figure 1.1 Approximate location of the Project in the Hunter River Catchment.	
	Source: NSW Department of Environment, Climate Change and Water (DECCW) 2010	GDA94 / September 2011

The majority of the Project area is within the ephemeral headwaters of the Surveyors and Wallis Creek catchments. Surveyors Creek flows into Wallis Creek downstream and north of the survey area (Figure 1.2), which then flows approximately 20 km to the confluence with the Hunter River near Maitland. The Hunter River flows east to the sea and empties into Stockton Bight at Newcastle (Figure 1.1).

The survey area for the aquatic ecology assessment included tributaries within the approximate extent of proposed West Borehole Seam workings, and immediately upstream and downstream (Figure 1.2).

1.2 Survey Details

Further details are presented in Appendix A.

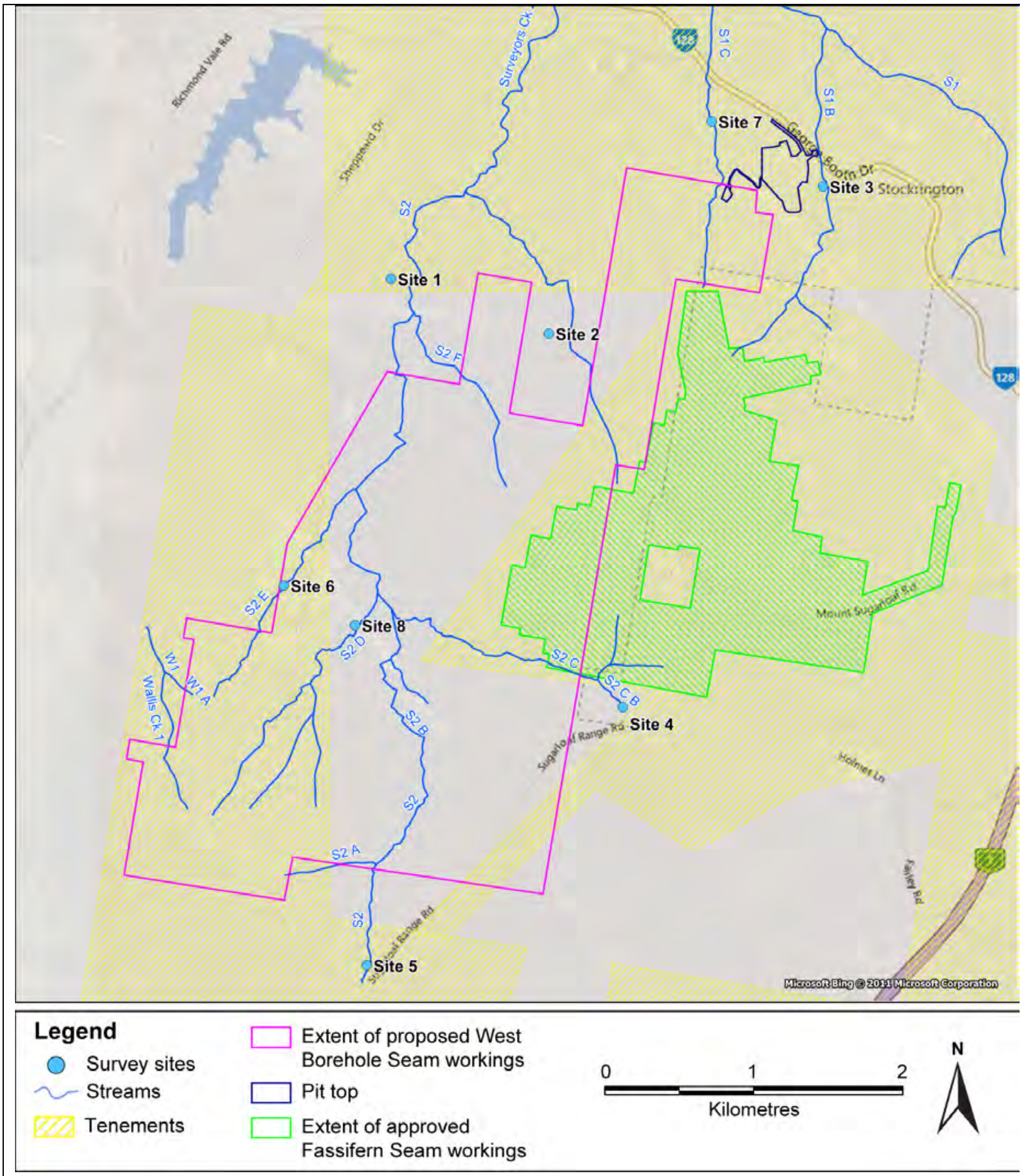
Aquatic habitat condition (including physical water quality), aquatic flora, aquatic macroinvertebrates and fish (including targeted surveys for listed threatened species and ecological communities) were surveyed from 9 to 11 June 2011.

Surveys were undertaken at eight sites, on the tributaries within the survey area (Figure 1.2):

- sites 4 and 5 (tributaries upstream of the extent of the proposed West Borehole Seam workings)
- sites 6 and 8 (tributaries within the extent of the proposed West Borehole Seam workings), and
- sites 1, 2, 3 and 7 (tributaries downstream of the extent of the proposed West Borehole Seam workings).

Results at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to background data, which were defined as the range of data at comparative (upstream of the extent of the proposed West Borehole Seam workings) sites in the survey, and those recorded in other studies in the region (where available).

Based on the literature reviewed, the surveys undertaken and in consideration of habitat diversity and the nature of predicted impacts, the survey effort undertaken as part of this assessment is considered adequate for the basis of the environmental impact assessment.



frc environmental AQUATIC ECOLOGISTS deep thinking.science.	110409	Tasman Aquatic Ecology
	Figure 1.2 Sites surveyed.	
	GDA94	September 2011

2 Relevant Legislation

The key legislation for aquatic species and ecological communities relative to the Project are summarised below.

Threatened aquatic species and ecological communities relevant to the survey area are listed in Table 2.1. These were based on database search results of:

- NSW Office of Environment and Heritage (OEH) (2011a) *Primary Industries (Fishing and Aquaculture) Threatened and Protected Species Records Viewer*
- OEH (2011b) *Threatened Species, Populations and Ecological Communities Search*
- OEH (2011c) *Bionet*
- Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) (2011) *EPBC Act Protected Matters Search,* and
- literature reviews.

The key legislation for aquatic species and communities relative to the Project are summarised below in Section 2.1 (FM Act), Section 2.2 (TSC Act) and Section 2.3 (EPBC Act).

Table 2.1 Listed aquatic species and ecological communities known from the Hunter sub-region.

Species or Community	Common Name	Conservation Status[a]		
		FM Act	TSC Act	EPBC Act
Aquatic Communities				
Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	Freshwater wetlands on coastal floodplains	–	EEC	–
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions	Swamp oak floodplain forest	–	EEC	–

Species or Community	Common Name	Conservation Status[a]		
		FM Act	TSC Act	EPBC Act
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregion	Swamp sclerophyll forest on coastal floodplains	–	EEC	–
Aquatic Flora				
Maundia triglochinoides	Maundia	–	V	–
Persicaria elatior	tall knotweed	–	V	V
Zannichellia palustris	Zanichellia	–	E	–
Aquatic Fauna				
Archaeophya adamsi	Adam's emerald dragonfly	E	–	–
Macquaria australasica	Macquarie perch	E	–	E
Mogurnda adspersa	purple spotted gudgeon	E	–	–

E: Endangered, V: Vulnerable, EEC: Endangered Ecological Community

[a] Threatened Species/Community Status under the FM Act, TSC Act and/or EPBC Act (current as of 24 February 2012)

2.1 New South Wales *Fisheries Management Act 1994*

The FM Act[1] sets out the regulatory framework for managing the state's fishing resources, in particular threatened fish and marine vegetation. It is administered by the NSW Department of Primary Industries (DPI) (Fishing and Aquaculture). Part 7A of the FM Act enables the listing of:

- threatened species
- populations
- ecological communities

[1] Reprint No. 38. Current version for 13 March 2012 compiled and maintained by the Parliamentary Counsel's Office.

- key threatening processes (activities that harm threatened species or could cause other species to become threatened), and
- critical habitat.

The FM Act provides the legislative framework for the protection and recovery of threatened species. Schedules 4, 4A and 5 of the FM Act list endangered, critically endangered and vulnerable species and ecological communities. Key threatening processes are listed under Schedule 6.

Threatened Species

There are three species listed as endangered under the FM Act that may occur in aquatic communities in the vicinity of the survey area (Table 2.1).

The Adam's emerald dragonfly (*Archaeophya adamsi*) is extremely rare, found only in small streams and creeks with gravel or sandy bottoms, specifically in narrow, shaded riffle zones with moss and rich riparian vegetation (DPI 2011). They are only found in four areas in NSW: Somersby Falls and Floods Creek near Gosford, Bedford Creek in the Lower Blue Mountains, and Hungry Way Creek in Wollemi National Park (Fisheries Scientific Committee 2008a).

The Macquarie perch (*Macquaria australasica*) is a native Australian fish that spends its entire life in freshwater streams, migrating between deep pools and fast flowing riffle habitats during different stages of its life history (McDowall 1996). It is endemic to the southern tributaries of the Murray-Darling River System (DPI 2005).

The purple spotted gudgeon (*Mogurnda adspersa*) is found in slow moving or still waters of rivers, creeks and billabongs, often among weeds, rocks and snags. The population was once widespread throughout the Murray-Darling River System and in the coastal drainages of NSW north of the Clarence River Catchment. The population has significantly declined in recent years due to predation by introduced fish (e.g. eastern gambusia [*Gambusia holbrooki*]) and habitat loss (Fisheries Scientific Committee 2008b).

Threatened Aquatic Communities

There are no aquatic ecological communities listed under the FM Act in vicinity of the survey area.

Key Threatening Processes

The key threatening processes listed under the FM Act that are relevant to the survey area are:

- hook and line fishing in areas important for the survival of threatened fish species
- human-caused climate change
- the introduction of fish to freshwaters within a river catchment outside their natural range
- the removal of large woody debris from NSW rivers and streams
- the degradation of native riparian vegetation along NSW watercourses, and
- instream structures and other mechanisms that alter natural flow.

2.2 New South Wales *Threatened Species Conservation Act 1995*

The TSC Act[2] provides for the protection and management of terrestrial biodiversity and threatened species in the state and is administered by the OEH.

Species, populations and ecological communities listed as endangered, critically endangered and vulnerable in NSW are listed in Schedules 1, 1A and 2 of the TSC Act.

Threatened Species

There are three aquatic floral species listed as threatened for the Hunter sub-region under the TSC Act (Table 2.1).

Maundia (*Maundia triglochinoides*) is listed as vulnerable; it is a perennial herb that grows in swamps or in shallow fresh water on heavy clay. It occurs in permanent swamps and wetlands on the central and north coasts of NSW. In the Hunter sub-region it is associated with dry schlerophyll forests, forested wetlands, and freshwater wetlands. Maundia is sensitive to changes in hydrology, water quality and weed invasion (OEH 2011d).

[2] Reprint No. 101. Current version for 9 March 2012 compiled and maintained by the Parliamentary Counsel's Office.

Tall knotweed (*Persicaria elatior*) is listed as vulnerable; it is a herb that grows in damp places, especially beside streams and lakes or in swamp forest. In the Hunter sub-region it is associated with forested wetlands, freshwater wetlands, heathlands, rivers, lakes and streams. Tall knotweed is threatened by the clearing of, and hydrological changes to, wetland vegetation (OEH 2011e). Flowers are produced in autumn and summer, and are required to identify the species.

Zannichellia (*Zannichellia palustris*) is listed as endangered; it is a submerged aquatic plant that grows in fresh or slightly saline stationary or slowly flowing water. In the Hunter sub-region it is associated with freshwater wetlands, saltmarshes, rivers, lakes and streams. Zannichellia is sensitive to changes in hydrological conditions and water quality (OEH 2011f).

Threatened Aquatic Communities

There are three aquatic communities listed as EECs for the Hunter sub-region under the TSC Act (Table 2.1).

Freshwater wetlands on coastal floodplains of the NSW north coast, Sydney basin and south-east corner bioregions are dominated by herbaceous plans and have very few woody species. They are associated with coastal areas, subject to periodic flooding, where standing fresh water persists for at least part of the year.

Swamp oak floodplain forests of the NSW north coast, Sydney basin and south-east corner bioregions have a dense to sparse tree layer dominated by swamp oaks (*Casuarina glauca*). Less than 3,200 hectares (ha) of swamp oak floodplain forests remain in the Hunter and Hunter-Central Rivers Catchments.

Swamp sclerophyll forests on coastal floodplains of the NSW north coast, Sydney basin and south-east corner bioregions comprise eucalypts (*Eucalypts* spp.) and paperbarks (*Melaleuca* spp.). Where trees are sparse or absent, the community also includes ferns, reeds and/or sedges.

These communities were not identified within the study area (Appendix B).

2.3 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

Any actions that are likely to have a significant impact on a matter of national environmental significance are subject to assessment under the EPBC Act[3] approval process. Matters of national environmental significance include:

- threatened species and ecological communities
- Wetlands of International Importance (Ramsar wetlands)
- World Heritage Properties
- National Heritage Places
- migratory species
- Commonwealth Marine Areas
- the Great Barrier Reef Marine Park, and
- nuclear actions.

The Macquarie perch (*Macquaria australasica*) is listed as an endangered species and tall knotweed is listed as a vulnerable species under the EPBC Act (Table 2.1, Section 2).

The Hunter Estuary Wetlands Ramsar site is located approximately 60 km downstream of the Project area, in the estuary of the Hunter River approximately 7 km north of Newcastle. The wetland has two components: the Koorangang Nature Reserve and Shortland Wetlands (the Hunter Wetlands Centre). The Hunter Estuary Wetlands Ramsar site is important as a feeding and roosting site for migratory shorebirds.

There are several places listed on the Register of National Estate that occur within 10 km of the survey area (SEWPaC 2010):

- Bow Wow Gorge Geological Site
- Bow Wow Creek Gorge
- Mulbring Road-Fill Quarry
- Mulbring Valley Landscape Conservation Area, and
- Richmond Main Colliery.

[3] Act no. 91 of 1999 as amended, prepared on 19 February 2012 taking into account amendments up to Act No. 46 of 2011. Prepared by the Office of Legislative Drafting and Publishing, Attorney-General's Department, Canberra.

There are several state reserves that occur within 10 km of the survey area (SEWPaC 2010):

- Werakata
- Sugarloaf, and
- the Hunter Lakes.

There are no World Heritage Properties, Commonwealth Marine Areas or listed migratory species [4] that occur in the survey area. The Great Barrier Reef Marine Park and nuclear actions are not relevant to the survey area.

[4] Refers to aquatic species only; excludes avian and amphibious fauna.

3 Habitat for Aquatic Fauna

Detailed methods and results are presented in Appendix B.

3.1 Methods

Assessment of the in-stream habitat condition at each site was based on the Australian River Assessment System (AUSRIVAS) protocol described in the *Australia-Wide Assessment of River Health: New South Wales AUSRIVAS Sampling and Processing Manual* (Turak & Waddell 2002). To enable a comparison of habitat quality between sites using an index of habitat condition, habitat bioassessment score datasheets (Queensland Department of Natural Resources and Mines [DNRM] 2001) were used to numerically score nine criteria, which were then allocated to one of four categories (excellent, good, moderate and poor).

Results at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to the data from the upstream sites.

Water quality was assessed at sites that held water, and included six of the nine sites. Physical water quality measurements were sampled *in situ* at each site. Water samples collected at each site were analysed by Advanced Analytical (a National Association of Testing Authorities Australia accredited laboratory) for alkalinity by a Hydrolab Q multi-parameter, water quality probe for water temperature, pH, electrical conductivity and dissolved oxygen and by a Hach 2100Q turbidity meter for turbidity.

Water quality data at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from the comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- NSW Quality Objectives (DECCW 2006) for uncontrolled streams and water bodies in the Hunter River Catchment for lowland [5] and upland rivers (sites 4 and 5 are >150 m in elevation).

[5] DECCW (2006) Guidelines define lowland streams as those below 150 m altitude

3.2 Results

The natural drainage gullies in the survey area are generally limited to pooled water following medium to high rain events, and so do not provide significant habitat for aquatic fauna.

The riparian zone at all upstream sites was generally diverse and was dominated by *Eucalyptus* spp., *Melaleuca* spp. and *Leptospermum* spp.. Lantana (*Lantana camera*), which is a weed of national significance (Commonwealth of Australia 2009), was only observed at site 8 (within the extent of the proposed West Borehole Seam workings). The land immediately next to the riparian zone was predominantly native vegetation. Some vegetation was cleared:

- at site 6, for a residential property
- upstream of sites 3 and 7, for a transmission line, and
- downstream of sites 2 (Figure 3.1) and 8, for transmission lines.

Bank stability at most sites was moderate to high. There was little evidence of recent erosion; however, the banks at sites 3 (downstream of the extent of the proposed West Borehole Seam workings) and 8 (within the extent of the proposed West Borehole Seam workings) (Figure 3.2) were undercut, indicating a lower bank stability, possibly due to the steepness of the drainage line in these areas.

Although channel diversity was low at all sites, in-stream habitat such as woody debris and overhanging/trailing bank vegetation provided refuge and food for aquatic fauna at most sites (Figure 3.3).

Surface sediment was dominated by:

- silt/clay at sites 6 and 7
- silt/clay and sand at sites 1 and 2
- bedrock at sites 4 and 5, and
- sand at sites 8 and 3.

Site 1 (downstream of the extent of the proposed West Borehole Seam workings) was a wet section of stream with Melaleuca trees present, however it does not meet the criteria of Swamp Sclerophyll Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.

Figure 3.1

Vegetation clearing downstream of site 2.

Figure 3.2

Steep banks with the potential for erosion at site 8.

Figure 3.3

Overhanging and trailing bank vegetation at site 6.

Vegetation across the Project area and surrounds has been mapped by Hunter Eco (2012a, 2012b). No aquatic EECs according to the EPBC Act and TSC Act were recorded in the Project area. Site 1 (downstream of the extent of the proposed West Borehole Seam workings) was a wet area with Melaleuca trees present, however Hunter Eco (2012a, 2012b) mapped this area as EEC MU17 'Lower Hunter Spotted Gum – Ironbark Forest in the Sydney Basin Bioregion EEC'. Potential impacts to the EEC have been considered in the terrestrial ecology assessment and are not discussed further in this report.

All sites had either a moderate or good habitat bioassessment score. The moderate habitat score at site 6 (within the extent of the proposed West Borehole Seam workings) was due to:

- evidence of channel alteration
- bottom scouring and deposition, and
- a lack of stable habitat.

Good habitat bioassessment scores (Figure 3.4) at the majority of sites was generally due to:

- more diverse habitat (e.g. woody debris and vegetation)
- good riparian vegetation cover, and
- stable banks and channels.

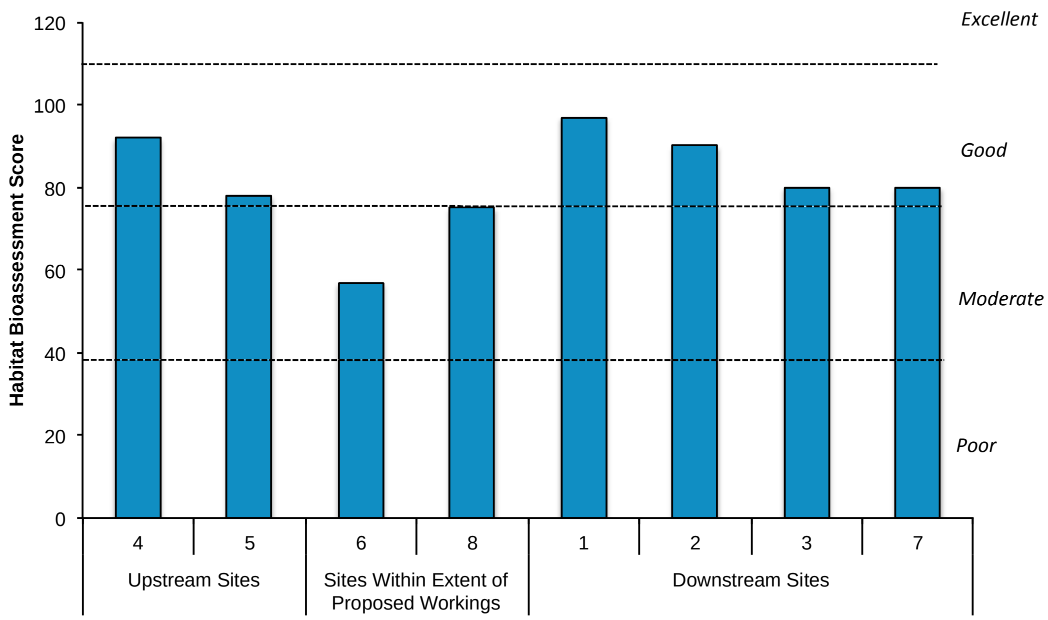


Figure 3.4 Habitat bioassessment scores at each site.

Water quality results were outside of the Hunter River Catchment Water Quality Objective (WQO) values for most parameters, including:

- turbidity, above the WQO high trigger values for lowlands at sites 1, 3, 6 and 7 (Figure 3.5)
- pH, below the WQO low trigger values for lowland and upland sites at sites 4, 5, 6 and 7 (Figure 3.6)
- electrical conductivity, above the WQO high trigger value for upland sites at sites 4 and 5, and above the WQO low trigger value for lowland sites at sites 1, 3 and 6 (Figure 3.7), and
- dissolved oxygen, below the WQO high and low trigger values for respective upland and lowland sites at all sites (Figure 3.8).

There are no WQOs for water temperature or alkalinity. The range in water temperature was 8.3 to 10.4°C (Appendix B). The range in alkalinity was 8 to 25 milligrams of calcium carbonate per litre (Appendix B).

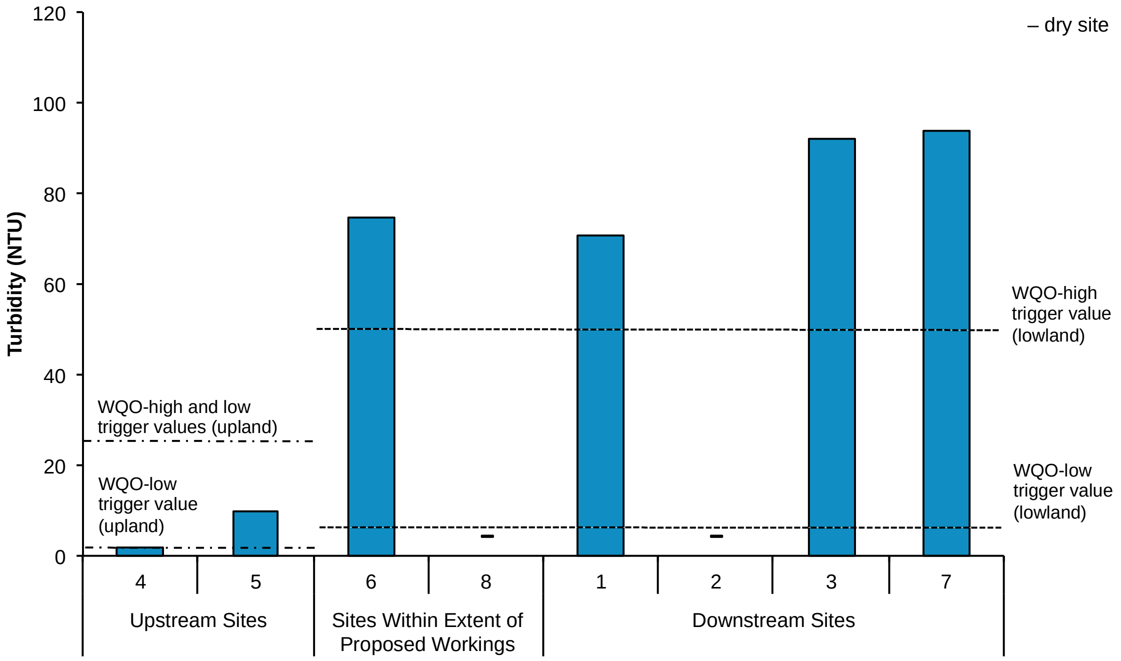


Figure 3.5 Turbidity at each site, and the Hunter River Catchment Water Quality Objective trigger value ranges.

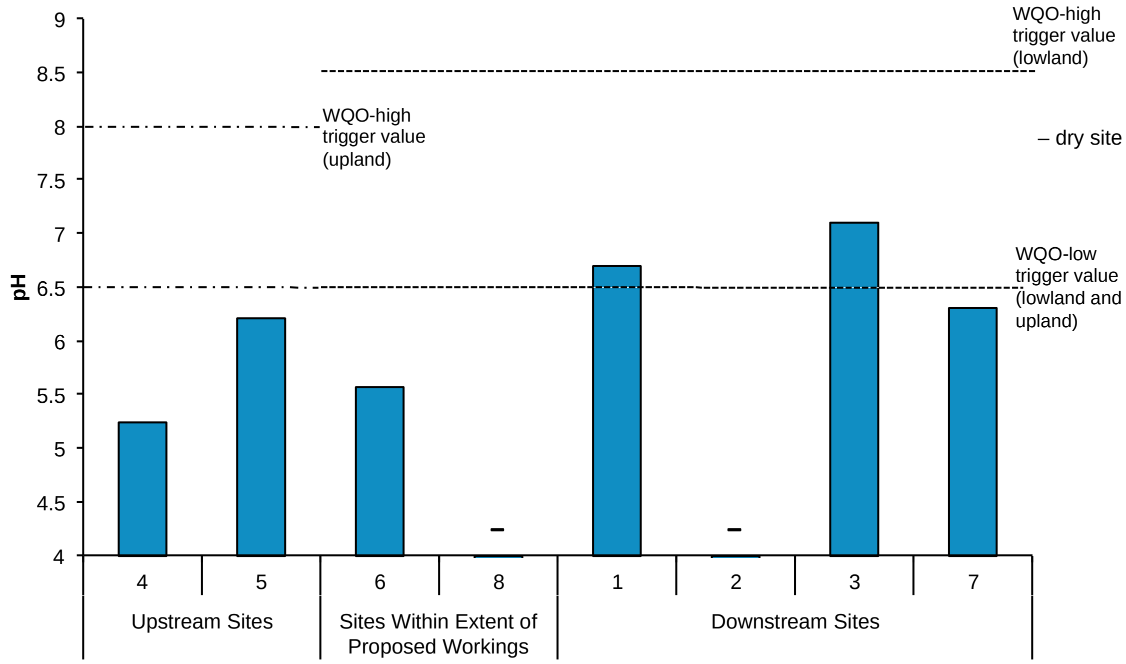


Figure 3.6 The pH at each site, and the Hunter River Catchment Water Quality Objective trigger values.

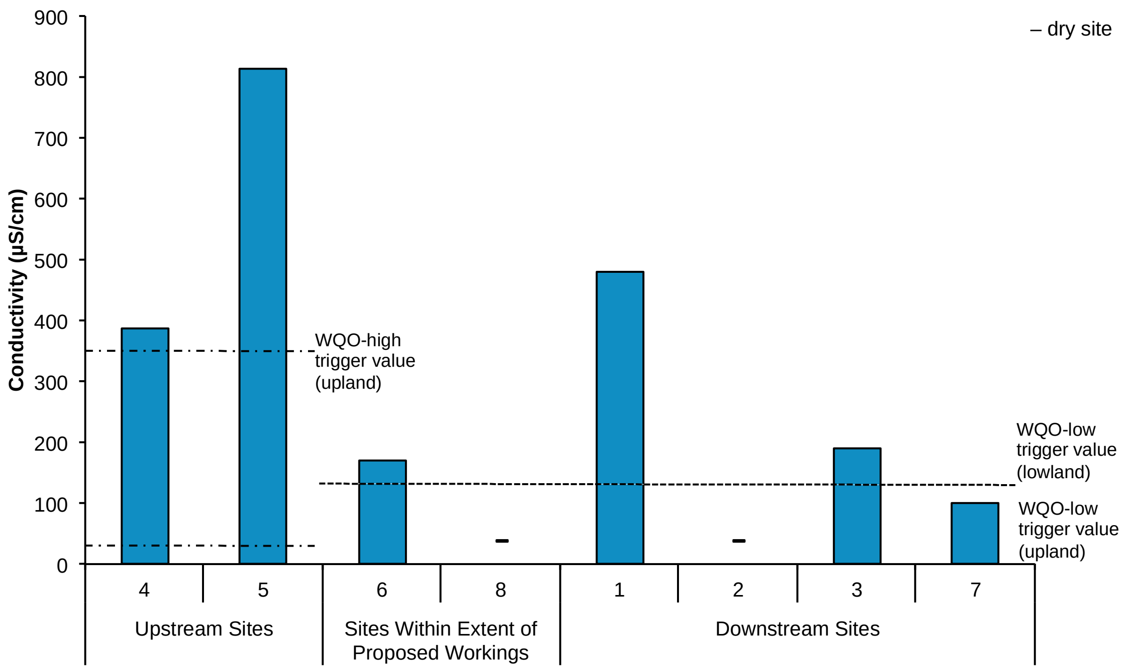


Figure 3.7 Electrical conductivity at each site, and the Hunter River Catchment Water Quality Objective trigger values.

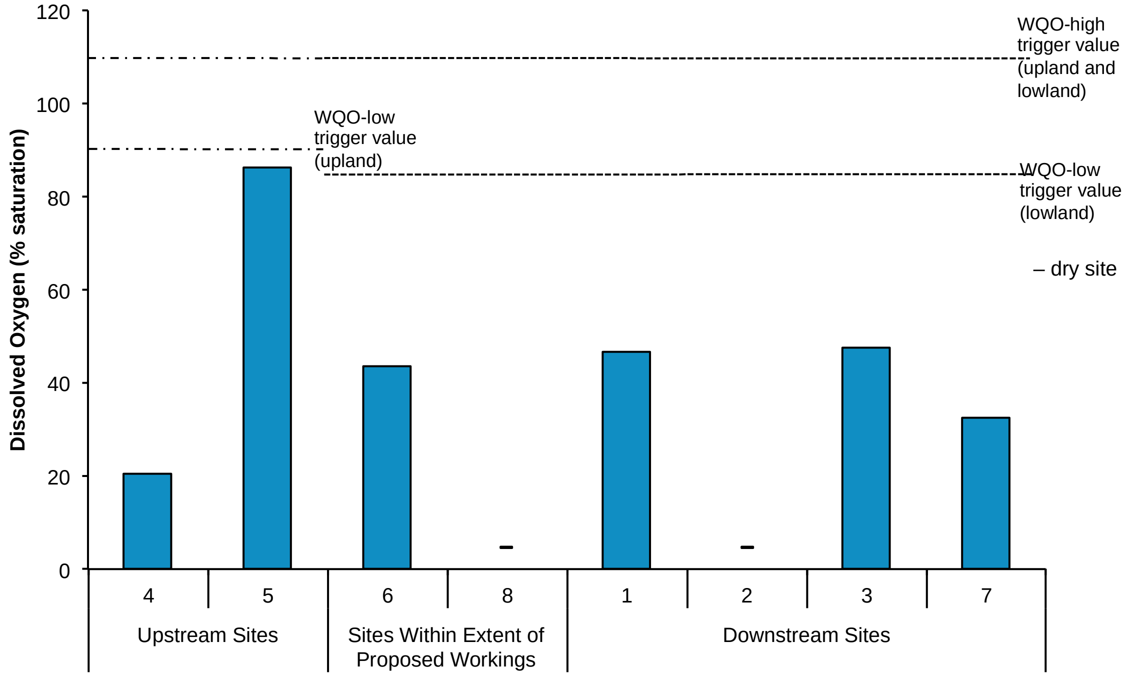


Figure 3.8 Dissolved oxygen at each site, and the Hunter River Catchment Water Quality Objective trigger values.

4 Aquatic Flora

Detailed methods and results are presented in Appendix C.

4.1 Methods

The macrophyte community at each site (Figure 1.2) was assessed along a 100 m reach within the stream (NSW Department of Environment and Conservation [DEC] 2004). Plants were identified and the following recorded:

- taxonomic richness
- mean percent (%) cover (% of substrate [bed/bank] covered by aquatic vegetation)
- total percent cover (% of substrate [bed/bank] covered by each aquatic species)
- growth form of each species (submerged, floating [free-floating or rooted] and emergent)
- whether the plant was native or introduced to Australia, and
- whether the plant was listed under state or commonwealth legislation.

Macrophyte data at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from the comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- results of a previous survey undertaken by frc environmental at the nearby Abel Underground Mine from 24 to 28 May 2010.

4.2 Results

A total of 23 species of macrophyte were identified within the survey area (Appendix C). The number of macrophytes found in the 100 m reach at each site ranged from three species at sites 2 and 8 (downstream or within the extent of the proposed West Borehole Seam workings) to nine species at site 1 (wetter area downstream of the extent of the proposed West Borehole Seam workings) (Figure 4.1). Except at site 1 (the wet site), the number of species at sites within and downstream of the extent of the proposed West Borehole Seam workings was lower than the number of species at the upstream sites (Figure 4.1). Taxonomic richness in the current survey was similar to richness at sites at the nearby Abel Underground Mine survey, which ranged from 2 to 11 species (frc environmental 2010a).

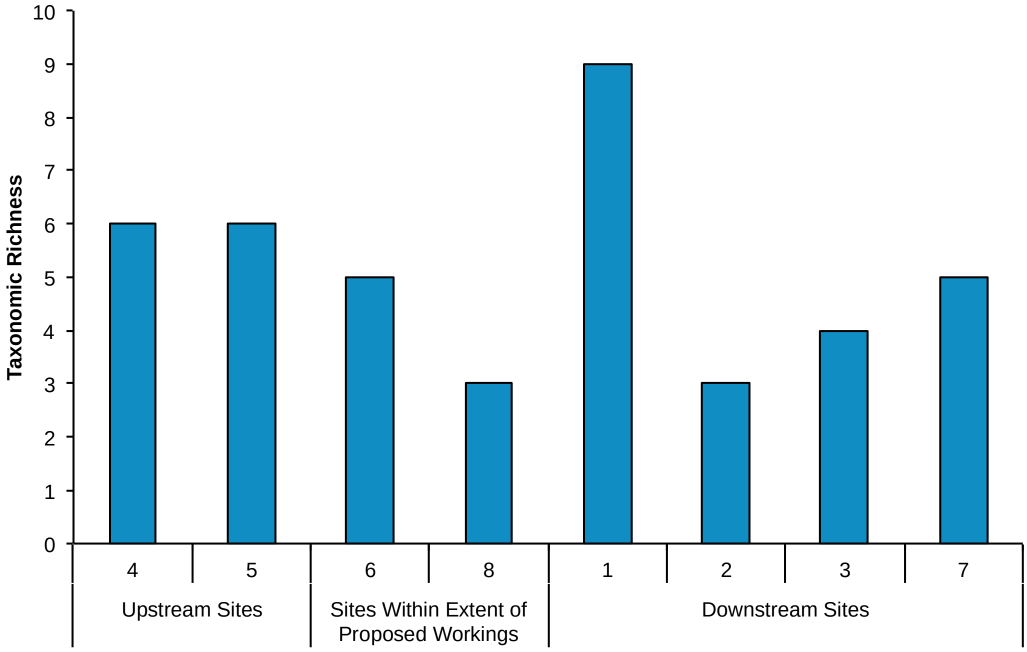


Figure 4.1 Taxonomic richness at each site.

The mean percent cover of macrophytes (as a percentage of the total substrate) ranged from 3 to 68% at each site (Figure 4.2).

In general, the percent cover of macrophytes at each site within and downstream of the proposed West Borehole Seam workings was similar to those upstream. Site 8 had the lowest percent of macrophytes at 3% and site 2 had the highest at 68% (Figure 4.2).

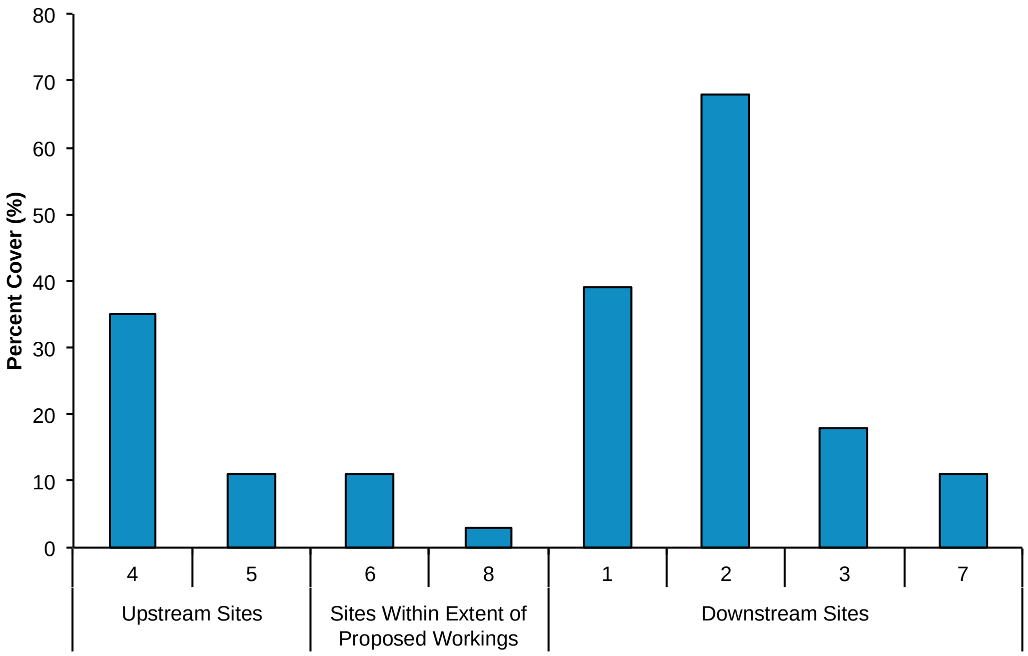


Figure 4.2 Percent cover of macrophytes at each site.

The high macrophyte cover at site 2 (downstream of the extent of the proposed West Borehole Seam workings) was due to a high abundance of perennial black bog weed (*Schoenus melanostachys*). Black bog weed was also common at site 4 (upstream of the extent of the proposed West Borehole Seam workings). High macrophyte cover at site 1 (wetter area downstream of the extent of the proposed West Borehole Seam workings) was due to a range of species, particularly Chinese water chestnut (*Eleocharis dulcis*) and a submerged macrophyte that was unable to be identified by the National Herbarium of NSW due to a lack of reproductive units.

In general, mean cover of macrophytes in the current survey was slightly lower than the mean cover in the Abel Underground Mine survey, which ranged from 10 to 75% (frc environmental 2010a).

A true grass from the family Poaceae (species unknown) was the most common species observed, found at six of the eight sites (Appendix C). Other common species found at three sites included (Appendix C):

- giant spike rush (*Eleocharis sphacelata*)
- wiry panic (*Entolasia stricta*), and
- variable sword sedge (*Lepidosperma laterale*).

Emergent macrophytes were the most common growth form at both upstream and downstream sites. Submerged macrophytes were at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings) (Appendix C). There were no species of floating macrophytes (Appendix C).

No aquatic flora listed under the EPBC Act or TSC Act were recorded during the survey or in the Abel Underground Mine survey. Based on the survey results and habitat assessments it is considered unlikely that threatened aquatic flora species occur in the study area. As such, no threatened species assessments have been undertaken.

No introduced aquatic flora species were recorded in the survey.

5 Aquatic Macroinvertebrate Communities

Detailed methods and results are presented in Appendix D.

5.1 Methods

Aquatic macroinvertebrate communities were assessed at five of the eight sites (those that held water) in a survey from 9 to 11 June 2011. Sites 2 and 8 were dry at the time of sampling, site 4 was reduced to a small pool and only edge habitat was sampled; and site 5 was reduced to several small shallow (less than 10 centimetres deep) pools that were not suitable for macroinvertebrate sampling.

At each site, macroinvertebrate samples were collected from bed and edge habitat. Macrocrustaceans were caught during fish surveys, using a combination of electrofishing and bait trapping.

Abundance, taxonomic richness, Plecoptera, Ephemeroptera and Trichoptera (PET) richness and Stream Invertebrate Grade Number-Average Level (SIGNAL) 2 scores were calculated for each sample. These indices were used to indicate the current ecological health of surveyed waterways.

Macroinvertebrate data at sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from comparative sites upstream of the extent of the proposed West Borehole Seam workings)
- results of a previous survey by frc environmental for the nearby Abel Underground Mine, from 24 to 28 May 2010 (frc environmental 2010a; 2010b; 2010c), and
- results from the Donaldson Coal Mine Macroinvertebrate Sampling Program Operations Survey: Spring 2010 (Robyn Tuft & Associates 2011) (where available), which summarises the results of macroinvertebrate sampling undertaken annually from September 2000 to December 2010 at six sites approximately 4 km north of the existing Tasman Underground Mine pit top.

Dragonfly larvae were examined for the presence of the endangered Adam's emerald dragonfly (*Archaeophya adamsi*).

5.2 Results

Macroinvertebrates

Non-biting midge larvae (sub-families Chironominae and Tanypodinae) were the most common and abundant taxa (Appendix D). Seed shrimp (class Ostracoda) were also found in high numbers at most sites, and marsh beetle larvae (family Scirtidae) were abundant at site 4 (upstream of the extent of the proposed West Borehole Seam workings) (Appendix D). Typically, these families are tolerant of a wide range of environmental conditions and are often found in moderately disturbed ecosystems (Chessman 2003). Larvae of the Adam's emerald dragonfly were not caught in this survey.

In addition to the dominant taxa recorded in the current survey, some sites in the Abel Underground Mine survey had a high abundance of caddisfly nymphs (family Leptoceridae) (frc environmental 2010c). Sites in the Donaldson Coal Mine macroinvertebrate sampling programme also included beetles (family Dytiscidae), water boatman (family Corixidae) and mayfly larvae (family Leptophlebiidae) (Robyn Tuft & Associates 2011).

The abundance of macroinvertebrates ranged from 33 to 196 individuals in bed habitat and from 75 to 354 in edge habitat (Appendix D).

Total taxonomic richness was lowest in bed habitat at site 3 (downstream of the proposed West Borehole Seam workings) and highest in edge habitat at sites 4 and 6 (within and upstream of the extent of the proposed West Borehole Seam workings, respectively) (Figure 5.1). In edge habitat, total taxonomic richness was lower at site 4 (upstream of the extent of the proposed West Borehole Seam workings) compared to richness at sites within and downstream of the extent of the proposed West Borehole Seam workings (Figure 5.1). This is not surprising given that site 4 comprised an ephemeral, isolated pool.

In general, total taxonomic richness at sites in the Abel Underground Mine survey was similar to taxonomic richness at sites in the current survey (frc environmental 2010c). Total taxonomic richness at sites in the Donaldson Coal Mine macroinvertebrate sampling programme varied over time; however, richness was slightly higher at most sites than at sites in the current survey (Robyn Tuft & Associates 2011).

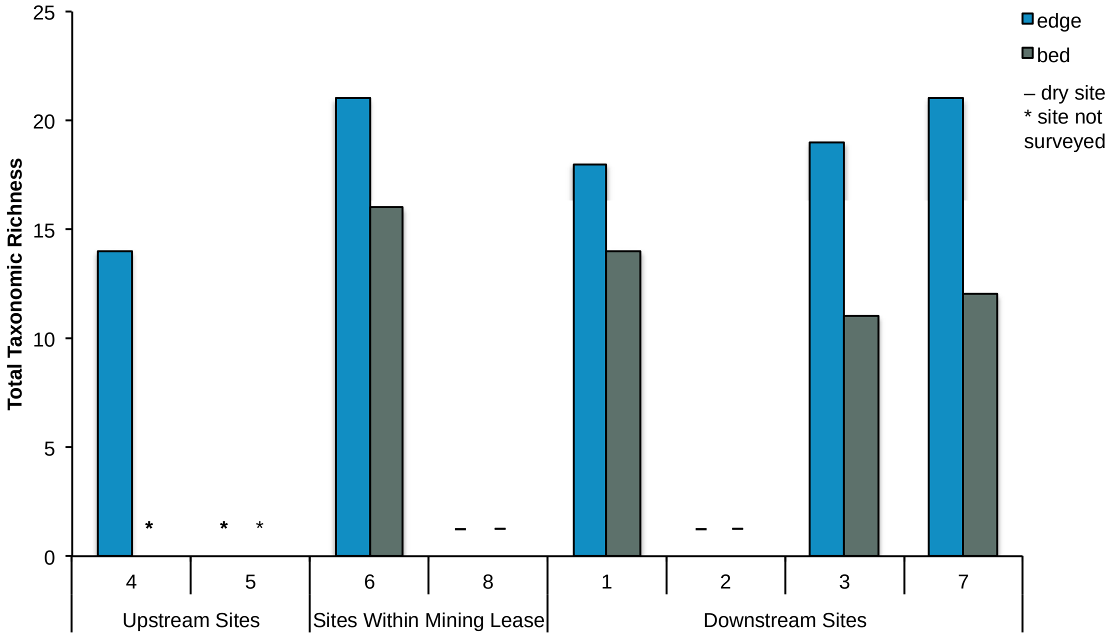


Figure 5.1 Total taxonomic richness in bed and edge habitats at each site.

PET taxa are sensitive to pollutants and changes in water quality and / or environmental degradation. Healthy streams are usually characterised by the presence of PET (pollution-sensitive) taxa. PET taxa were found at sites 1, 3, 4, 6 and 7 (Figure 5.2). Total PET richness was highest, in both bed and edge habitats, at site 6 (within the extent of the proposed West Borehole Seam workings) (Figure 5.2).

Total PET richness at sites in the Abel Underground Mine survey was similar to PET richness at sites in the current survey (frc environmental 2010c).

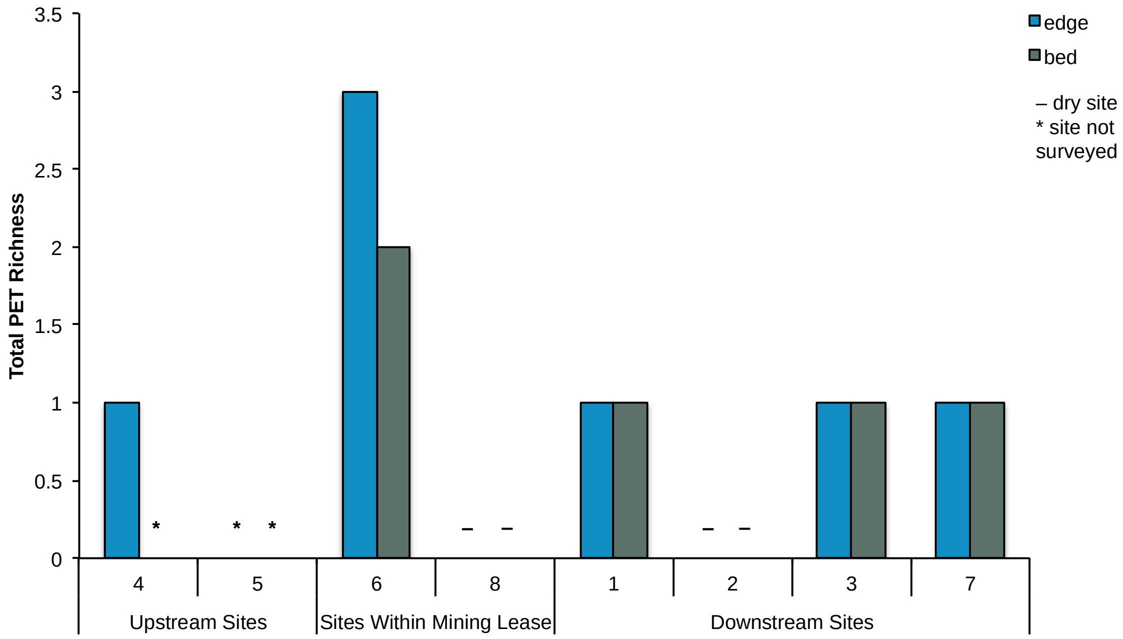


Figure 5.2 Total PET richness in bed and edge habitats at each site.

In general, SIGNAL 2 scores were low (< 4), and were higher in edge habitat than in bed habitat, the exception being site 7 where the reverse is true (Figure 5.3). SIGNAL 2 scores at sites within and downstream of the extent of the proposed West Borehole Seam workings were higher than scores obtained from upstream sites (Figure 5.3).

In general, SIGNAL 2 scores for sites for the Abel Underground Mine were slightly higher than at sites in the current survey (frc environmental 2010c). SIGNAL 2 scores at sites in the Donaldson Coal Mine macroinvertebrate sampling programme were also higher than at sites in the current survey; in autumn 2010, SIGNAL 2 scores ranged from 4.2 to 5.8 (Robyn Tuft & Associates 2011). SIGNAL 2 scores remained relatively consistent from 2000 to 2010 (Robyn Tuft & Associates 2011).

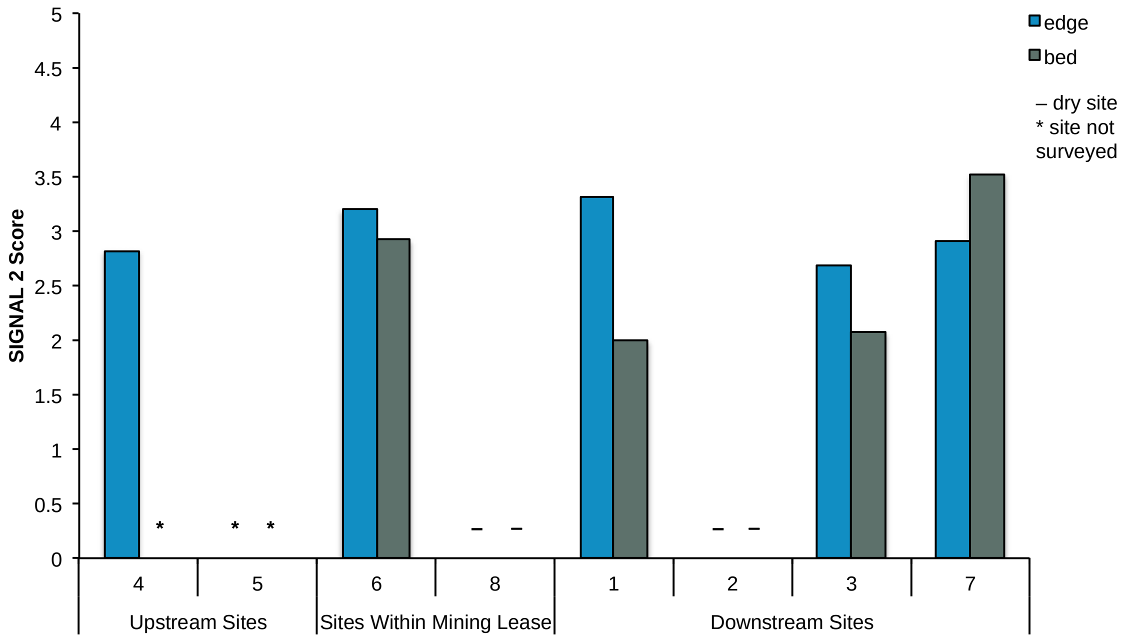


Figure 5.3 Total SIGNAL 2 score in bed and edge habitats at each site.

The NSW AUSRIVAS model results indicated that the macroinvertebrate communities at site 7 (downstream of the proposed West Borehole Seam workings) and 3 (downstream of the extent of the proposed West Borehole Seam workings) were significantly impaired (i.e. there were less taxa than were expected at these sites), which may be due to sub-optimal water quality or habitat quality (Table 5.1). The macroinvertebrate community at site 6 (within the extent of the proposed West Borehole Seam workings) was comparable to the condition of macroinvertebrate communities at the AUSRIVAS reference sites (i.e. macroinvertebrate diversity was high) (Table 5.1).

The AUSRIVAS model results for autumn surveys in 2009 and 2010 at sites in the Donaldson Coal Mine macroinvertebrate sampling programme were similar to results in the current survey; macroinvertebrate communities at five of the six sites were significantly impaired (Band B – poorer in biodiversity than reference condition and species expected), while one site was in reference condition (Band A – similar in biodiversity to reference condition and species expected). The condition of macroinvertebrate communities at all sites had declined since the baseline survey in autumn 2001, when all sites were in reference condition.

Table 5.1 New South Wales AUSRIVAS model results for macroinvertebrate communities in edge habitat.

Model Output	Upstream Sites		Sites Within the extent of the proposed West Borehole Seam workings		Downstream Sites			
	4 [a]	5	6	8	1 [b]	2	3	7
Observed/ Expected	NA	–	0.89	–	NA	–	0.78	0.77
Band	NA	–	A	–	NA	–	B	B
Condition	NA	–	reference	–	NA	–	significantly impaired	significantly impaired

– not surveyed

NA data not available

[a] site was outside the experience of the model due to its high elevation

[b] data from this site were not included as the AUSRIVAS model was designed for streams and rivers and does not apply to wetlands

[c] impairment (degradation) of either water quality or habitat quality or both

Macrocrustaceans

Macrocrustaceans were caught at four of the five sites (sites 1, 3, 6 and 7) surveyed (Appendix D). Three species of macrocrustaceans were caught:

- freshwater prawn (family Atyidae)
- orange-fingered crayfish (*Cherax depressus),* and
- common yabby (*Cherax destructor*).

Freshwater prawns dominated the catch of macrocrustaceans at two of the sites, with 41 individuals caught at site 6 and 86 individuals caught at site 1, while only one to two individuals of the orange-fingered crayfish and common yabby were caught per site (Appendix D). Freshwater prawns (family Atyidae), and yabbies (family Parastacidae) were also recorded at sites for the Abel Underground Mine and Donaldson Coal Mine macroinvertebrate sampling programme (frc environmental 2010c; Robyn Tuft & Associates 2011).

The Donaldson Coal Mine macroinvertebrate sampling programme has shown that macroinvertebrate communities are variable between sites and surveys (Robyn Tuft & Associates 2011). However, there was no evidence of an obvious deterioration in water quality at the sites downstream of the mine (Robyn Tuft & Associates 2011). Specific sites were affected by immediate environmental conditions (Robyn Tuft & Associates 2011), which may explain the differences in community composition between sites.

No aquatic macroinvertebrates listed under the EPBC Act or TSC Act were recorded during the survey or in the Abel Underground Mine survey. Based on the survey results and habitat assessments it is considered unlikely that threatened aquatic macroinvertebrate species occur in the study area. As such, no threatened species assessments have been undertaken.

6 Fish Communities

Detailed methods and results are presented in Appendix E.

6.1 Methods

Fish communities were surveyed using a combination of electrofishing (backpack or boat unit) and baited traps at five sites that held water (sites 1, 3, 4, 6 and 7).

Fish communities at each site were assessed for the:

- taxonomic richness (total number of species caught at a site)
- total abundance (total number of individuals caught at a site)
- abundance of exotic species, and
- abundance of species listed under the EPBC Act, TSC Act or FM Act.

Data at sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- results of a previous survey by frc environmental for the nearby Abel Undergound Mine, from 24 to 28 May 2010 (frc environmental 2010b).

6.2 Results

Fish were only caught at site 1 (wetter area downstream of the extent of the proposed West Borehole Seam workings). Three species were caught in the survey, out of 41 freshwater species known in the Hunter-Central Rivers Catchment (Table 6.1):

- eastern gambusia (*Gambusia holbrooki*)
- empire gudgeon (*Hypseleotris compressa*), and
- firetail gudgeon (*Hypseleotris galii*).

Table 6.1 Fish species in the Hunter-Central Rivers Catchment.

Family *Species Name*	**Common Name**	**Current Survey**	**frc environmental 2010** [a]	**NSW Rivers Survey (2006 and 2010)** [b]
Anguillidae				
Anguilla australis	short-fin eel	–	yes	yes
Anguilla reinhardtii	marbled eel	–	yes	yes
Atherinidae				
Atherinosoma microstoma	small-mouthed hardyhead	–	–	yes
Ariidae				
Arius graeffei	lesser salmon catfish	–	–	yes
Clupeidae				
Potamalosa richmondia	freshwater herring	–	–	yes
Cyprinidae				
Carassius auratus	common goldfish [c]	–	–	yes
Cyprinus carpio	common carp [d]	–	–	yes
Eleotridae				
Gobiomorphus australis	striped gudgeon	–	yes	yes
Gobiomorphus coxii	Cox's gudgeon	–	–	yes
Hypseleotris compressa	empire gudgeon	yes	yes	yes
Hypseleotris galii	firetail gudgeon	yes	yes	–
Hypseleotris klunzingeri	western carp gudgeon	–	yes	yes
Philypnodon grandiceps	flathead gudgeon	–	yes	yes
Philypnodon macrostomus	dwarf flathead gudgeon	–	yes	–
Philypnodon sp. 1	gudgeon sp.	–	–	yes
Galaxiidae				
Galaxias brevipinnis	climbing galaxias	–	–	yes
Galaxias maculatus	common jollytail	–	–	yes
Galaxias olidus	mountain galaxias	–	–	yes

Family *Species Name*	**Common Name**	**Current Survey**	**frc environmental 2010** [a]	**NSW Rivers Survey (2006 and 2010)** [b]
Gobiidae				
Redigobius macrostoma	large-mouth goby	–	–	yes
Megalopidae				
Megalops cyprinoids	oxeye herring	–	–	yes
Monodactylidae				
Monodactylus argenteus	diamondfish	–	–	yes
Mugilidae				
Mugil cephalus	flathead mullet	–	–	yes
Myxus petardi	freshwater mullet	–	–	yes
Percichthyidae				
Macquaria ambigua	golden perch	–	–	yes
Macquaria novemaculeata	Australian bass	–	–	yes
Plotosidae				
Tandanus tandanus	freshwater catfish	–	–	yes
Poecilidae				
Gambusia holbrooki	eastern gambusia [d]	yes	yes	yes
Pseudomugilidae				
Pseudomugil signifer	Pacific blue eye	–	–	yes
Retropinnidae				
Retropinna semoni	Australian smelt	–	–	yes
Salmonidae				
Oncorhynchus mykiss	rainbow trout [c]	–	–	yes
Salmo trutta	brown trout [c]	–	–	yes
Salvelinus fontinalis	brook char [c]	–	–	yes
Scatophagidae				
Scatophagus argus	spotted scat	–	–	yes
Selenotoca multifasciata	banded scat	–	–	yes

Family *Species Name*	Common Name	Current Survey	frc environmental 2010 [a]	NSW Rivers Survey (2006 and 2010) [b]
Scorpaenidae				
Notesthes robusta	bullrout	–	–	yes
Serranidae				
Epinephelus daemelii	black cod	–	–	yes
Epinephelus coioides	estuary cod	–	–	yes
Terapontidae				
Bidyanus bidyanus	silver perch	–	–	yes
Leiopotherapon unicolor	spangled perch	–	–	yes
Terapon jarbua	crescent perch	–	–	yes
Tetrarogidae				
Notesthes robusta	bullrout	–	–	yes

– not caught
[a] frc environmental (2010b)
[b] DPI (2006); Howell & Creese (2010)
[c] exotic non-indigenous species
[d] exotic non-indigenous species, declared noxious under the NSW *Fisheries Regulation 2008*

The most abundant species caught was the eastern gambusia (*Gambusia holbrooki*) with a total of 105 individuals. Eastern gambusia is declared as noxious under the FM Act, and is considered a pest by the DPI (Fishing and Aquaculture).

In the Abel Underground Mine survey, eight native and one exotic fish species (eastern gambusia [*Gambusia holbrooki*]) was caught (frc environmental 2010b). Species richness ranged from one to six species per site and abundance was dominated by eastern gambusia, which comprised 75% of the individuals caught.

No fish listed under the EPBC Act or TSC Act were recorded during the survey or in the Abel Underground Mine survey. Based on the survey results and habitat assessments it is considered unlikely that threatened fish species occur in the study area. As such, no threatened species assessments have been undertaken.

7 Description of Proposed Development

This section describes the aspects of the Project that have the potential to impact on aquatic ecology.

7.1 General Description

Donaldson Coal is proposing an extension of underground mining operations at the Tasman Underground Mine for an additional operational life of 15 years. The main activities associated with the development of the Project would include:

- continued underground mining of the Fassifern Seam using a combination of total and partial pillar extraction methods within Mining Lease 1555
- underground mining of the West Borehole Seam using a combination of total and partial pillar extraction methods
- production of run-of-mine (ROM) coal up to 1.5 million tonnes per annum
- development of a new pit top facility, associated ROM coal handling infrastructure and intersection with George Booth Drive
- development of ventilation surface infrastructure
- continued transport of Fassifern Seam ROM coal from the existing Tasman Underground Mine pit top to the Bloomfield Coal Handling and Preparation Plant (CHPP) via truck on public and private roads to approximately 2015 (inclusive)
- transport of West Borehole Seam ROM coal from the new pit top to the Bloomfield CHPP via truck on public and private roads
- progressive development of sumps, pumps, pipelines, water storages and other water management equipment and structures
- ongoing exploration activities
- ongoing surface monitoring, rehabilitation and remediation of subsidence effects, and
- other associated infrastructure, plant, equipment and activities.

Further detail on the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement.

Construction and mining activities have the potential to impact on aquatic ecology, through activities including:

- the operation and maintenance of vehicles and equipment
- vegetation clearing and earthworks
- management of water resources
- changes to flow regimes, and
- underground mining.

7.2 Operation and Maintenance of Vehicles and Equipment

Fuel Spills

Various vehicles and equipment would be used in the construction and operation phases of the Project. Vehicles and plant would be diesel operated and may use substances such as hydraulic fluid and lubricating fluids, each of which poses a potential threat to aquatic ecology, if spilt.

Vehicle maintenance facilities, including fuel storage facilities, would be located within the proposed pit top.

Litter and Waste

Litter and waste are likely to be associated with vehicle maintenance and mining operations.

7.3 Vegetation Clearing and Earthworks

Vegetation clearing and earthworks would be required in association with the Project, including 11 ha for the:

- establishment of the new Project pit top, and
- construction of a new ventilation shaft and associated access road.

Additional minor clearing would also be required for monitoring, exploration, remediation and associated access.

7.4 Management of Water Resources

The current water management system at the existing Tasman Underground Mine comprises:

- separation of undisturbed area runoff from disturbed area runoff
- collection and re-use of surface runoff from disturbed area
- capture of groundwater inflows and re-used as process water or injected into abandoned working within the West Borehole Seam, and
- delivery of make-up water from the Bloomfield Colliery and / or Donaldson Open Cut Mine (Donaldson Coal 2011).

During the continued operation of the existing pit top as part of the Project, the water management system at the existing pit top would continue as per the existing and approved water management system described above. There would be no interaction between the proposed water management system for the new pit top area and the water management system at the existing pit top area.

The water management system at the new pit top would be based on the water management system at the existing pit top (as described above). Runoff from rainfall at the new pit top area would either be:

- directed off-site (untreated) for runoff from undisturbed areas;
- directed off-site via sediment traps/bio-retention systems for runoff from areas where handling of coal and/or hydrocarbons does not occur (e.g. administration office area); or
- directed to an on-site surface runoff storage dam (Figure 2-9) via sediment traps and/or sumps for runoff from areas where the handling of coal and/or hydrocarbons would occur.

The Project has been designed to avoid the release of mine water from the pit top. Limited quantities of stormwater runoff (e.g. from the administration and car park areas) would drain from the pit top area. Where this water comes from areas where it has the potential to contain sediment or traces of oils or grease, this water would be captured and stored in sediment dams to reduce sediment loads. Oil and grease separators would be installed where required to avoid downstream water quality effects. Water would only be released subject to compliance with relevant Environment Protection Licences to the satisfaction of the NSW Environment Protection Agency (Evans & Peck 2012).

Regular monitoring of water quality upstream and downstream of the pit top would be undertaken throughout the life of the Project (Evans & Peck 2012).

7.5 Changes to Flow Regimes

Mine subsidence can potentially results in localised impacts to stream baseflow through subsidence impacts (Ditton Geotechnical Services 2012). However as described by RPS Aquaterra (2012), due to the implementation of the Subsidence Control Zones, the Project would not result in any more than negligible impacts to stream baseflow.

7.6 Underground Mining

Underground mining of the Fassifern and West Borehole Seams would take place using total and partial pillar extraction methods. There is the potential for subsidence associated with these methods to result in impacts to watercourses, as mine subsidence can potentially result in localised increases in levels of ponding, flooding or scouring in locations where subsidence induced tilts are greater than the natural stream gradients (Ditton Geotechnical Services 2012). However, due to the implementation of the Subsidence Control Zones, no more than negligible changes to stream flow regimes are expected within third order streams or within first or second order streams associated with groundwater dependant ecosystems, steep slopes or cliff lines (Ditton Geotechnical Services 2012). In the limited reaches of first and second order streams outside these areas, the predicted tilts are considered small when compared to the existing natural grades and are unlikely to results in any significant increases in ponding, flooding or scouring.

Mine subsidence has the potential to increase erosion (particularly in steep areas), resulting in increased sediment loads within streams (Ditton Geotechnical Services 2012). Based on the implementation of the Subsidence Control Zones (particularly those relating to steep slopes, cliff lines, third order streams and first and second order streams in areas with less than 80 m depth of cover) the predicted change in stream sediment loads due to increased erosion is expected to be negligible when compared to background levels and erosion processes (Ditton Geotechnical Services 2012; Evans & Peck 2012).

7.7 Performance Measures

Specific performance measures are proposed for subsidence surface constraints as outlined in Table 7.1.

Table 7.1 Proposed Subsidence Surface Constraints and Performance Measures.

Surface Feature	Performance Measure
Cliff Lines	Minor impact resulting in negligible environmental consequence.
Steep Slopes	Minor impact resulting in negligible environmental consequence.
Third Order Streams[1] or above	Negligible environmental consequences (that is, negligible diversion of flows and negligible change in the natural drainage behaviour of pools). Negligible connective cracking to underground workings.
First and Second Order[1] Steams	Not more than minor environmental consequences. Negligible connective cracking to underground workings.
Groundwater Dependent Ecosystems (Warm Temperate Rainforest and Alluvial Tall Moist Forest), and Hunter Lowlands Redgum Forest on Third Order Streams[1]	Negligible environmental consequence.

[1] In accordance with the Strahler stream order system

Note: Cliff Lines - a continuous rock face with minimum height of 10 m and minimum slope of 2 to1

Steep Slopes - an area of land having gradient between 1 in 3 and 2 in 1

Minor - Relatively small in quantity, size and degree given the relative context

Negligible -Small and unimportant

8 Potential Impacts

8.1 Operation and Maintenance of Vehicles and Other Equipment

Fuel Spills

Fuel and oil required for the operation of vehicles and construction and mining machinery presents a risk to water quality and aquatic ecology, if spills enter watercourses (via either surface or ground water). Both diesel and petrol are toxic to aquatic flora and fauna, at relatively low concentrations.

Spilt diesel and petrol are both likely to form a layer on the surface of the water. The volatility of both diesel and petrol contributes to substantial evaporative loss, while neither product is likely to form water-in-oil emulsions due to their low viscosity. Lubricating oils, of the kind used in diesel engines and gearing, are of a relatively similar density to diesel oils. As such, lubricants would be expected to behave in a similar way to diesel oil, and form a surface layer. Lubricants are much less volatile and would not evaporate as rapidly. Once incorporated into the sediment, the degradation of oil is significantly slowed, and hydrocarbons may persist in sediment for some time (Boehm et al. 1987 and Struck et al. 1993, both cited in Nicodem et al. 1997).

Where the recommended mitigation measures are adopted (Section 9.1), the risk to aquatic ecosystems from a fuel spill, within the maintenance workshop and fuel and oil storage facilities, is likely to be very low, due to the high level of control demanded by Australian Standard (AS) 1940-2004: *The storage and handling of flammable and combustible liquids*.

Spilt fuel is most likely to enter the creeks via an accidental spill on the roads near creek crossings; or when there are construction activities next to waterways. A significant fuel spill (tens or hundreds of litres) to a watercourse is likely to have a locally significant impact on both flora and fauna. The length of the stream impacted would depend on the quantity of fuel spilt and the volume of water in the creeks.

Implementation of best practice fuel management will effectively address this risk (Section 9.1). Additionally, the risk to aquatic flora and fauna in the Project area, and downstream waters, is reduced as the creeks are dry or are isolated pools for much of the year. Therefore, many spills could be effectively cleaned up before they can disperse downstream.

Litter and Waste

Litter and waste associated with vehicle maintenance and mining operations has the potential to entangle fauna, and contribute to the degradation of water and sediment quality. Where appropriate controls are in place, such as a waste management system, the risk to aquatic ecology from litter and spilt waste from the Project area is likely to be very low.

8.2 Vegetation Clearing and Earthworks

Following vegetation clearing and earthworks, there is a potential for soil erosion and sedimentation during rainfall. This could lead to impacts on aquatic ecology (i.e. increased turbidity and nutrients) in these waterways, as well as alteration of aquatic habitats.

Increased Turbidity

Vegetation clearing and / or earthworks have the potential to increase sediment runoff to creeks, resulting in increased turbidity. Increased turbidity may negatively impact fish and macroinvertebrates, as highly turbid water reduces respiratory and feeding efficiency (Karr & Schlosser 1978, cited in Russell & Hales 1993). Increased turbidity may also adversely affect submerged macrophytes, as light penetration (required for photosynthesis) is reduced. Reduced light penetration can also lead to a reduction in temperature throughout the water column (DNR 1998).

Turbidity in the Project area is variable, and ranges from low at some sites to high at others (Section 3.2). Based on the published tolerances of the caught species, most of the faunal communities of the survey area are capable of living in turbid waters. There were no species of submerged macrophyte recorded in the Project area; though several species were found in a wetter area downstream of the Project area. Given these background conditions, small increases in turbidity would be unlikely to have a significant impact on aquatic ecology; however significant increases in turbidity could adversely impact the health, feeding and breeding ecology of some species of both macroinvertebrates and fishes, and macrophyte growth downstream of the Project area.

Input of Nutrients or Other Contaminants

Aquatic biota could also be impacted by nutrients, or other contaminants, washed into waterways with the sediment. Nutrient inputs can lead to algal or macrophyte blooms. During the day, as the algae photosynthesises, these blooms can produce high levels of dissolved oxygen. However, at night, there is a net consumption of oxygen as the algae continue to respire. This can cause dissolved oxygen to be reduced to very low levels during the night and early morning, and this is harmful to fish and biota.

Input of nutrients or other contaminants into the waterways would impact on aquatic flora and fauna. Where the spill is a one-off occurrence, communities may be impacted but would be expected to recover over time. Communities would be likely to fully recover by the next wet season. Chronic inputs of nutrients or contaminants to the waterways would be expected to have longer-term impacts on floral and faunal communities.

Decreased Habitat for Aquatic Fauna

Vegetation clearing and earthworks near and within the waterways of the Project area may decrease the amount of habitat for aquatic fauna. Aquatic fauna use a variety of in-stream and off-stream structures for habitat including large and small woody debris, bed and banks, detritus, tree roots, boulders, undercut banks, and in-stream, overhanging and trailing bank vegetation, which were all found in the survey area.

In-stream habitat is an important habitat component and territory marker for many fish and macroinvertebrates. Many species live on or around in-stream habitat as it provides shelter from temperature, current and predators; contributes organic matter to the system; and is important for successful reproduction. Australian fish species typically spawn either on in-stream vegetation or on hard surfaces like cobbles, boulders, and woody debris.

The deposition of fine sediment can decrease the roughness of in-stream bed and decrease habitat diversity, and may result in existing pools being filled in. Within the minor (first order) tributaries throughout the Project area, this would be unlikely to have a significant impact, as these streams would only carry stormwater flows and they do not generally hold water. However, in larger watercourses (second order and higher) such as the lower reaches of Surveyors Creek, sediment deposition would lead to a decrease in habitat diversity and a reduction in the number of pools available as refuge habitat in the dry season.

A decrease in available habitat for aquatic fauna could lead to a decline in the abundance and diversity of both macroinvertebrate and fish communities in the creeks; and potentially lead to a decline in dependant predators (e.g. birds, reptiles and small mammals).

8.3 Management of Water Resources

Mine-affected ('dirty') water will not be released from the pit top to the natural environment. Stormwater will be treated in sediment dams and by oil and grease separators where required, prior to release to the natural environment. Where all releases are in accordance with the relevant Environmental Protection Licences (as is planned), no significant impacts to aquatic ecology in the receiving environment are expected.

8.4 Changes to Flow Regimes

Changes to the flood regime, and the timing and magnitude of flows in watercourses, have the potential to impact on aquatic ecology.

There will be a very minor reduction in flows due to the retention of approximately 12 megalitres per year of dirty water from the pit top. This will be partially off-set by release of treated stormwater runoff from the sealed carpark (approximately 8 megalitres per year). This change in flow is not expected to result in a significant impact to aquatic ecology.

Changes to flow may also occur as secondary impacts of subsidence, due to cracking or changes in the location and nature of pools (ponding). Surface cracking has the potential to re-route surface flows during heavy rain. In studies conducted by Umwelt (Australia) Pty Limited (2010) of the West Wallsend Colliery, surface flow change was not expected to result in a loss of water from the creek; instead water was expected to resurface further downstream. For the Tasman Extension Project, the implementation of Subsidence Control Zones means that it is unlikely or very unlikely that surface cracks will form and affect flows (Ditton Geotechnical Services 2012; Evans and Peck 2012).

A change in the location and nature of pools would result in changes to the levels of seepage and evaporation. However, changes in bed slope as a result of subsidence are unlikely to have any significant impact in reducing or increasing the volume of the observed pools. Accordingly, the water retained within the pools and the overall water balance of these pools (in terms of seepage and evaporation losses) is not expected to change significantly (Ditton Geotechnical Services 2012; Evans and Peck 2012). Changes in bedslope are also unlikely to result in significant increases in flow velocity in the streams, with the greatest increase in velocity expected to occur in a 150 m section of a first order tributary of Surveyors Creek (stream S2E), where velocities may increase by 30% (Evans and Peck 2012). This stream was in moderate ecological condition but did not support fish during the aquatic ecological survey, and this is not expected to have a significant negative impact on the stream of the aquatic ecology of the study area. This tributary will be monitored and revised estimates of subsidence will be done as the Project progresses (Evans and Peck 2012).

Levels of flooding, ponding and scouring are not expected in major streams (third order) and important minor (first and second order) streams such as those associated with groundwater dependent ecosystems, steep slopes or cliff lines. There may be some impacts to other minor streams, however as these streams have limited aquatic ecological values due to their ephemeral nature, and because the impacts to ponding, flooding and scouring are not expected to be significant compared with the natural scenario, no significant impacts to aquatic ecology are expected.

Changes in stream baseflows can also occur due to changes in groundwater levels as a result of underground mining. Based on assessments completed by RPS Aquaterra (2012), Ditton Geotechnical Services (2012) and Evans and Peck (2012), the Tasman Extension Project will result in minor losses to baseflow in the creeks. However these losses are considered to be negligible in the context of the existing stream flow, and as such no impacts to aquatic ecology are predicted due to a change in baseflow conditions.

8.5 Creek Crossings

Construction of Creek Crossings

Construction of new, permanent and temporary crossings may disturb sediment, leading to increases in localised turbidity and sediment deposition. When construction is carried out during the dry season, these impacts will be minimal or absent, although a highly localised loss of macrophytes and riparian vegetation may be expected within the construction footprint. The impacts of disturbance to habitat will be highly localised and are considered acceptable in both a local and regional context. However, after the installation of crossings, the newly formed bed and banks may continually erode following heavy rainfall. This may result in an increase in channel width and a loss in channel definition, which could in turn lead to a decrease in downstream flow.

When construction of creek crossings is carried out in the wet season, there will be an impact to fish passage, and potentially also to water quality. If the waterway holds water, isolation of the work area may leave fish stranded. These fish will perish unless they are relocated.

Obstruction of Fish Passage

Stream crossings can create waterway barriers that prevent or impede movements of aquatic fauna (e.g. fish). Many of the fish native to ephemeral and intermittent systems in Australia migrate up- and downstream and between different habitats at particular stages of their lifecycle. Poorly-designed crossings have the potential to impact on fish movement within the Project area.

8.6 Underground Mining

Underground mining has the potential to impact on groundwater resources and surface streams due to subsidence. The two most common forms of surface expression of subsidence from pillar extraction methods are sink-hole collapse and a saucer-shaped depression following pillar failure (Blodgett & Kuipers 2002).

Subsidence Effects on Surface Streams

Direct impacts of conventional subsidence on watercourses can include (Department of Planning 2008):

- loss of flow from the creeks
- loss of riparian zone and groundwater dependent vegetation and habitat in the affected streams
- increased minewater make, which may be polluted, that needs to be disposed
- increases in ponded areas
- change in stream erosion and sedimentation zones
- reduced surface water quality
- impacts on local flooding regime
- loss of water resources for downstream habitats
- lowering of stream embankments

- change in stream gradient
- tilting of the bed so that flow is biased to one side of the watercourse, and
- cracking of the watercourse bed.

These impacts can have a number of consequences, including acceleration of erosion, localised effects on water quality, and/or persistence of low flows.

Gippel (2012) has identified the following potential geomorphic impacts to the streams of the Project area:

- cliff fall in upper headwaters
- knickpoint migration upstream of areas of subsided stream bed, particularly in areas immediately downstream of existing knickpoints, and
- cracking of bedrock sections of stream beds.

Gippel (2012) also notes that mobile sand-bed sections will probably be resilient through rapid infilling of subsided areas. There are also few pools within the proposed mining area; the most important pools are downstream of the area likely to be affected by subsidence, and therefore at low risk. There were no fish recorded at sites within the Project area and the small wetter area downstream of the extent of the proposed West Borehole Seam workings had a depauperate fish community dominated by an exotic species. Reversal of flow direction is unlikely due to the sufficiently high gradient of the streams.

As such, it is considered that subsidence is unlikely to impact on key aquatic habitats in the study area, and locally-significant impacts to aquatic flora and fauna as a result of subsidence are not expected.

Subsidence Effects on Groundwater

Subsidence-related impacts may affect groundwater resources, causing potential reduction in baseflow contributions to local watercourses. However negligible changes in stream baseflow are predicted, and as such no impacts to aquatic ecology related to changes in baseflow are predicted as discussed in Section 8.4.

9 Measures to Avoid, Minimise and Mitigate Impacts

9.1 Operation and Maintenance of Vehicles and Equipment

Fuel Spills

Risks associated with the spillage of fuels and other contaminants can be substantially reduced, if not eliminated, where:

- vehicle maintenance areas, portable refuelling stations and storage of fuels, oils and batteries is undertaken within bunded areas, designed and constructed in accordance with AS1940-2004 – *The storage and handling of flammable and combustible liquids*
- all spills of contaminants over 10 litres are reported to the Mine's Environmental Officer (or delegated person), and
- appropriate spill containment kits are available and used for the cleanup of spills in the field. Equipment that is susceptible to spills and / or leaks should have a spill kit within 5 m of the equipment at all times. The kits should contain equipment for clean-up of both spill on land or in dry creek beds, and spills to water (e.g. floating booms).

9.2 Vegetation Clearing and Earthworks

The risk of sediment-laden runoff to nearby waterways will be reduced where:

- an erosion and sediment control management plan is developed and implemented
- sediment dams are constructed before vegetation clearing and earthworks
- vegetation clearing and earthworks are done in stages over the life of the mine, and
- timing of clearing and earthworks, for the construction of creek crossings, is in the dry periods, if possible.

During and after construction, water quality and ecosystem health of nearby waterways may be protected by:

- erosion control (e.g. jute matting, rock mulching, or similar), placed in ditches and drainage lines running from all cleared areas, especially on slopes and levee banks

- contour banks, ditches or similar formed across cleared slopes to direct runoff towards surrounding vegetation and away from creeks
- sediment dams and levee banks, constructed during each stage of construction, to protect natural waterways from sediment-laden runoff
- monitoring water quality of creeks downstream of clearing/exposed soil in accordance with the Environmental Protection Licence, and
- rehabilitation of the landscape, focusing on the:
  - salvaging clumps of native grass, shrubs and trees before clearing
  - using native vegetation of local provenance for replanting where possible, and
  - replanting along the margins of creeks, after the construction of the creek crossings. The width of the replanted riparian vegetation should be equal or greater than the width of existing riparian vegetation at the crossing. Planted trees in the riparian zone should provide canopy cover and have root systems that can stabilise the banks and the disturbed area.

9.3 Management of Water Resources

The proposed management of surface water resources, as described by Evans and Peck (2012), is considered to be suitable for protecting the aquatic ecology values of the receiving environment.

9.4 Changes to Flow Regimes

The proposed implementation of Subsidence Control Zones to limit impacts to flow in third order streams and important minor (first and second order) streams will minimise impacts to aquatic ecology as a result of altered baseflow and increases in flooding.

9.5 Creek Crossings and Obstruction of Fish Passage

It is not envisaged that the Project would require the construction of any new creek crossings. If any unforseen creek crossings are required during the mine life (e.g. for exploration or monitoring access) they would be designed and constructed in accordance with the DPI's report *Reducing the impact of road crossing on aquatic habitat in coastal waterways – Hunter-Central Rivers, NSW* (DPI 2006).

The Surface Water Assessment (Appendix C of the EIS) (Evans and Peck, 2012) recommends that Donaldson Coal undertake flow monitoring within the Project area. Should any permanent gauging structures be installed, they should be designed in so that they do not impede fish passage.

9.6 Underground Mining

Subsidence Effects on Surface Waters

Best practice assessment and engineering practices should be employed to minimise the likelihood and effects of subsidence due to underground mining. Any subsidence movements affecting watercourses should be addressed by reviewing the overall drainage pattern in the area (DERM 1995). Suggested mitigation measures include regularly reviewing changes to drainage pathways and undertaking targeted channel earth works if necessary to re-establish surface flows (Evans and Peck 2012).

It is considered that implementation of the Subsidence Control Zones, as described in detail in Ditton Geotechnical Services (2012), to limit impacts to ponding, flooding and scouring in major streams and important minor streams will address this and minimise impacts to ponding, flooding and scouring in surface waters. The predicted impacts to stream sediment loads as a result of increased erosion are expected to be negligible when compared to background levels, and as such the Project is unlikely to result in an increase in impediments to fish passage (see Section 9.5).

Subsidence Effects on Groundwater

The implementation of the Subsidence Control Zones is likely to minimise impacts to baseflows and aquatic ecology.

9.7 Monitoring Requirements

The ongoing monitoring of aquatic ecosystems would:

- monitor the impacts of the Project (including any subsidence and water releases) on downstream waterways

- advise the continual improvement of the Donaldson Coal Environmental Management Plan, and
- trigger the requirement for remedial action, should an impact be detected.

It is envisaged that a detailed monitoring programme would be designed and implemented prior to construction. The monitoring programme design would incorporate the following:

- selection of suitable monitoring sites, including:
  - sites on major and minor streams
  - sites in and outside of the Subsidence Control Zones, and
  - sites downstream of the mine, including sites downstream of stormwater release points
- monitoring at an appropriate frequency to determine seasonal impacts, and
- monitoring of biological indicators such as macroinvertebrates and fish.

Following implementation of the above recommendations it is expected that the Project is very unlikely to have any real or significant impact on aquatic ecology.

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Appendix A Survey Design

Contents

Tables

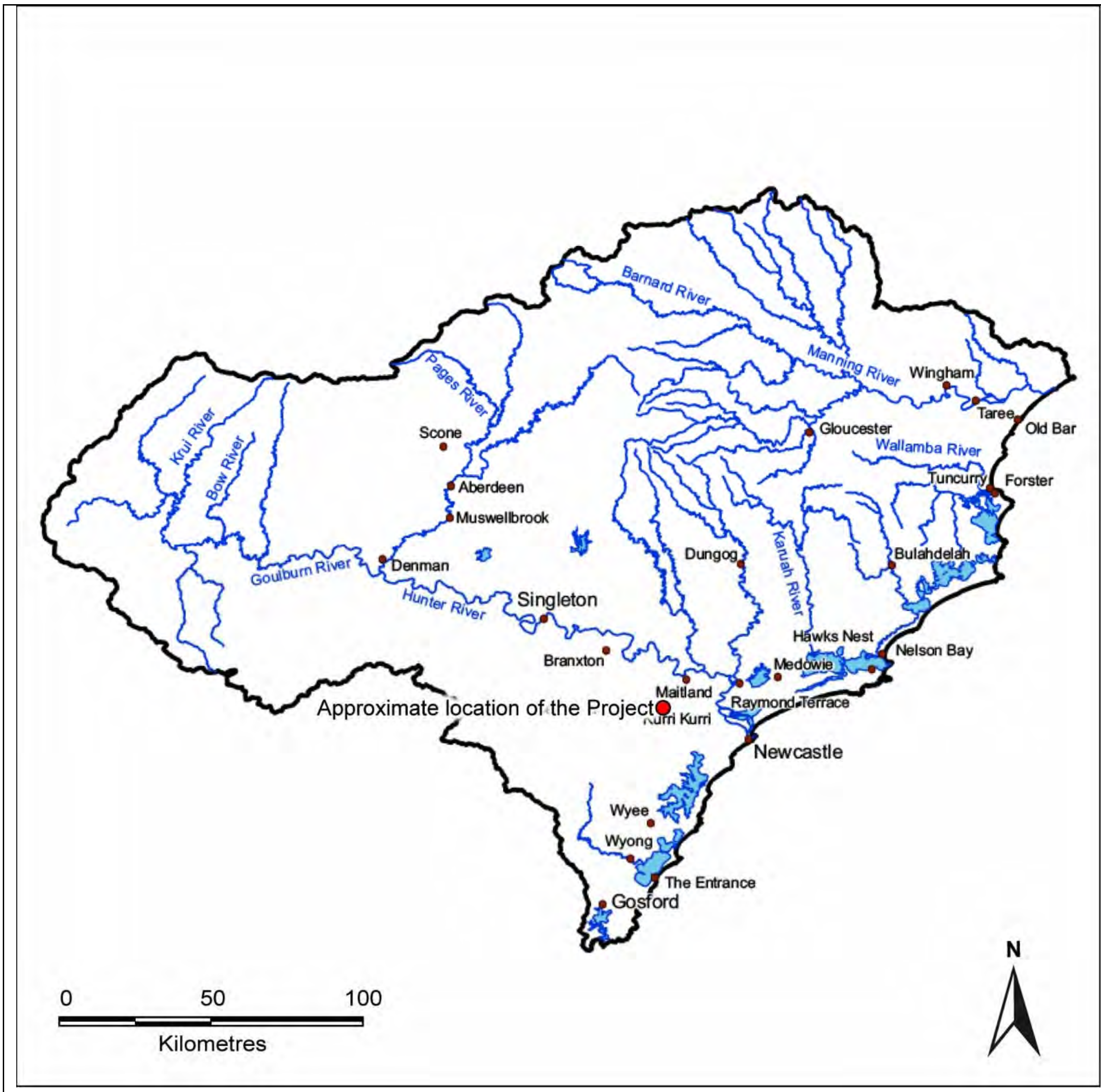
Figures

1 Description of Survey Area

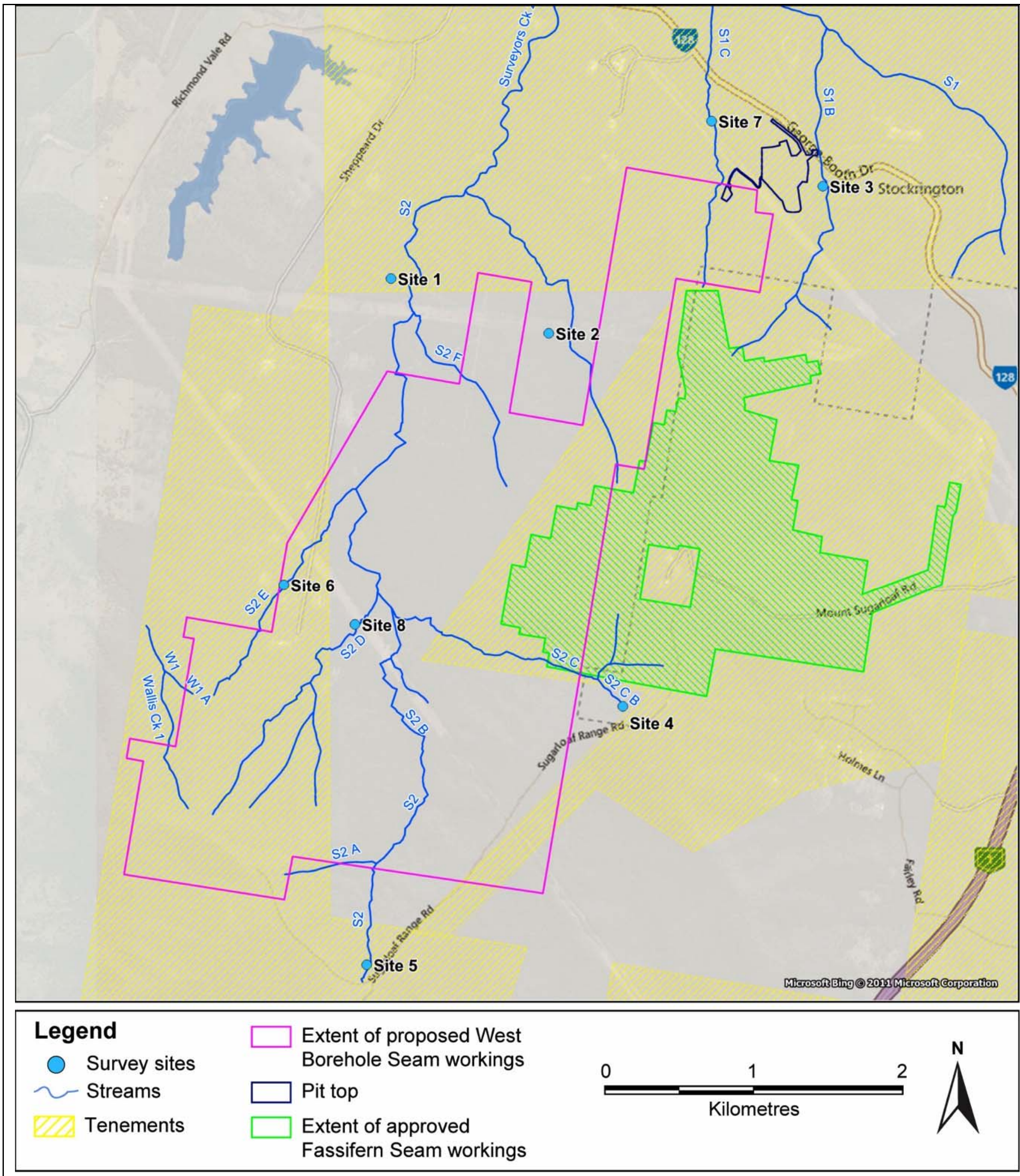
The Tasman Underground Mine is an underground coal mine located approximately 20 kilometres (km) west of Newcastle and approximately 8 km south-east of Kurri Kurri, on the central coast of New South Wales (NSW) (Figure 1.1). The Tasman Underground Mine is located in the Hunter River Catchment, which covers approximately 22,000 square kilometres. The Tasman Extension Project (the Project) area is situated in the Sugarloaf State Conservation Area and Heaton State Forest in the Congewai Range, at an elevation of 40 to 370 metres (m) Australian Height Datum. The terrain is characterised by several natural drainage gullies.

The majority of the Project area is within the ephemeral headwaters of the Surveyors and Wallis Creek catchments. Surveyors Creek flows into Wallis Creek to the north of the survey area, which then flows approximately 20 km to the confluence with the Hunter River at Maitland. The Hunter River flows east to the sea and empties into Stockton Bight at Newcastle.

The survey area for the aquatic ecology assessment included tributaries within the Project area (the approximate extent of the proposed West Borehole Seam workings), and immediately upstream and downstream of the Project area (Figure 1.2).



frc environmental AQUATIC ECOLOGISTS deep thinking.science.	110409		Tasman Aquatic Ecology
	Figure 1.1 Approximate location of the Project in the Hunter River Catchment.		
	Source: NSW Department of Environment, Climate Change and Water (2010)	GDA94	September 2011



frc environmental AQUATIC ECOLOGISTS deep thinking. science.	110409	Tasman Aquatic Ecology
	Figure 1.2 Sites surveyed.	
	GDA94	March 2012

2 Survey Design

2.1 Survey Timing

Aquatic habitat condition (including physical water quality), aquatic flora, aquatic macroinvertebrates and fish (including targeted surveys for listed threatened species and ecological communities) were surveyed from 9 to 11 June 2011 (Table 2.1).

There was significant rainfall in the survey area in the weeks before the survey, and light showers on 11 June 2011. Otherwise, the weather was fine to overcast throughout the survey.

2.2 Site Details

Surveys were undertaken at eight sites, on the tributaries within the survey area (Figure 1.2 and Table 2.1):

- sites 4 and 5 (upstream of the extent of the proposed West Borehole Seam workings)
- sites 6 and 8 (within the extent of the proposed West Borehole Seam workings), and
- sites 1, 2, 3 and 7 (downstream of the extent of the proposed West Borehole Seam workings).

Sites upstream of the extent of the proposed West Borehole Seam workings (upstream of potential influences from the Project) were chosen to represent the range of aquatic habitats in the area, and to match the sites within and downstream of the extent of the proposed West Borehole Seam workings, including:

- waterbody type (e.g. natural channel and dams)
- stream order
- environmental conditions (e.g. erosion, vegetation and available habitat), and
- other sources of disturbance (e.g. cattle, exotic species and creek/road crossings).

Results at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to background data, which were defined as the range of data at comparative (upstream of the extent of the proposed West Borehole Seam workings) sites in the survey, and those recorded in other studies in the region (where available). These studies included a previous survey by frc environmental for the nearby Abel Underground Mine (frc environmental 2010a, 2010b, 2010c), and surveys undertaken for the Donaldson Coal Mine Macroinvertebrate Sampling Program (Robyn Tuft & Associates 2011). The locations of survey sites for these studies are shown in Figure 2.1.

Table 2.1 GPS location, date and type of survey at each site (WGS 84, decimal degrees).

Site	Location (Stream Name) [a]	Latitude	Longitude	Survey			
				Aquatic Habitat	Aquatic Flora	Aquatic Macro-invertebrates	Fish
Sites Upstream of the extent of the proposed West Borehole Seam workings							
4	first order tributary of Surveyors Creek 2 (S2CB)	-32.8989	151.5354	2011-06-10	2011-06-10	2011-06-10	2011-06-10
5	first order tributary of Surveyors Creek 2 (S2)	-32.9144	151.5174	2011-06-10	2011-06-10	–	–
Sites Within the extent of the proposed West Borehole Seam workings							
6	first order tributary of Surveyors Creek 2 (S2E)	-32.8922	151.5107	2011-06-09	2011-06-09	2011-06-09	2011-06-09
8	second order tributary of Surveyors Creek 2 (S2D)	-32.8942	151.5164	2011-06-09	2011-06-09	–	–
Sites Downstream of the extent of the proposed West Borehole Seam workings							
1	off-stream wet area approximately 0.2 km west of third order tributary of Surveyors Creek 2 (S2)	-32.8727	151.5194	2011-06-09	2011-06-09	2011-06-09	2011-06-11
2	first order stream approximately 0.2 km west of first order stream of Surveyors Creek (S2G)	-32.8765	151.5303	2011-06-09	2011-06-09	–	–
3	second order tributary of Surveyors Creek 1 (SB1)	-32.8673	151.5504	2011-06-09	2011-06-09	2011-06-09	2011-06-11
7	first order tributary of Surveyors Creek 1 (S1C)	-32.8634	151.5421	2011-06-09	2011-06-09	2011-06-11	2011-06-11

– not surveyed

[a] stream names (in brackets) assigned according to the convention of Gippel (2012).

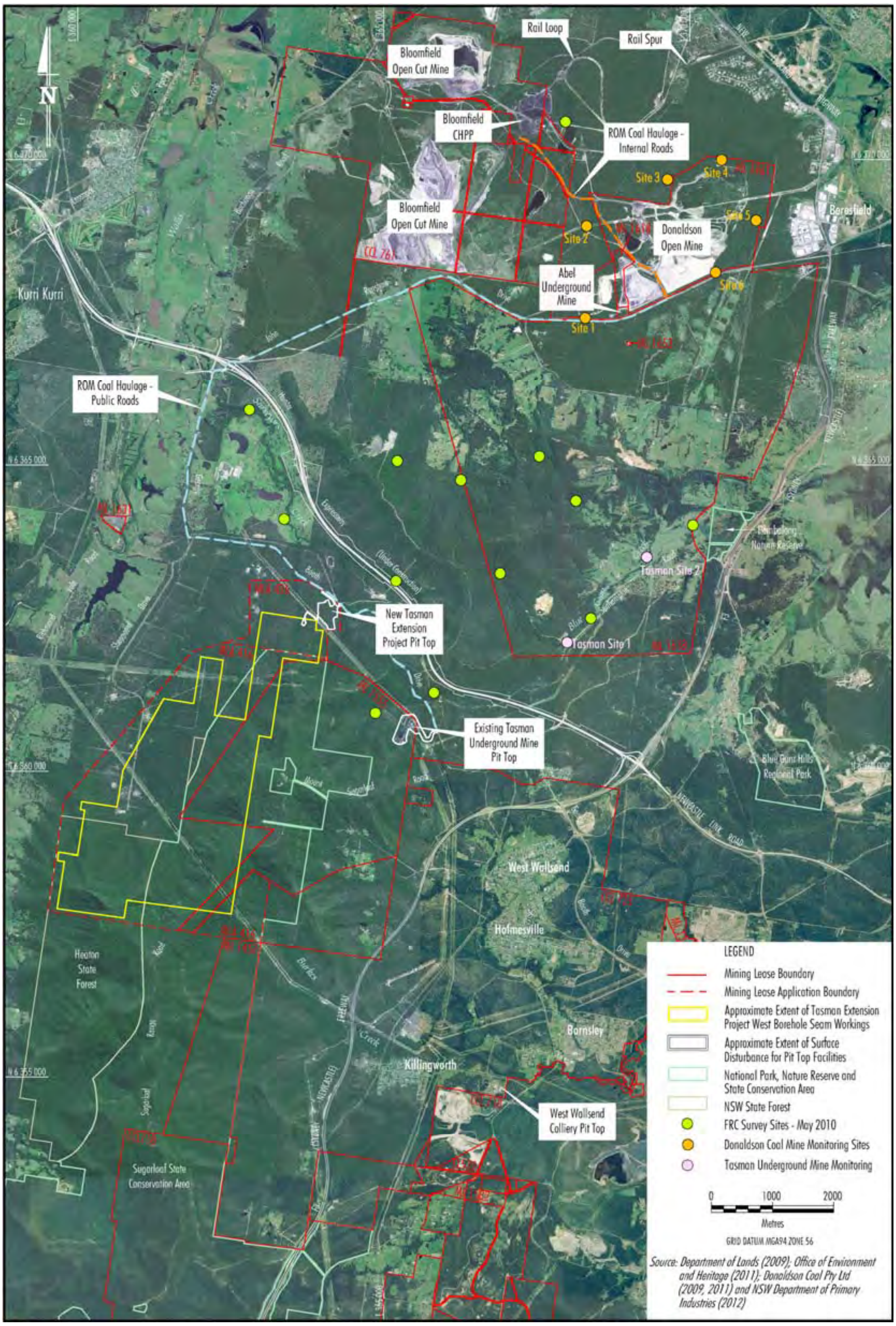


Figure 2.1 Sites for Abel Underground Mine survey by frc environmental and the Donaldson Coal Mine monitoring sites.

A brief description of the surveys at each site is presented in Table 2.2.

Table 2.2 Description of each survey site.

Reach	Description	Photograph
Sites Upstream of the extent of the proposed West Borehole Seam workings		
Site 4 first order tributary of Surveyors Creek 2 (S2CB)	Site comprised a steep un-defined channel with a shallow, isolated pool. Both the left and right banks were steep and moderately high (0.5 to 3.5 m) with high stability. The riparian zone was 20 m wide on each bank and dominated by grass, shrubs, ferns and Eucalypt trees. In-stream habitat included woody debris, detritus, boulder, undercut banks and vegetation. In-stream substrate was dominated by bedrock and sand, with some boulder, silt/clay, pebbles and gravel. Overall disturbance was very low. This site was approximately 170 m downstream of Sugarloaf Range Road.	 View upstream at site 4
Site 5 first order tributary of Surveyors Creek 2 (S2)	Site comprised a relatively steep, well-defined channel with several shallow (0.1 m), isolated pools. Both the left and right banks were steep and relatively low (0.5 to 2.5 m high) with low to moderate stability. The riparian zone was 10 m wide on each bank and dominated by grass, shrubs and Eucalypt trees. In-stream habitat was dominated by woody debris and boulders, with some cobbles, undercut banks, vegetation and detritus. In-stream substrate was dominated by bedrock, with some sand, gravel and pebble. Overall disturbance was very low.	 View upstream at site 5
Sites Within the extent of the proposed West Borehole Seam workings		
Site 6 first order tributary of Surveyors Creek 2 (S2E)	Site comprised a shallow (0.5 m), isolated pool in a well-defined narrow channel. Both the left and right banks were low (0.5 to 2 m high) with moderate stability. The riparian zone was 5 to 10 m wide on each bank and dominated by grass, shrubs, Eucalypt and Melaleuca trees. In-stream habitat was dominated by woody debris and detritus, with some vegetation, cobble and man-made structures. In-stream substrate was dominated by silt/clay, with some sand and bedrock. Overall disturbance was low.	 View upstream at site 6

Reach	Description	Photograph
Site 8 second order tributary of Surveyors Creek 2 (S2D)	Site comprised a narrow, meandering channel that was dry at the time of survey. Both the left and right banks were low (0.3 to 2.5 m high) with low to moderate stability. The riparian zone was 5 to 10 m wide on each bank and dominated by grass, shrubs, Eucalypt and Melaleuca trees. Lantana was also present on the right bank. In-stream habitat was dominated by small woody debris and detritus, together with vegetation. In-stream substrate was dominated by sand with small amounts of silt/clay and gravel. Overall disturbance was low.	 View downstream at site 8
Sites Downstream of the extent of the proposed West Borehole Seam workings		
Site 1 wet area approximately 0.2 km west of third order tributary of Surveyors Creek 2 (S2)	Site comprised an unconfined, relatively deep (1.2 m) area. Both banks were sloping and low (0.3 m high), with moderate to high stability. The riparian zone was 20 to 30 m wide on both banks and was dominated by grass, shrubs and Melaleuca trees. In-stream habitat included woody debris, vegetation and detritus, with some undercut banks and deep pools. In-stream substrate was dominated by sand and silt/ clay. Overall disturbance was low, although vegetation had been cleared upstream of the site for access to a power transmission line. Area appears to likely retain water most of the time, with the possible exception of following extended dry periods.	 View upstream at site 1
Site 2 first order stream approximately 0.2 km west of first order stream of Surveyors Creek (S2G)	Site comprised a straight gently sloping channel that was dry at the time of the survey. This site likely held water after prolonged heavy rainfall. Both banks were low (0 to 2 m high) with high stability. The riparian zone was 10 m wide on each bank and dominated by grass, shrubs, Eucalypt and Melaleuca trees. In-stream habitat included extensive woody debris, vegetation and detritus. In-stream substrate was dominated by sand and silt/clay. Disturbance was low, although vegetation had been cleared downstream of the site for access to a power transmission line.	 View upstream at site 2

Reach	Description	Photograph
Site 3 second order tributary of Surveyors Creek 1 (SB1)	Site comprised a chain of narrow and relatively shallow (0.6 m) isolated pools in an irregular channel. Both the left and right banks were vertical and low (0 to 1 m high) with low to moderate stability. The riparian zone was >30 m wide on each bank and dominated by grass, shrubs and Eucalypt and Melaleuca trees. In-stream habitat included woody debris, detritus, undercut banks and detritus. There was also some overhanging and trailing bank vegetation and deep pools. In-stream substrate was dominated by sand with some silt/clay. Overall disturbance was low. George Booth Drive was approximately 100 m downstream of the site.	 View upstream at site 3
Site 7 first order tributary of Surveyors Creek 1 (S1C)	Site comprised a narrow channel with a chain of several small, relatively deep (1 m) pools. Both the left and right banks were low (0.3 to 1 m high) and vertical, with moderate to high stability. The riparian zone was 20 to 30 m wide on each bank and dominated by grass, shrubs and Eucalypt and Melaleuca trees. In-stream habitat was dominated by woody debris, undercut banks and detritus, together with vegetation. In-stream substrate was dominated by silt/clay, with some sand and gravel. Overall disturbance was low, although vegetation had been cleared approximately 40 m upstream of the site for access to a power transmission line.	 View downstream at site 7

3 References

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Appendix B Habitat for Aquatic Fauna

Contents

Tables

Figures

1 Methods

1.1 Aquatic Habitat of the Survey Area

The aquatic habitat of the survey area was assessed at nine sites in a survey from 9 to 11 June 2011.

Details of the sites surveyed are presented in Appendix A.

Habitat Assessment

Based on the Australian River Assessment System (AUSRIVAS) protocol described in the *Australia-Wide Assessment of River Health: New South Wales AUSRIVAS Sampling and Processing Manual* (Turak & Waddell 2002), the in-stream habitat condition at each site was assessed based on the following parameters:

- riparian vegetation and adjacent land use
- bank stability
- substrate composition (silt/clay, sand, pebble, cobble and boulder)
- channel diversity
- in-stream habitat (in-stream vegetation and substrate characteristics), and
- water quality.

Habitat Bioassessment Scores

To enable a comparison of habitat quality between sites using an index of habitat condition, habitat bioassessment score datasheets in the Australia-Wide Assessment of River Health: Queensland Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual (Queensland Department of Natural Resources and Mines 2001) were used to numerically score nine criteria, which were then allocated to one of four categories (excellent, good, moderate and poor). The sum of the numerical rating from each category produced an overall habitat assessment score (Table 1.1):

- Excellent: >110.
- Good: 75 to 110.
- Moderate: 39 to 74.
- Poor: 38.

Table 1.1 Habitat bioassessment scores used to derive overall condition categories.

Habitat Category	Category Score Range			
	Excellent	**Good**	**Moderate**	**Poor**
Bottom substrate/available cover	16–20	11–15	6–10	0–5
Embeddedness	16–20	11–15	6–10	0–5
Velocity/depth category	16–20	11–15	6–10	0–5
Channel alteration	12–15	8–11	4–7	0–3
Bottom scouring & deposition	12–15	8–11	4–7	0–3
Pool/riffle, run/bend ratio	12–15	8–11	4–7	0–3
Bank stability	9–10	6–8	3–5	0–2
Bank vegetative stability	9–10	6–8	3–5	0–2
Streamside cover	9–10	6–8	3–5	0–2
Total (Habitat Bioassessment Score for the Site)	**111–135**	**75–110**	**39–74**	**0–38**

Water Quality

Physical water quality measurements were sampled *in situ* at each site to aid in the interpretation of biological data. A Hydrolab Quanta multi-parameter water quality probe was used to measure:

- water temperature
- pH
- electrical conductivity, and
- dissolved oxygen.

A Hach 2100Q turbidity meter was used to measure turbidity. Alkalinity was determined by collecting water samples from each site that were analysed by Advanced Analytical (a National Association of Testing Authorities, Australia-accredited laboratory).

The Hydrolab Quanta water quality meter was calibrated daily for all parameters. The Hach 2100Q turbidity meter was calibrated at the start of the survey.

Endangered Ecological Communities

Wet areas were assessed to determine whether they met the criteria of an endangered ecological community (EEC) under the New South Wales (NSW) *Threatened Species Conservation Act 1995* (TSC Act).

Data Analysis

Water quality data at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from the comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- NSW Water Quality Objectives (WQO) (NSW Department of Environment, Climate Change and Water [DECCW] 2006) for uncontrolled streams and water bodies in the Hunter River Catchment for lowland[1] and upland rivers (sites 4 and 5 are >150 metres [m] in elevation) (Table 1.2).

The Hunter River Catchment WQO include the key water quality indicators and related numerical criteria (default trigger values) described in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment Conservation Council [ANZECC] and Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ] 2000). These guidelines are relevant for assessing and monitoring the health of aquatic ecosystems within the survey area.

[1] DECCW (2006) guidelines define lowland streams as those below 150 m altitude

Table 1.2 Water quality guidelines for water quality parameters measured in freshwater systems in the current survey.

Parameter	Units	Water Quality Guidelines	
		Upland Streams	Lowland Streams
Temperature	°C	–	–
Turbidity	NTU	2–25	6–50
pH	pH units	6.5–8.0	6.5–8.5
Electrical conductivity	µS/cm	30–350	125–2 200
Dissolved oxygen [a]	% saturation	90–110	85–110
Alkalinity	mg $CaCO_3$/L	–	–

Source DECCW (2006)
[a] dissolved oxygen values derived from daytime measurements, and may vary overnight and with depth
– not available
°C = degrees Celsius
NTU = nephelometric turbidity unit
µS/cm = microSiemens per centimetre
% = percent
mg $CaCO_3$/L = milligrams of calcium carbonate per litre

1.2 Aquatic Habitat of the Region

The typical aquatic habitat of the streams and creeks in the lower Hunter River Catchment were described through literature review, to provide a regional context for the condition of the streams within the survey area.

2 Results and Discussions

2.1 Riparian Vegetation and Adjacent Land Use

The riparian zone at all upstream sites was dominated by *Eucalyptus*, *Melaleuca* and *Leptospermum* species. The riparian zone at all sites was generally diverse and included large trees, shrubs and grasses (Figure 2.1). Lantana (*Lantana camera*), which is a weed of national significance (Commonwealth of Australia 2009), was only observed at site 8 (within the extent of the proposed West Borehole Seam workings), and was the dominant vegetation on the right bank at site 8 (Figure 2.2).

At all sites, the land immediately next to the riparian zone was predominantly native vegetation. Some vegetation was cleared:

- at site 6, for a residential property
- upstream of sites 3 and 7, for a transmission line, and
- downstream of sites 2 and 8, for transmission lines (Figure 2.3).

Figure 2.1

Riparian zone at site 4 including trees, shrubs and grasses.

Figure 2.2

Lantana on the right bank at site 8.

Figure 2.3

Vegetation clearing downstream of site 2.

2.2 Bank Stability

Bank stability at most sites was moderate to high. There was little evidence of recent erosion; however, the banks at sites 3 (downstream of the extent of the proposed West Borehole Seam workings) and 8 (within the extent of the proposed West Borehole Seam workings) may potentially be eroded during periods of high flow, due to the steepness and the areas where the banks were undercut (Figure 2.4 and Figure 2.5).

Figure 2.4

Steep and undercut banks at site 3.

Figure 2.5

Steep banks with the potential for erosion at site 8.

2.3 Substrate Composition

Surface sediment was dominated by:

- silt/clay at sites 6 and 7
- silt/clay and sand at sites 1 and 2
- bedrock at sites 4 and 5, and
- sand at sites 8 and 3.

Upstream sites 4 and 5 had the most diverse mixture of surface sediments; and sites 1 and 2 (downstream of the extent of the proposed West Borehole Seam workings) had the lowest (Figure 2.6). Boulders were only present at sites 4 and 5, along with bedrock, which was also present at site 6 (within the extent of the proposed West Borehole Seam workings) (Figure 2.6).

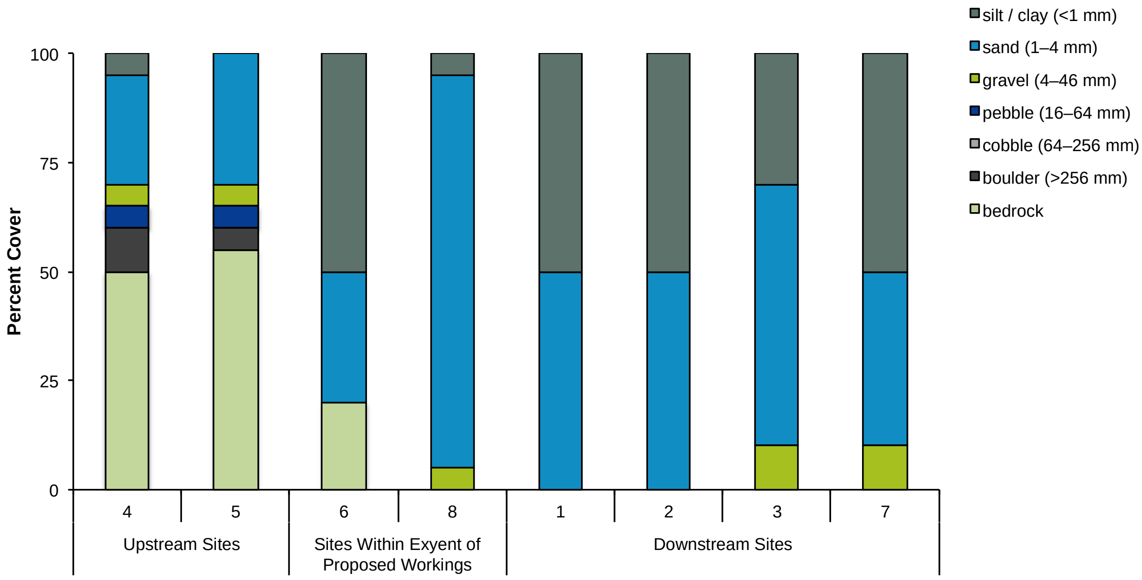


Figure 2.6 Percent cover of substrate types at each site.

2.4 Channel Diversity

Channel diversity was low at all sites and was limited to pool habitat as there was no flow. Upstream sites 4 and 5 have the potential for cascade and riffle habitat during periods of flow. All other sites have the potential for run habitat during periods of flow. There were also deep pools at sites 1, 3, 6 and 7 (Figure 2.7). Bends and changes in water depth are likely to provide some channel diversity during periods of higher flow.

Figure 2.7

Deep pool at site 3.

2.5 In-stream Habitat

In-stream habitat (i.e. structural elements) provides refuge and food for aquatic fauna (e.g. fish, turtles and macrocrustaceans). In-stream habitat was dominated by woody debris and overhanging/trailing bank vegetation (Figure 2.8 and Figure 2.9) and boulders provided additional habitat at sites 4 and 5 (upstream of the extent of the proposed West Borehole Seam workings) (Figure 2.10).

Figure 2.8

Woody debris at site 2.

Figure 2.9

Overhanging and trailing bank vegetation at site 6.

Figure 2.10

Boulders at site 5.

2.6 Water Quality

Water Temperature

There are no Hunter River WQO for water temperature (DECCW 2006). The range in water temperature was 8.3 to 10.4 °C (Figure 2.11).

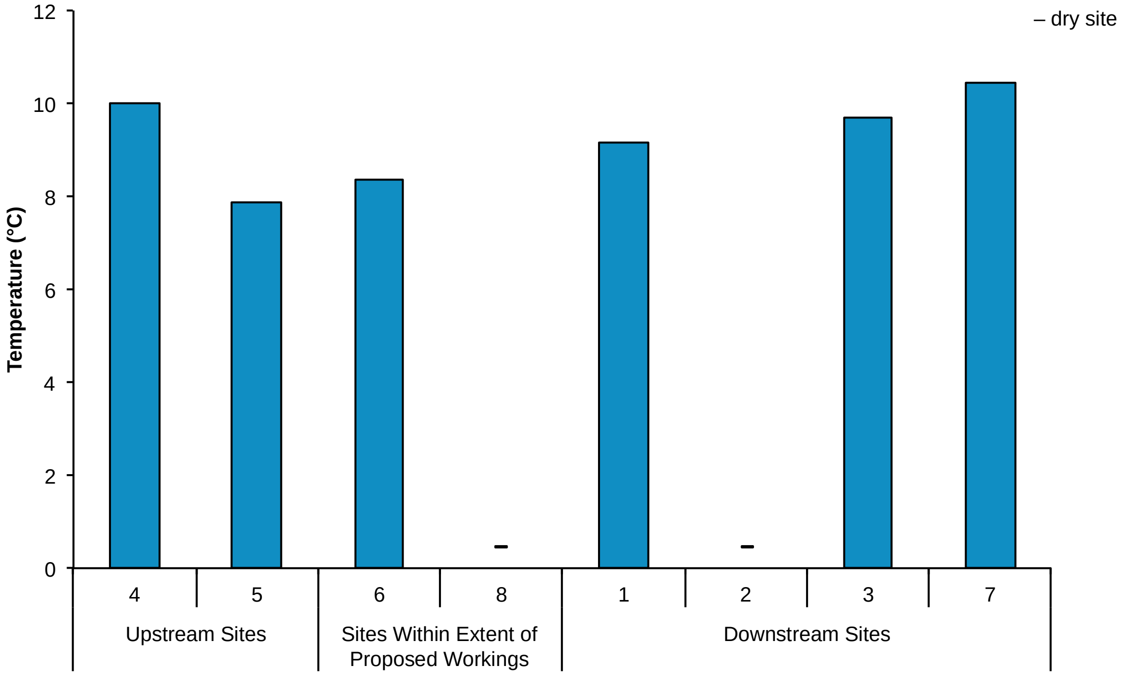


Figure 2.11 Water temperature at each site.

Temperature varied between sites, but the range of water temperatures was similar at sites upstream of, within, and downstream of the extent of the proposed West Borehole Seam workings. Water temperature at any given site was likely to reflect a number of factors including the:

- season
- time of day
- size of the waterbody
- prevailing weather conditions
- flow, and
- riparian cover.

Turbidity

At all lowland sites, turbidity was above the Hunter River Catchment upper WQO trigger value for lowland streams. Turbidity was within the WQO trigger values for upland streams at sites 4 and 5 (upstream of the extent of the proposed West Borehole Seam workings). The range in turbidity was 2.0 to 93.7 NTU (Figure 2.12).

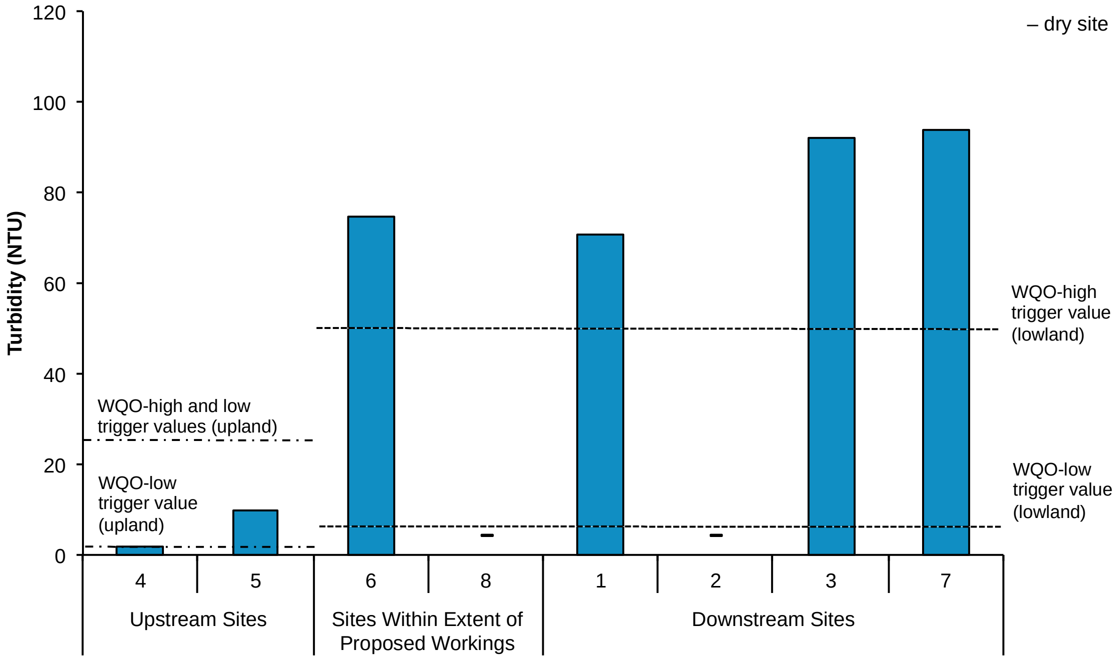


Figure 2.12 Turbidity at each site, and the Hunter River Catchment Water Quality Objective trigger value ranges.

Turbidity varied between sites. The range at sites within and downstream of the extent of the proposed West Borehole Seam workings was above the range at upstream sites. Turbidity is a potential indicator of sedimentation and erosion. It is possible that the high turbidity at site 6 was due to the clearing of vegetation for the residential property; and the high turbidity at sites 1, 3 and 7 was due to the clearing of vegetation for the transmission line (Figure 2.12).

pH

The pH was below the Hunter River Catchment lower WQO trigger value for upland streams at sites 4 and 5 (upstream of the extent of the proposed West Borehole Seam workings) and lowland streams at sites 6 and 7 (within and downstream of the extent of the proposed West Borehole Seam workings, respectively). The pH at sites 1 and 3 (downstream of the extent of the proposed West Borehole Seam workings) was within the WQO trigger values for lowland streams. The range in pH was 5.2 to 7.1 (Figure 2.13).

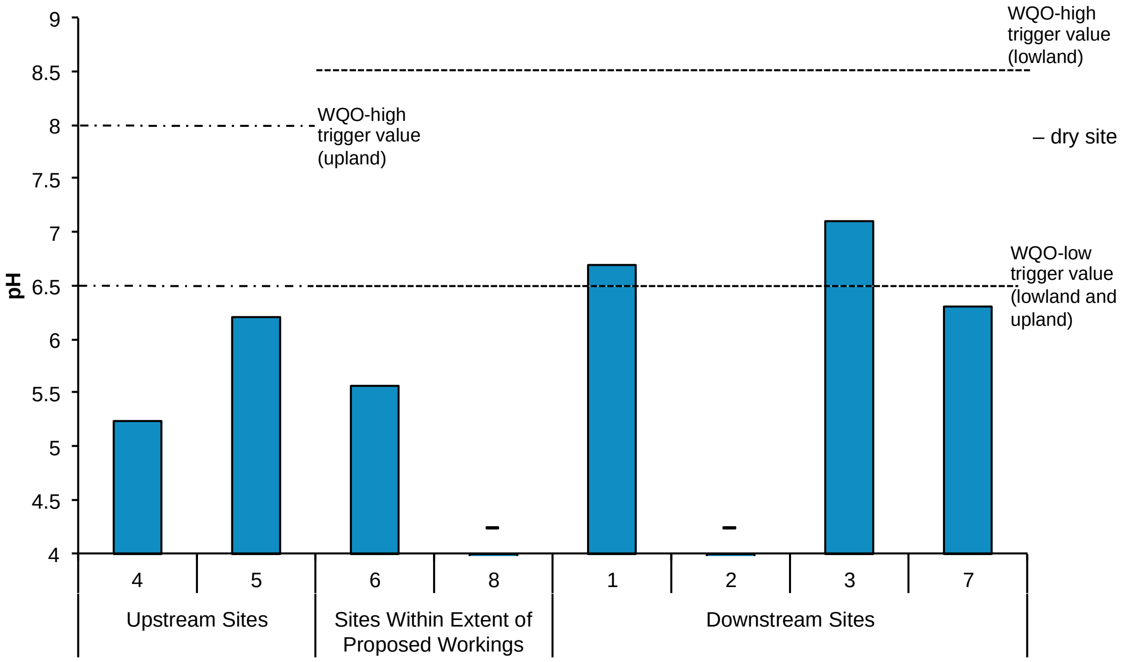


Figure 2.13 The pH at each site, and the Hunter River Catchment Water Quality Objective trigger values.

The pH at sites 6 and 7 (within and downstream of the extent of the proposed West Borehole Seam workings, respectively) was similar to the range at upstream sites. The lower pH at sites 4 and 6 was likely to be related to site-specific geology.

Electrical Conductivity

Electrical conductivity was above the Hunter River Catchment upper WQO trigger value for upland streams at sites 4 and 5 (upstream of the extent of the proposed West Borehole Seam workings). At sites 1 and 3 (downstream of the extent of the proposed West Borehole Seam workings) and site 6 (within the extent of the proposed West Borehole Seam workings), electrical conductivity was above the WQO low trigger values for lowland streams. Electrical conductivity at site 7 was below the lower WQO trigger value for lowland streams (Figure 2.14).

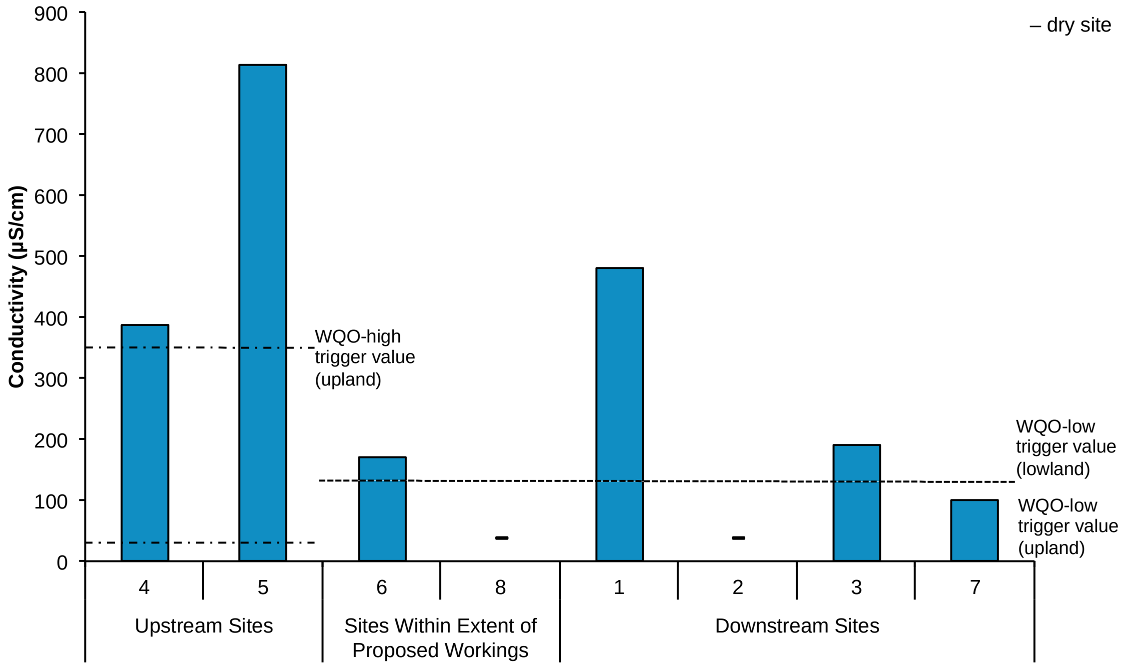


Figure 2.14 Electrical conductivity at each site, and the Hunter River Catchment Water Quality Objective trigger values.

In general, electrical conductivity at sites within and downstream of the extent of the proposed West Borehole Seam workings was below the range at upstream sites (Figure 2.14). Electrical conductivity depends on a number of factors including catchment run-off and local geology.

Dissolved Oxygen

The percent saturation of dissolved oxygen was below the Hunter River Catchment WQO trigger values for lowland and upland streams at all sites. Low dissolved oxygen can be a natural feature of isolated, drying pools in ephemeral systems. The range in dissolved oxygen was 20.6 to 86.3% (Figure 2.15).

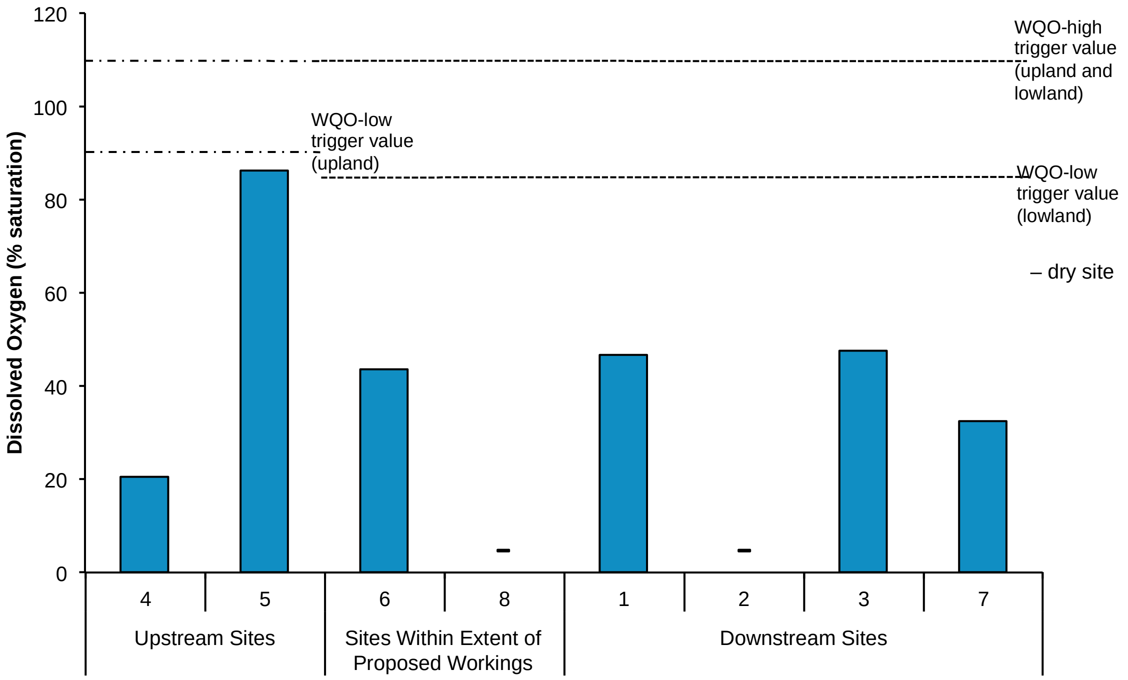


Figure 2.15 Dissolved oxygen at each site, and the Hunter River Catchment Water Quality Objective trigger values.

The differences in dissolved oxygen at each site were likely to reflect the:

- time of day measurements were taken (plants photosynthesise during the day, producing oxygen)
- photosynthetic rates of algae and macrophytes (which are affected by light availability and temperature)
- rate of oxygen uptake by micro-organisms in the waterway associated with decomposing organic matter, and
- amount of surface mixing (caused by wind, water movement and bird activity).

Alkalinity

Alkalinity is the ability of a solution to resist changes in pH. Fluctuations in alkalinity are related to the proportions of surface water and rainfall; alkalinity is inversely related to rainfall.

There are no Hunter River WQO trigger values for alkalinity (DECCW 2006). The range in alkalinity was 8 to 25 mg $CaCO_3$/L (Figure 2.16). Alkalinity varied between sites, and was higher at sites within and downstream of the extent of the proposed West Borehole Seam workings than at upstream sites (Figure 2.16). The lower alkalinity may explain the lower pH at sites 4, 5 and 7.

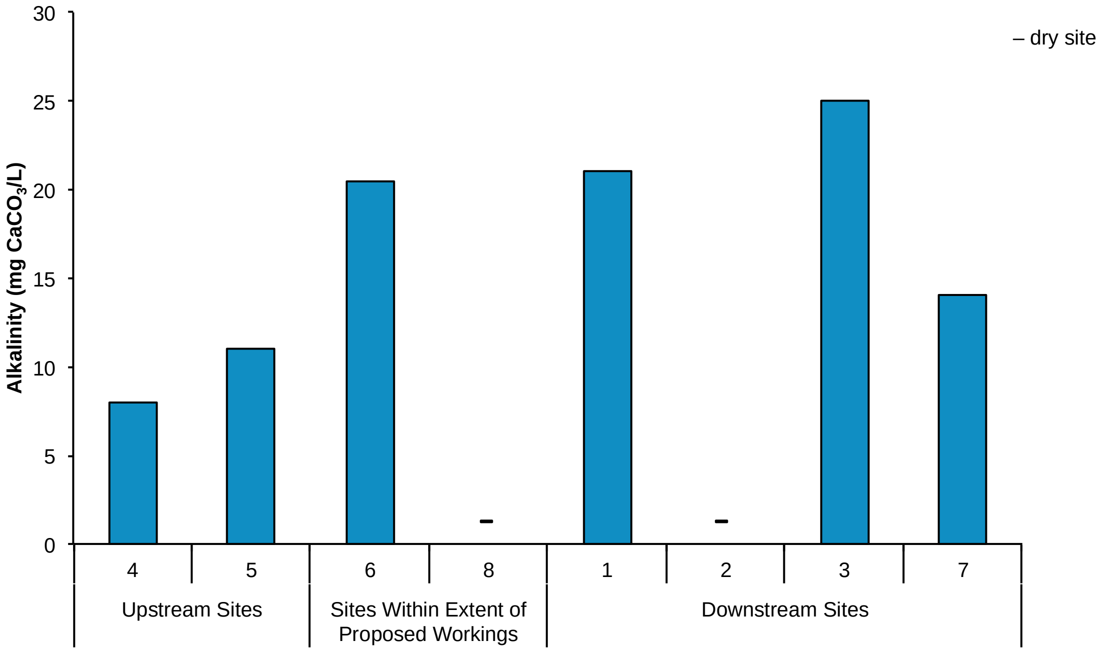


Figure 2.16 Alkalinity at each site.

2.7 Habitat Bioassessment Scores

All sites had either a moderate or good habitat bioassessment score. Generally, sites within and downstream of the extent of the proposed West Borehole Seam workings had similar habitat scores to upstream sites (Figure 2.17). Sites 6 and 8 (within the extent of the proposed West Borehole Seam workings) had lower scores than the sites upstream and downstream of the extent of the proposed West Borehole Seam workings (Figure 2.17).

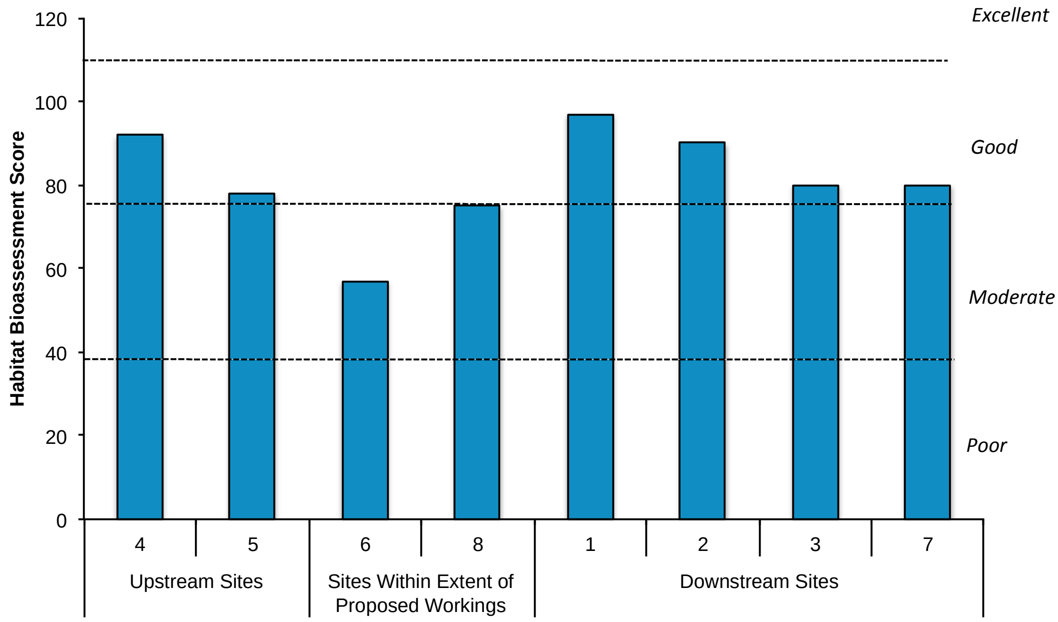


Figure 2.17 Habitat bioassessment scores at each site, and the thresholds for habitats.

The moderate habitat score at site 6 (within the extent of the proposed West Borehole Seam workings) was due to:

- evidence of channel alteration
- bottom scouring and deposition, and
- a lack of stable habitat.

Good habitat scores at the majority of sites was generally due to:

- more diverse habitat (e.g. woody debris and vegetation)
- good riparian vegetation cover, and
- stable banks and channels.

2.8 Endangered Ecological Communities

No aquatic EECs were recorded in the Project area. Site 1 (downstream of the extent of the proposed West Borehole Seam workings) was a wet area with Melaleuca trees present, however it does not meet the criteria of ‘Swamp Sclerophyll Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions’. The following characteristics of site 1, precludes the site from being designated as this EEC:

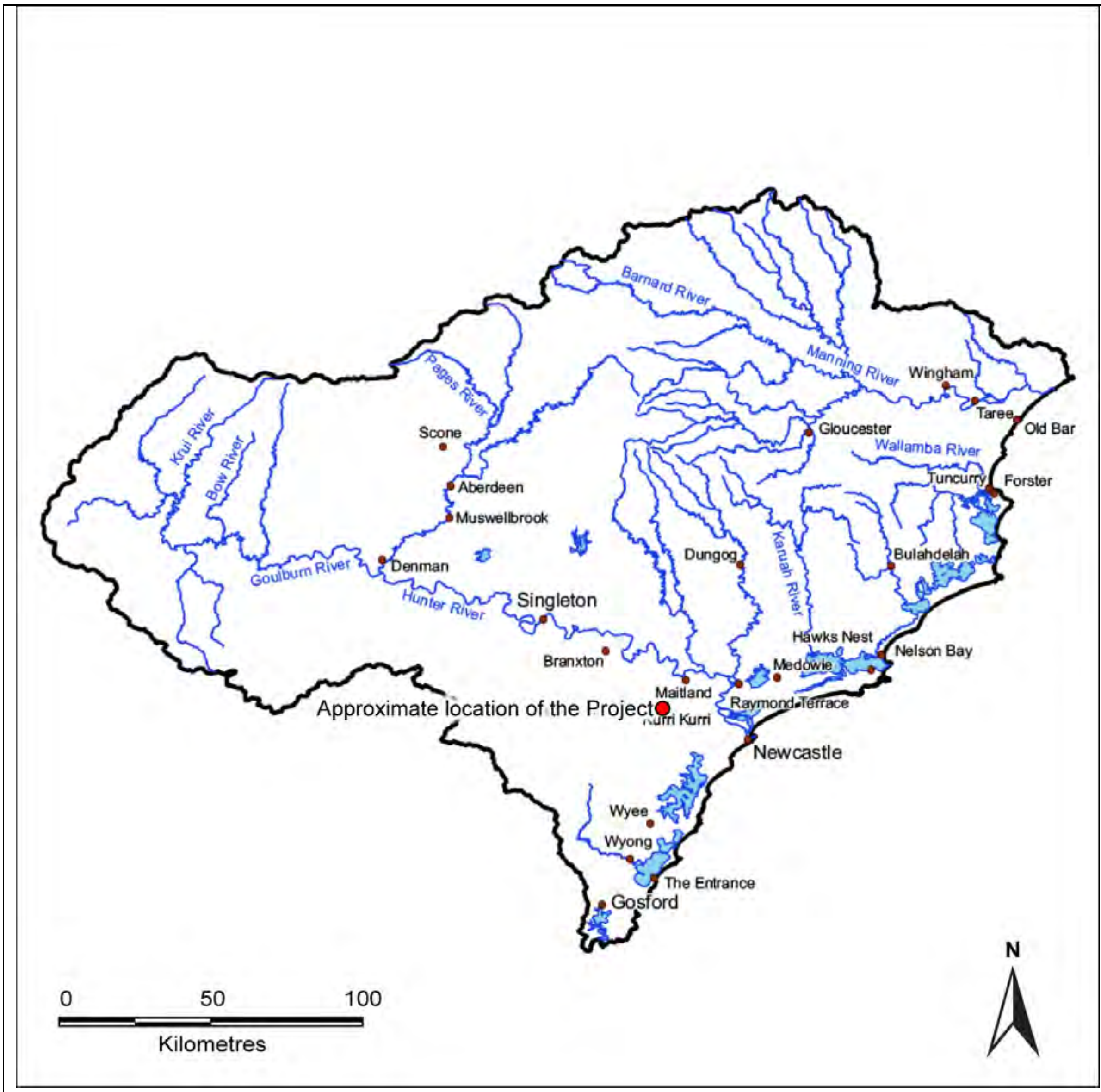
- the elevation was slightly above the range in which Swamp Sclerophyll Forest is expected to occur
- aquatic flora identified at the site were not listed on the characteristic species list for Swamp Sclerophyll Forest (refer to Appendix C) (Office of Environment and Heritage 2011), and
- Hunter Eco (2012a, 2012b) mapped this area as EEC MU17 ‘Lower Hunter Spotted Gum – Ironbark Forest in the Sydney Basin Bioregion EEC’. Potential impacts to the EEC have been considered in the terrestrial ecology assessment and are not discussed further in this report.

3 Regional and Ecological Perspective

The first State of the Catchments assessment was completed for the Hunter-Central Rivers Catchment of NSW in 2010 (DECCW 2010a). The Hunter-Central Rivers Catchment covers 37,000 square kilometres of the east coast of NSW from Taree in the north to Gosford in the south (Figure 3.1). It includes the Hunter River and other major tributaries of the Hunter River Valley: the Goulburn, Paterson, Allyn and Williams rivers.

Hose & Turak (2004) provide further information on the health of the local aquatic habitat. This report provides a regional summary of AUSRIVAS assessments sampled in the Central Coast, Hunter and Lower North Catchments from 1994 to 1999. Site Hunt 590 on Wallis Creek, was near the current survey area.

Additional surveys of the region were conducted by Umwelt (Australia) Pty Limited (2010) for the continued operations of the West Wallsend Colliery at the southern end of the Sugarloaf Range.



frc environmental AQUATIC ECOLOGISTS deep thinking.science.	110409		Tasman Aquatic Ecology
	Figure 3.1 Hunter-Central Rivers Catchment.		
	Source: DECCW (2010a)	GDA94	September 2011

3.1 Riparian Vegetation and Adjacent Land Use

Historically, the riparian vegetation of the Hunter River downstream of the survey area has been heavily degraded. Clearing of vegetation has led to bank erosion and invasion of exotic plant species, including willow trees (Hose & Turak 2004).

The land next to the lower reaches of the Hunter River is predominantly used for agricultural activity. Across the catchment, land-uses include:

- coal mining
- quarrying
- power generation
- heavy industry
- urban development
- tourism and recreation
- forestry
- aquaculture, and
- a wide range of agricultural activities (DECCW 2010a).

Land use associated with the continued underground mining of the West Wallsend Colliery area is predominantly coal mining and residential holdings (Umwelt (Australia) Pty Limited 2010).

3.2 Bank Stability

The main erosion problems in the Hunter River Catchment are:

- floodplain stripping, and
- bank erosion.

Floodplain stripping is the removal of alluvial soil during floods, and is the main riverine degradation problem of areas around the Hunter River (Raine & Gardiner 1995). Bank erosion is a natural process; however it can be accelerated by anthropogenic practices such as the removal of riparian vegetation, or changes in the sediment or hydraulic regime.

Erosion problems in the region near the West Wallsend Colliery result from 4WD tracks and the composition of the soil (e.g. sandy clay within Diega Creek) (Umwelt (Australia) Pty Limited 2010).

3.3 Substrate Composition

There is no information readily available on the substrate composition of aquatic habitats in the Hunter-Central Rivers Catchment.

3.4 Channel Diversity

The Hunter River Catchment contains a variety of channels, with pools and extensive runs, separated by riffles and occasional boulder/gravel bars. In-stream zones may comprise pool-riffle sequences with cascades, runs and glides (Thomson et al. 2004). Creek tributaries of the region are typical of ephemeral systems, with flows only occurring during storms and prolonged rainfall; however, isolated pools can be permanent or semi-permanent (Umwelt (Australia) Pty Limited 2010).

3.5 In-stream Habitat

The de-snagging of in-stream channels and the decline in natural replenishment of in-stream wood have been identified as potential pressures that are impacting the riverine ecosystems within the Hunter-Central Rivers Catchment. There are also reports that the roots of invasive willow trees have altered the in-stream habitat within the Hunter-Central Rivers Catchment (Hose & Turak 2004).

There is no overall rating for riverine ecosystem condition within the Hunter-Central Rivers region (DECCW 2010b). Overall, wetlands in the Hunter-Central Rivers Catchment are in very poor condition (DECCW 2010c).

3.6 Water Quality

The overall rating for water quality in the Hunter-Central Catchment has not been determined (DECCW 2010b); however, the hydrology of the Hunter River has been rated as being in good condition (NSW Government 2009).

Historically, water quality at the Wallis Creek AUSRIVAS site upstream of the survey area has been good, with low turbidity and nutrients, but higher than expected water temperature and conductivity (Hose & Turak 2004).

The West Wallsend Colliery monitors waters upstream and downstream of mine discharge along Burkes Creek for arsenic, chromium, manganese, selenium and zinc. Data collected from 2006 to 2008 indicated that only chromium and zinc were above ANZECC & ARMCANZ (2000) guidelines, but this was not attributed to discharges from the colliery (Umwelt (Australia) Pty Limited 2010).

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Appendix C Aquatic Flora

Contents

Tables

Figures

1 Methods

The aquatic flora of the survey area was assessed at eight sites in a survey from 9 to 11 June 2011.

Details of the sites surveyed are presented in Appendix A.

1.1 Macrophyte Assessment

The macrophyte community at each site was assessed along a 100 metre (m) reach. Plants were identified, and the following recorded:

- taxonomic richness
- mean percent cover (% of substrate [bed/bank] covered by aquatic vegetation)
- total percent cover (% of substrate [bed/bank] covered by each aquatic species)
- growth form of each species (submerged, floating [free-floating or rooted] and emergent) (Table 1.1)
- whether the plant was native or introduced to Australia, and
- whether the plant was listed under state or commonwealth legislation.

Macrophyte data at the sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from the comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- results of a previous survey undertaken by frc environmental for the nearby Abel Underground Mine from 24 to 28 May 2010 (frc environmental 2010).

The locations of sites for the frc environmental survey for the nearby Abel Underground Mine are shown on Figure 2.1 in Appendix A.

Table 1.1 Macrophyte growth forms.

Growth Form	Description
Submerged	• predominantly grow beneath the surface of the water • flowers may project above the water surface • some leaves may float on the water surface
Floating	• can be either free-floating or rooted • free-floating species are usually not attached to the substrate • rooted species are attached to the substrate and normally have at least the mature leaves floating on the water surface
Emergent	• rooted in the substrate • stems, flowers and most of the mature leaves project above the water surface

Source: Sainty & Jacobs 2003.

Total percent cover of each species was assessed visually and the total percent cover of listed species (under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* [EPBC Act] or New South Wales [NSW] *Threatened Species Conservation Act 1995)* [TSC Act] was determined for each site. Macrophyte species were identified in the field, where practical. Representative specimens were collected for identification by the National Herbarium of NSW. Species were identified as native or exotic according to *New South Wales Flora Online* (National Herbarium of New South Wales 2011).

The sampling of macrophytes was conducted under NSW Scientific Licence SL100158 issued to frc environmental.

2 Results and Discussion

2.1 Taxonomic Richness

A total of 23 species of macrophyte were identified within the survey area. The number of macrophytes found within the 100 m reach at each site ranged from three species at sites 2 and 8 (downstream and within the extent of the proposed West Borehole Seam workings) to nine species at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings, respectively). Sites 2 and 8, which had the lowest taxonomic richness, were both dry at the time of survey. Except at site 1, the number of species at sites within and downstream of the extent of the proposed West Borehole Seam workings was lower than the number of species at the upstream sites (Figure 2.1). Taxonomic richness in the current survey was similar to richness at sites in the Abel Underground Mine survey, which ranged from 2 to 11 species at each site (frc environmental 2010).

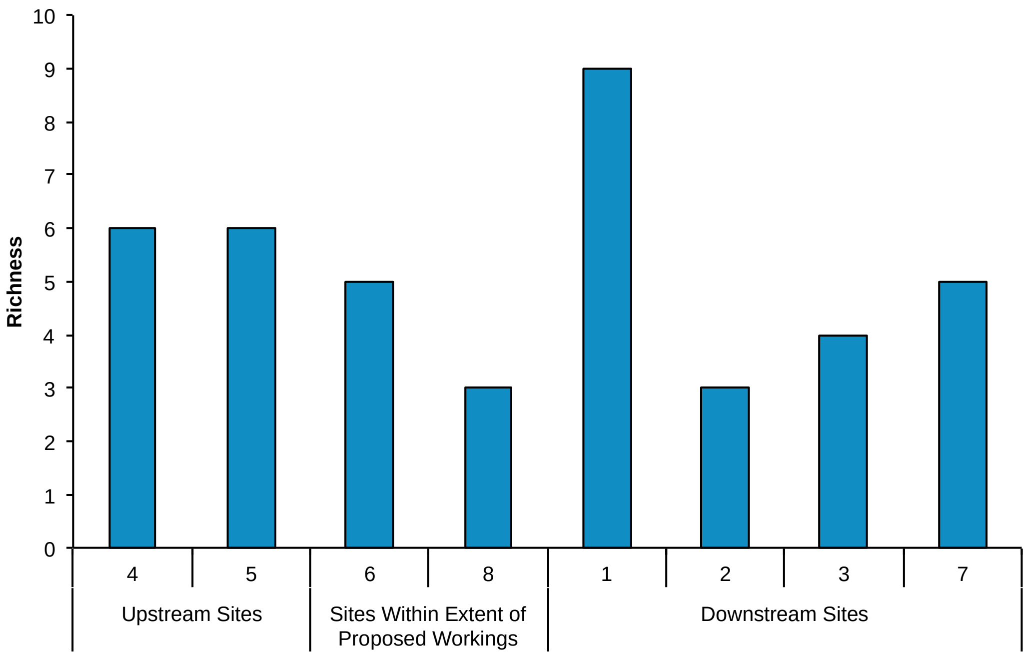

Figure 2.1 Taxonomic richness at each site.

2.2 Percent Cover

The mean percent cover of macrophytes (as a percentage of the total substrate) ranged from 3 to 68% at each site. In general, the macrophyte cover at sites within and downstream of the extent of the proposed West Borehole Seam workings was within or above the range at the upstream sites. Site 8, which was dry at the time of survey, had the lowest percent cover of macrophytes; whereas site 2, which was also dry, had the highest percent cover (Figure 2.2). In general, mean cover of macrophytes in the current survey was slightly lower than the mean cover in the Abel Underground Mine survey, which ranged from 10 to 75% at each site (frc environmental 2010).

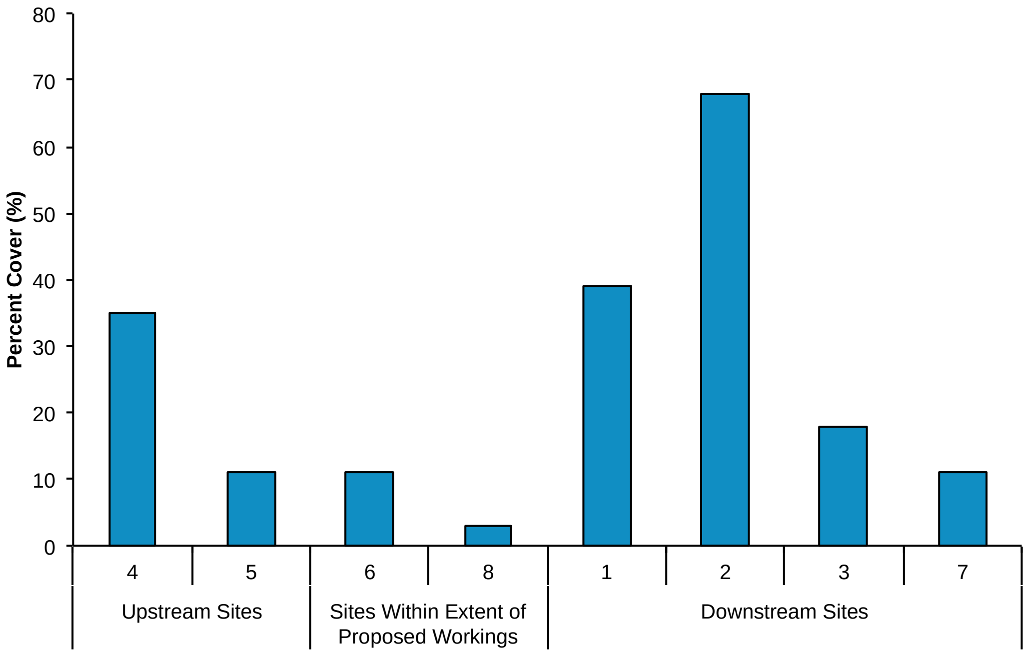

Figure 2.2 Percent cover of macrophytes at each site.

The high macrophyte cover at site 2 (downstream of the extent of the proposed West Borehole Seam workings) was due to a high abundance of perennial black bog weed (*Schoenus melanostachys*). Black bog weed was also common at site 4 (within the extent of the proposed West Borehole Seam workings). High macrophyte cover at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings) was due to a range of species, particularly Chinese water chestnut (*Eleocharis dulcis*) and three submerged macrophytes that were unable to be identified by the National Herbarium of NSW due to a lack of reproductive units (Table 2.1).

Table 2.1 Total percent cover of macrophyte species at each site.

Species Name	Common Name	Growth Form	Upstream Sites		Sites within the extent of the proposed West Borehole Seam workings		Downstream Sites				Total
			4	5	6	8	1	2	3	7	
Baumea juncea	bare twigrush	E	–	–	–	–	–	–	5	–	**5**
Cyperus exaltatus	giant sedge	E	–	–	–	–	1	–	–	–	**1**
Cyperus trinervis	Australian flatsedge	E	–	–	–	1	–	–	–	–	**1**
Eleocharis dulcis	Chinese water chestnut	E	–	–	–	–	10	–	–	–	**10**
Eleocharis sphacelata	giant spike rush	E	–	–	–	–	1	–	2	1	**4**
Entolasia stricta	wiry panic	E	1	1	3	–	–	–	–	–	**5**
Gahnia clarkei	tall saw-sedge	E	–	–	–	–	–	–	–	2	**2**
Gahnia melanocarpa	black fruit saw-sedge	E	–	–	–	1	–	1	–	–	**2**
Imperata cylindrica	blady grass	E	–	–	–	–	–	–	–	2	**2**
Isolepis inundata	swamp club-rush	E	–	1	–	–	1	–	–	–	**2**
Juncus prismatocarpus	branching rush	E	–	–	1	–	–	–	–	–	**1**
Juncus sp. [a]	–	E	–	1	1	–	–	–	–	–	**2**
Juncus usitatus	common rush	E	–	1	–	–	5	–	1	–	**7**
Lepidosperma elatius	tall sword sedge	E	10	–	–	–	–	–	–	–	**10**
Lepidosperma laterale	variable sword sedge	E	2	–	5	–	–	2	–	–	**9**

Species Name	Common Name	Growth Form	Upstream Sites		Sites within the extent of the proposed West Borehole Seam workings		Downstream Sites				Total
			4	5	6	8	1	2	3	7	
Persicaria strigosa	spotted knotweed	E	–	–	–	–	3	–	–	–	**3**
Schoenus melanostachys	black bog-rush	E	15	–	–	–	–	65	–	–	**80**
Poaceae (Family) [a]	true grasses	E	2	5	1	1	–	–	10	5	**24**
Emergent species 1 [a]	–	E	5	2	–	–	–	–	–	–	**7**
Emergent species 2 [a]	–	E	–	–	–	–	–	–	–	1	**1**
Submerged species 1 [a]	–	S	–	–	–	–	15	–	–	–	**15**
Submerged species 2 [a]	–	S	–	–	–	–	2	–	–	–	**2**
Submerged species 3 [a]	–	S	–	–	–	–	1	–	–	–	**1**
Total			**35**	**11**	**11**	**3**	**39**	**68**	**18**	**11**	

E: emergent; S: submerged

[a] unable to be identified by National Herbarium of NSW

A true grass from the family Poaceae (species unknown) was the most common species observed, found at six of the eight sites (Figure 2.3). Other common species, found at three sites, included (Table 2.1):

- giant spike rush (*Eleocharis sphacelata*) (Figure 2.4)
- wiry panic (*Entolasia stricta*) (Figure 2.5), and
- variable sword sedge (*Lepidosperma laterale*) (Figure 2.6).

Figure 2.3

True grass (family Poaceae) at site 8.

Figure 2.4

Giant spike rush (*Eleocharis sphacelata*) at site 1.

Figure 2.5

Wiry panic (*Entolasia stricta*) at site 5.

Figure 2.6

Variable sword sedge (*Lepidosperma laterale*) at site 6.

The following additional macrophyte species were identified in the Abel Underground Mine survey:

- water couch (*Paspalum distichum*)
- common reed (*Phragmites australis*)
- Prince's feather (*Persicaria orientalis*)
- slender knotweed (*Persicaria decipiens*)
- pale knotweed (*Persicaria lapathifolia*)
- streaked arrow-grass (*Triglochin striatum*)
- lesser joyweed (*Alternanthera denticulata*)

- rice sedge (*Cyperus difformis*)
- basket grass (*Lomandra longifolia*)
- swamp lily (*Ottelia ovalifolia*)
- water primrose (*Ludwigia peploides*), and
- duckweed (*Lemna* sp.) (frc environmental 2010).

2.3 Growth Forms

Emergent macrophytes were the most common growth form at both upstream and downstream sites. Submerged macrophytes were at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings) only. There were no species of floating macrophytes. The lack of submerged and floating macrophytes at most sites suggested that water levels fluctuated considerably and / or that the water column was likely to be highly turbid. Submerged macrophytes cannot survive dry periods and high turbidity (high turbidity reduces light in the water column and inhibits photosynthesis); emergent forms are most tolerant of dry conditions.

Emergent growth forms were also the most common growth form in the Abel Underground Mine survey; however, several floating macrophytes were at one site:

- swamp lily (*Ottelia ovalifolia*)
- water primrose (*Ludwigia peploides*), and
- duckweed (*Lemna* sp.) (frc environmental 2010).

2.4 Introduced Species

No introduced species were recorded in the survey.

2.5 Listed Species

No macrophytes, listed under the EPBC Act or TSC Act, were recorded in the current survey or in the Abel Underground Mine survey (frc environmental 2010). Based on samples and photos of the five macrophyte species that were unable to be identified in the current survey, it is considered unlikely that these plants are listed species, based on their morphology.

3 References

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Appendix D Aquatic Macroinvertebrate Communities

Contents

Tables

Figures

1 Methods

Aquatic macroinvertebrate communities were assessed at five of the eight sites in a survey from 9 to 11 June 2011, including the following sites that held water:

- site 4 (upstream of the extent of the proposed West Borehole Seam workings)
- site 6 (within the extent of the proposed West Borehole Seam workings), and
- sites 1, 3 and 7 (downstream of the extent of the proposed West Borehole Seam workings).

Macroinvertebrate surveys were not undertaken at sites 2, 5 and 8 where the water level was too low or the sites were dry.

Details of the sites surveyed are presented in Appendix A.

1.1 Sample Collection

Macroinvertebrate Samples

At each site, one sample from the bed habitat and one sample from the edge habitat were collected, to enable comparison to other Australian River Assessment System (AUSRIVAS) data sets from the local area. This sampling followed the methods in the New South Wales (NSW) AUSRIVAS sampling manual, and was designed to provide a broad description of macroinvertebrate communities, rather than a quantitative assessment (Turak & Waddell 2002). A standard triangular-framed, macroinvertebrate sampling net with 250 micrometre mesh was used to collect the samples. In this method a 10 metre long section of bed or edge habitat was disturbed, and a sample collected by sweeping the net through the disturbed area.

The sampling of macroinvertebrates was conducted under NSW Scientific Licence SL100158 issued to frc environmental.

Macrocrustacean Samples

Macrocrustaceans (e.g. prawns, shrimps and yabbies) were caught during fish surveys, using a combination of electrofishing and bait trapping. Electrofishing was undertaken using a Smith-Root LR-24 backpack electrofisher or a Smith-Root boat 2.5 GPP (generator powered pulsator) electrofishing system. All available habitats were fished at each site. Electrofishing was conducted in accordance with the *Australian Code of Electrofishing Practice 1997*.

Details on fishing methods and survey efforts are presented in Appendix E.

1.2 Sample Processing

All samples were frozen and returned to frc environmental's Brisbane laboratory, where they were sorted, counted and identified to the lowest practical taxonomic level (in most instances family), to comply with AUSRIVAS standards and those described by Chessman (2003).

Dragonfly larvae were examined for the presence of the endangered Adam's emerald dragonfly (*Archaeophya adamsi*).

1.3 Data Analysis

Macroinvertebrate data at sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from comparative sites upstream of the extent of the proposed West Borehole Seam workings)
- results of a previous survey by frc environmental for the nearby Abel Underground Mine, from 24 to 28 May 2010 (frc environmental 2010), and
- results from the Donaldson Coal Mine Macroinvertebrate Sampling Program Operations Survey: Spring 2010 (Robyn Tuft & Associates 2011) (where available), which summarises the results of macroinvertebrate sampling undertaken biannually in autumn and spring from September 2000 to December 2010 at six sites approximately 4 kilometres north of the existing Tasman Underground Mine pit top.

The locations of sites for the frc environmental survey for the nearby Abel Underground Mine, and sites for the Donaldson Coal Mine Macroinvertebrate Sampling Program Operations Survey are shown in Appendix A.

Calculation of Indices

Abundance, taxonomic richness, Plecoptera, Ephemeroptera and Trichoptera (PET) richness and Stream Invertebrate Grade Number-Average Level (SIGNAL) 2 scores were calculated for each sample. These indices were used to indicate the current ecological health of surveyed waterways.

Abundance

Abundance is the total number of macroinvertebrates.

Taxonomic Richness

Taxonomic richness is the number of taxa (in this assessment, families). Taxonomic richness is a basic, unambiguous and effective diversity measure. It is however, affected by arbitrary choice of sample size. Where all samples are of equal size, taxonomic richness is a useful tool when used in conjunction with other indices. Richness does not take into account the relative abundance of each taxon, so rare and common taxa are considered equally.

PET Richness

While some groups of macroinvertebrates are tolerant to pollution and environmental degradation, others are sensitive to these stressors (Chessman 2003). Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies) are referred to as PET taxa, and they are particularly sensitive to disturbance. There are typically more PET families within sites of good habitat and water quality than in degraded sites. PET taxa are often the first to disappear when water quality or environmental degradation occurs (EHMP 2007). The lower the PET score, the greater the inferred degradation.

SIGNAL 2 Scores

SIGNAL 2 scores are also based on the sensitivity of each macroinvertebrate family to pollution or habitat degradation. The SIGNAL system has been under continual development for over 10 years, with the current version known as SIGNAL 2. Each macroinvertebrate family has been assigned a grade number between 1 and 10 based on their sensitivity to various pollutants. A low number means that the macroinvertebrate is tolerant of a range of environmental conditions, including common forms of water pollution (e.g. suspended sediments and nutrient enrichment).

SIGNAL 2 scores are weighted for abundance. The scores take the relative abundance of tolerant or sensitive taxa into account (instead of only the presence/absence of these taxa). The overall SIGNAL 2 score for a site is based on:

- the total of the SIGNAL grade
- multiplied by the weight factor for each taxon, and
- divided by the total of the weight factors for each taxon.

SIGNAL 2 scores are interpreted in conjunction with the number of families found in the sample. This is achieved using a SIGNAL 2/Family bi-plot (Chessman 2003). The plots are divided into quadrants, with each quadrant indicative of particular conditions (Figure 1.1). Interim quadrant boundaries for edge/alcove habitat in Australia (excluding the Murray-Darling Basin and Queensland east of the great Dividing Range) were used in this survey (Chessman 2001).

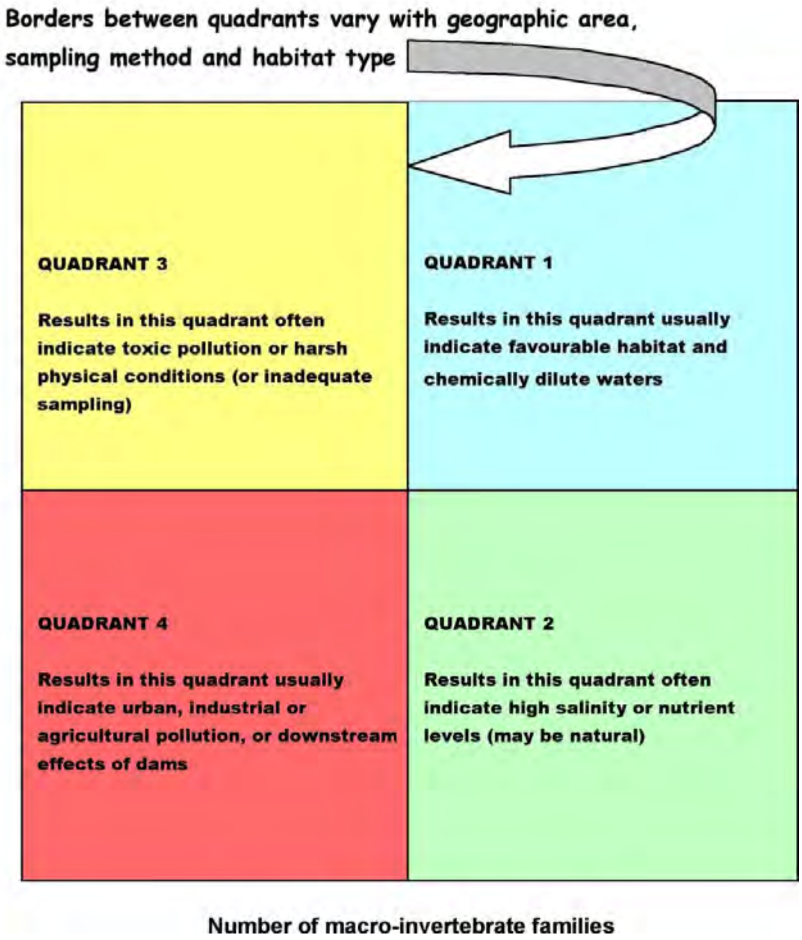

Figure 1.1 Quadrant diagram for SIGNAL 2/Family bi-plot.

AUSRIVAS Bandings

Data for the AUSRIVAS samples from edge habitat at river and stream sites (all sites except site 1, which was a semi-permanent wet area) were run through the *AUSRIVAS Macroinvertebrate Bioassessment Predictive Modelling Software V3.1.1* to determine the AURIVAS bandings for each site (Table 1.1).

The NSW AUSRIVAS model for autumn surveys includes the following predictive variables:

- alkalinity
- altitude
- substrate components
- distance from the source

- slope, and
- rainfall.

Table 1.1 NSW AUSRIVAS bandings for autumn surveys of macroinvertebrate communities in edge habitat.

Band Level	Upper Limit	Band Name	Band Description
X	infinite	more biologically diverse than reference sites	· more taxa found than expected · potential biodiversity hot-spot · possible mild organic enrichment
A	1.17	reference condition	· most/all of the expected families found · water quality and/or habitat condition roughly equivalent to reference sites · impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity
B	0.81	significantly impaired	· fewer families than expected · potential impact either on water quality or habitat quality or both resulting in loss of taxa
C	0.46	severely impaired	· many fewer families than expected · loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality
D	0.11	extremely impaired	· few of the expected families remain · extremely poor water and/or habitat quality · highly degraded

Source: Turak & Waddell 2001

2 Results and Discussion

2.1 Macroinvertebrates

Community Composition

Non-biting midge larvae (sub-families Chironominae and Tanypodinae) were the most common and abundant taxa. Seed shrimp (class Ostracoda) were also found in high numbers at most sites, and marsh beetle larvae (family Scirtidae) were abundant at site 4 (upstream of the extent of the proposed West Borehole Seam workings). Typically, these families are tolerant of a wide range of environmental conditions and are often found in moderately disturbed ecosystems (Chessman 2003).

The community composition of macroinvertebrates at sites in the Abel Underground Mine survey was similar to sites in the current survey. Non-biting midge larvae (sub-family Chironominae) were the most common and abundant taxa and some sites had a high abundance of seed shrimp (class Ostracoda). Caddisfly nymphs (family Leptoceridae), which are from the PET order Trichoptera, were also abundant at most sites (frc environmental 2010).

In addition to the dominant taxa recorded in the current survey (non-biting midge larvae), sites in the Donaldson Coal Mine macroinvertebrate sampling program autumn 2010 survey also included beetles (family Dytiscidae), water boatman (family Corixidae) and mayfly larvae (family Leptophlebiidae) (Robyn Tuft & Associates 2011).

Abundance

The abundance of macroinvertebrates ranged from 33 (site 7) to 196 (site 6) individuals in bed habitat and from 75 (site 1) to 354 (site 4) in edge habitat (Figure 2.1). At most sites, abundance was higher in edge habitat than in bed habitat (Figure 2.1). This is a common result, and likely to be a reflection of habitat structure. Macroinvertebrates were most abundant in edge habitat at site 4 (upstream of the extent of the proposed West Borehole Seam workings) and least abundant in bed habitat at site 7 (downstream of the extent of the proposed West Borehole Seam workings) (Figure 2.1). Site 4 was reduced to a single narrow pool with no bed habitat available for sampling, while site 5 was reduced to several small (less than 10 centimetres deep) pools not suitable for macroinvertebrate sampling. Sites 2 and 8 were dry (Figure 2.1).

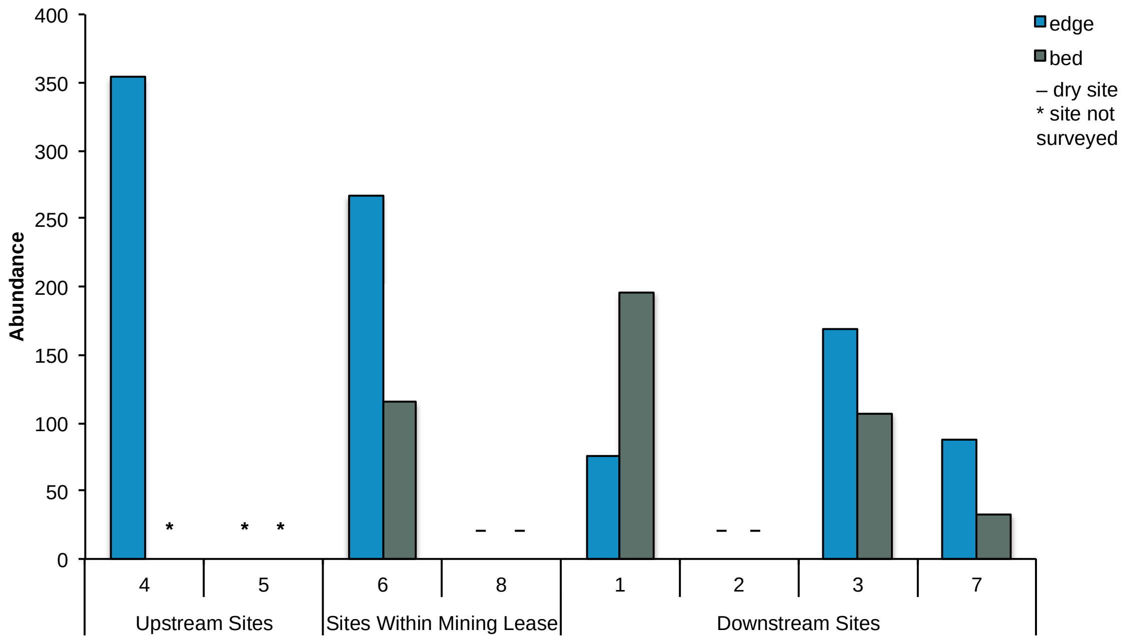

Figure 2.1 Abundance of macroinvertebrates in bed and edge habitats at each site.

In general, the abundance of macroinvertebrates was higher at sites in the Abel Underground Mine survey than at sites in the current survey; abundance ranged from 78 to 1961 individuals at sites in the Abel Underground Mine survey (Figure 2.2) (frc environmental 2010). This higher abundance is likely to be because most sites in the Abel Underground Mine survey were within permanent or intermittent water bodies; while most sites in the current survey were in ephemeral streams.

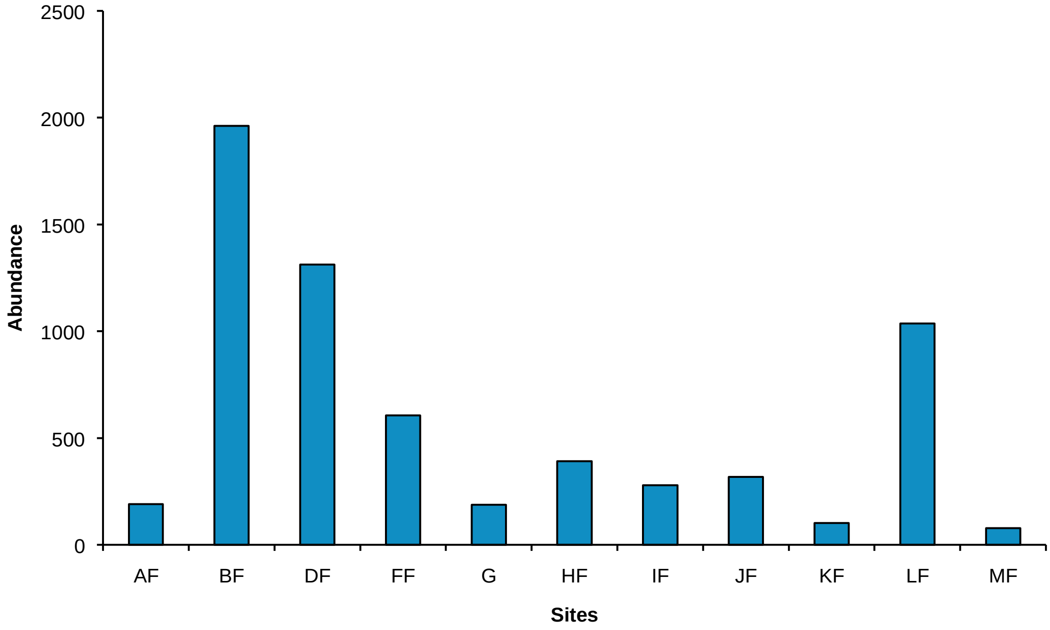

Figure 2.2 Abundance of macroinvertebrates in edge habitat at each site, in the Abel Underground Mine survey.

Total Taxonomic Richness

Total taxonomic richness was lowest in bed habitat at site 3 (downstream of the extent of the proposed West Borehole Seam workings) and highest in edge habitat at sites 6 and 7 (within and downstream of the extent of the proposed West Borehole Seam workings, respectively). In edge habitat, total taxonomic richness was lowest at site 4 (upstream of the extent of the proposed West Borehole Seam workings). This is not surprising given that site 4 comprised an ephemeral, isolated pool. Site 4 was reduced to a single narrow pool with no bed habitat available for sampling, while site 5 was reduced to several small (less than 10 centimetres deep) pools not suitable for macroinvertebrate sampling. Sites 2 and 8 were dry (Figure 2.3).

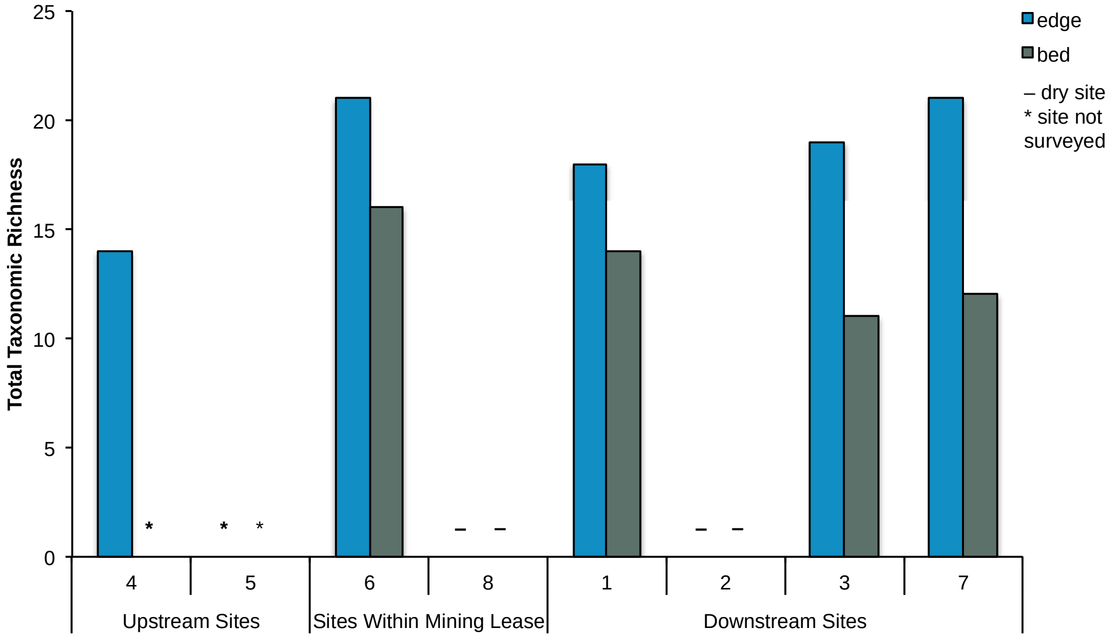

Figure 2.3 Total taxonomic richness in bed and edge habitats at each site.

In general, total taxonomic richness in edge habitat at sites in the Abel Underground Mine survey was similar to taxonomic richness at sites in the current survey (frc environmental 2010) (Figure 2.4).

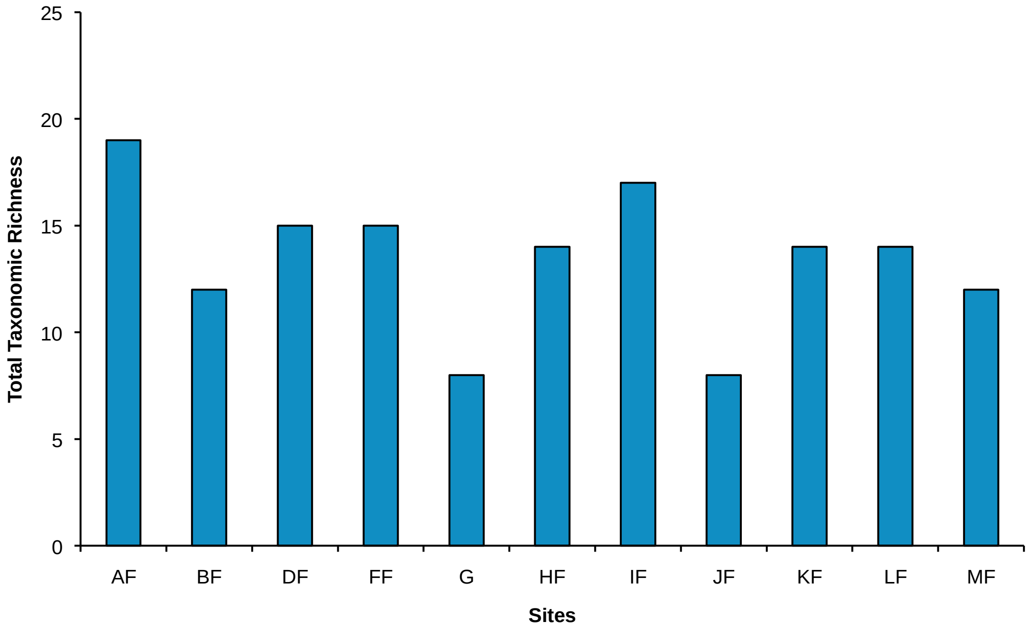

Figure 2.4 Total taxonomic richness in edge habitat at each site, in the Abel Underground Mine survey.

Total taxonomic richness at sites in the Donaldson Coal Mine macroinvertebrate sampling program varied over time, however, richness in the Donaldson Coal Mine autumn surveys was slightly higher at most sites than at sites in the current survey. Diversity at all sites had generally declined since the initial baseline survey in 2000. In autumn 2010, taxonomic richness at sites ranged from 6 to 30, which was 25 to 85% lower than baseline levels (Robyn Tuft & Associates 2011).

Total PET Richness

PET taxa are sensitive to pollutants and changes in water quality and/or environmental degradation. Healthy streams are usually characterised by the presence of PET (pollution-sensitive) taxa. PET taxa were found at all sites; total PET richness was highest, in both bed and edge habitats, at site 6 (within the extent of the proposed West Borehole Seam workings). Site 4 was reduced to a single narrow pool with no bed habitat available for sampling, while site 5 was reduced to several small (less than 10 centimetres deep) pools not suitable for macroinvertebrate sampling. Sites 2 and 8 were dry (Figure 2.5).

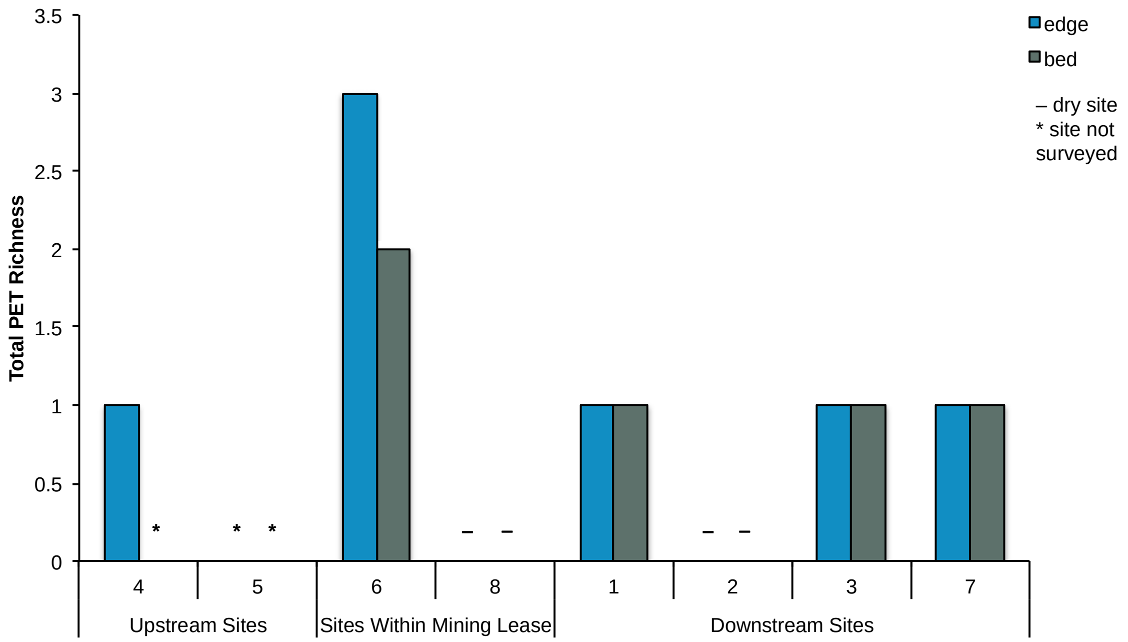

Figure 2.5 Total PET richness in bed and edge habitats at each site.

Total PET richness at sites in the Abel Underground Mine survey was similar to PET richness at sites in the current survey (frc environmental 2010) (Figure 2.6).

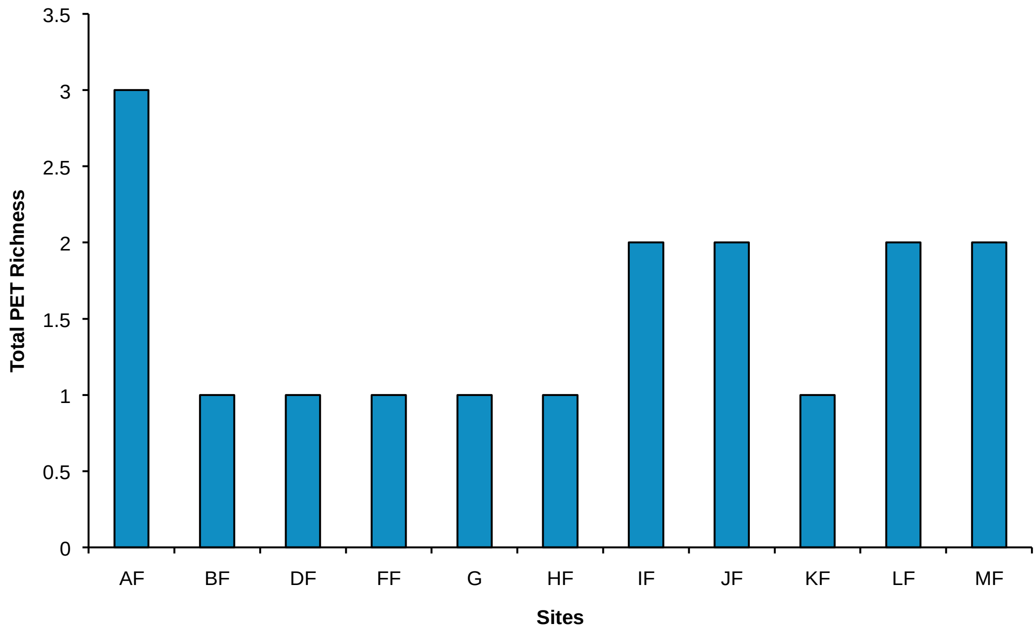

Figure 2.6 Total PET richness in edge habitat at each site, in the Abel Underground Mine survey.

SIGNAL 2 Scores

In general, SIGNAL 2 scores were low (< 4), and were higher in edge habitat than in bed habitat. Site 4 was reduced to a single narrow pool with no bed habitat available for sampling, while site 5 was reduced to several small (less than 10 centimetres deep) pools not suitable for macroinvertebrate sampling. Sites 2 and 8 were dry (Figure 2.7).

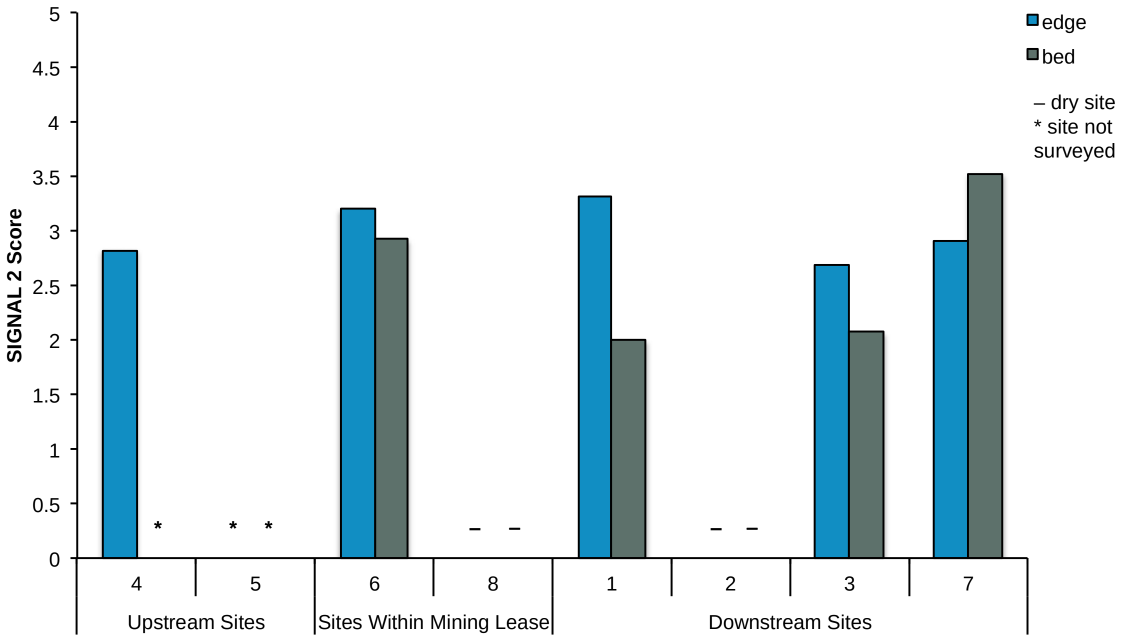

Figure 2.7 Total SIGNAL 2 score in bed and edge habitats at each site.

In general, SIGNAL 2 scores for sites for the Abel Underground Mine were slightly higher than at sites in the current survey (frc environmental 2010) (Figure 2.8).

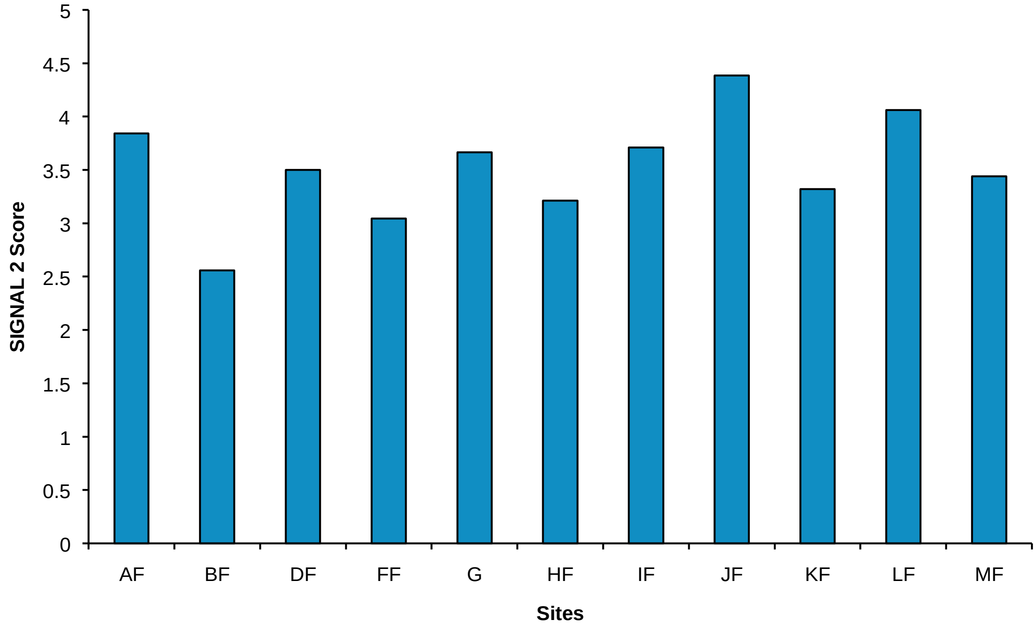

Figure 2.8 Total SIGNAL 2 score in edge habitat at each site in the Abel Underground Mine survey.

SIGNAL 2 scores at sites in the Donaldson Coal Mine macroinvertebrate sampling program were also higher than at sites in the current survey; in autumn 2010, SIGNAL 2 scores ranged from 4.2 to 5.8. SIGNAL 2 scores remained relatively consistent from 2000 to 2010 (Robyn Tuft & Associates 2011).

A family bi-plot comparison of taxonomic richness and SIGNAL 2 scores in edge habitat shows that most sites were within quadrant 2, which indicates that the macroinvertebrate community was influenced by high salinity or nutrient levels (which may be natural). For bed habitat, sites were generally within quadrant 4, which indicates that the macroinvertebrate communities were influenced by urban, agricultural or industrial pollution (Figure 2.9).

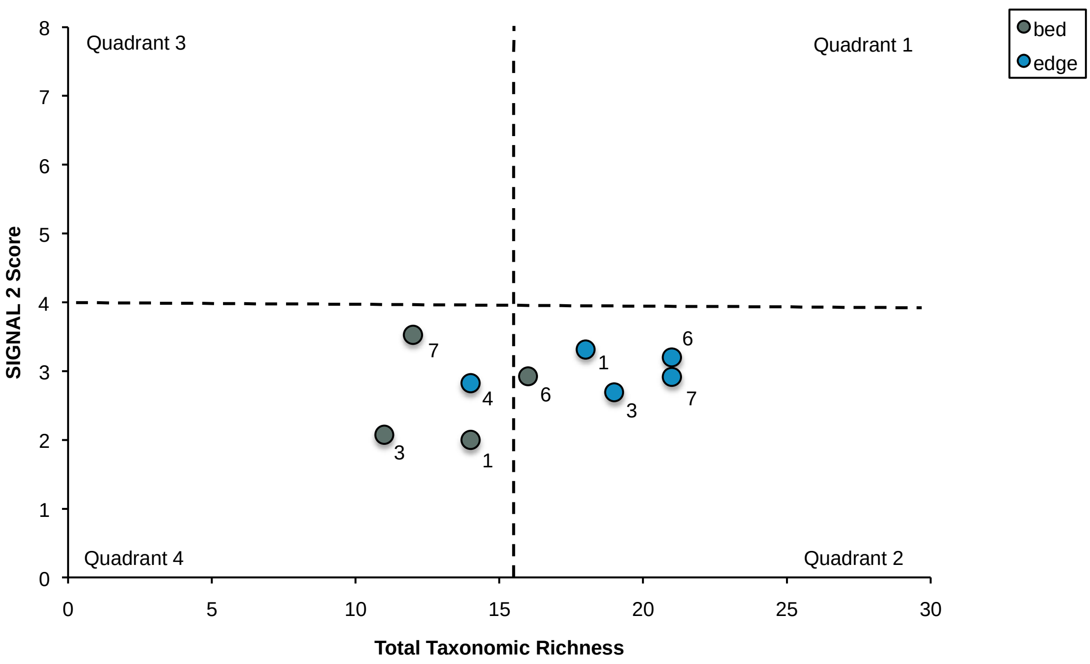

Figure 2.9 SIGNAL 2/family bi-plot in bed and edge habitat at each site.

Similar to the results of the current survey, macroinvertebrate communities in edge habitat at sites for the Abel Underground Mine survey were generally within quadrant 4, indicating influences from urban, agricultural or industrial pollution (frc environmental 2010). Two sites were also within quadrant 3, which indicates that these communities were influenced by pollution, and/or the harsh physical conditions associated with ephemeral streams (Figure 2.10).

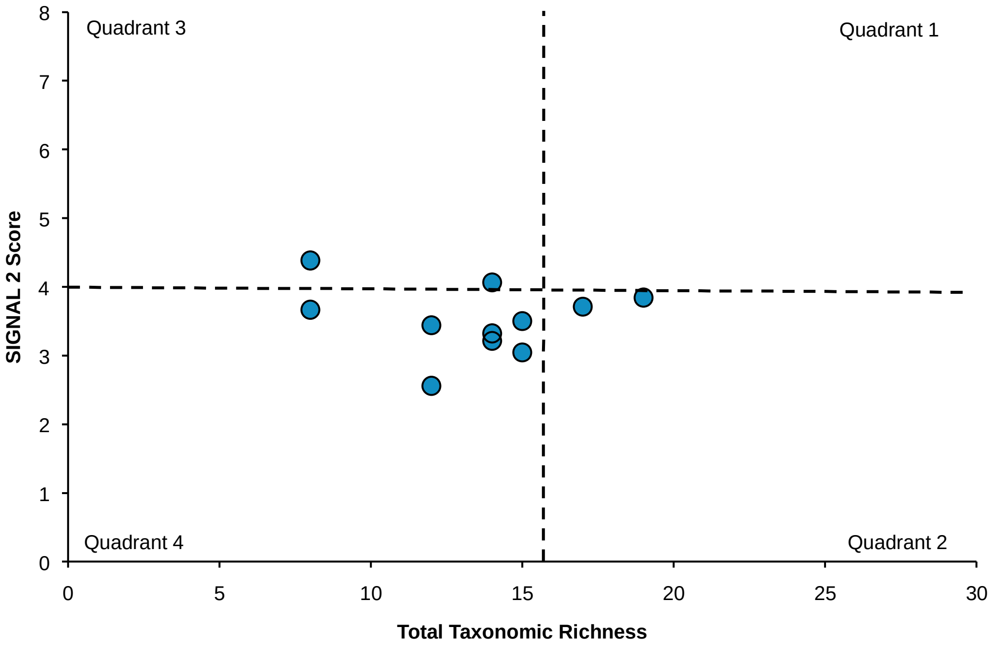

Figure 2.10 SIGNAL 2/family bi-plot in edge habitat at each site for the Abel Underground Mine.

AUSRIVAS Bandings

The NSW AUSRIVAS model results indicated that the macroinvertebrate communities at sites 3 and 7 (downstream of the extent of the proposed West Borehole Seam workings) were significantly impaired (i.e. there were less taxa than were expected at these sites), which may be due to sub-optimal water quality or habitat quality. The macroinvertebrate community at site 6 (within the extent of the proposed West Borehole Seam workings) was comparable to the condition of macroinvertebrate communities at the AUSRIVAS reference sites (i.e. macroinvertebrate diversity was high) (Table 2.1).

Table 2.1 NSW AUSRIVAS model results for macroinvertebrate communities in edge habitat.

Model Output	Upstream Sites		Sites Within the extent of the proposed West Borehole Seam workings		Downstream Sites			
	4 [a]	5	6	8	1 [b]	2	3	7
Observed/ Expected	NA	–	0.89	–	NA	–	0.78	0.77
Band	NA	–	A	–	NA	–	B	B
Condition	NA	–	reference	–	NA	–	significantly impaired	significantly impaired

– not surveyed

NA data not available

[a] site was outside the experience of the model due to its high elevation

[b] data from this semi-permanent wet site were not included as the AUSRIVAS model was designed for streams and rivers

The AUSRIVAS model results for autumn surveys in 2009 and 2010 at sites in the Donaldson Coal Mine macroinvertebrate sampling program were similar to results in the current survey; macroinvertebrate communities at five of the six sites were significantly impaired (Band B), while one site was in reference condition (Band A). The condition of macroinvertebrate communities at all sites had declined since the baseline survey in autumn 2001, when all sites were in reference condition. However, the Donaldson Coal Mine macroinvertebrate sampling programme has shown that macroinvertebrate communities are variable between sites and surveys, and that there was no evidence of an obvious deterioration in water quality at the sites downstream of the mine (Robyn Tuft & Associates 2011). Specific sites were affected by immediate environmental conditions including shading, turbidity levels and site-specific disturbances (Robyn Tuft & Associates 2011), which may explain the differences in community composition between sites.

2.2 Macrocrustaceans

Freshwater Prawns

Three species of macrocrustaceans were caught:

- freshwater prawn (family Atyidae) (Figure 2.11)
- orange-fingered crayfish (*Cherax depressus)* (Figure 2.12), and
- common yabby (*Cherax destructor*) (Figure 2.13).

Figure 2.11

Freshwater prawn at sites 1 and 6.

Figure 2.12

Orange-fingered crayfish at sites 6 and 7.

Figure 2.13

Common yabby at sites 3 and 7.

Macrocrustaceans were caught at four of the five sites surveyed; macrocrustaceans were not caught at site 4 (upstream of the extent of the proposed West Borehole Seam workings). Freshwater prawns dominated the catch of macrocrustaceans at sites 1 and 6. Orange-fingered crayfish were caught at sites 6 and 7 (within and downstream of the extent of the proposed West Borehole Seam workings, respectively). The common yabby was caught at sites 3 and 7 (downstream of the extent of the proposed West Borehole Seam workings). Sites 2 and 8 had no water, while site 5 was too shallow to effectively survey for macrocrustaceans (Table 2.2).

Table 2.2 Abundance of macrocrustaceans at each site.

Family Common name	**Upstream Sites**		**Sites within the extent of the proposed West Borehole Seam workings**		**Downstream Sites**				**Total**
	4	**5**	**6**	**8**	**1**	**2**	**3**	**7**	
Atyidae freshwater prawn	0	–	41	–	86	–	0	0	**127**
Parastacidae orange-fingered crayfish	0	–	2	–	0	–	0	1	**3**
Parastacidae common yabby	0	–	0	–	0	–	2	2	**4**
Total	**0**	**–**	**43**	**–**	**86**	**–**	**2**	**3**	

– site not surveyed

Freshwater prawns (family Atyidae), and yabbies (family Parastacidae) were also recorded at sites for the Abel Underground Mine and Donaldson Coal Mine macroinvertebrate sampling program (frc environmental 2010; Robyn Tuft & Associates 2011).

The common yabby is listed as vulnerable on the International Union for Conservation of Nature (IUCN) and Resources Red List of Threatened Species (IUCN 2010), but is not listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999,* or the NSW *Threatened Species Conservation Act 1995*.

2.3 Listed Species

Larvae of the Adam's emerald dragonfly were not caught in this survey.

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Appendix E Freshwater Fish Communities

Contents

Tables

Figures

1 Methods

1.1 In-situ Snapshot

Aquatic macroinvertebrate communities were assessed at five of the eight sites in a survey from 9 to 11 June 2011, including the following sites that held water:

- site 4 (upstream of the extent of the proposed West Borehole Seam workings)
- site 6 (within the extent of the proposed West Borehole Seam workings), and
- sites 1, 3 and 7 (downstream of the extent of the proposed West Borehole Seam workings).

Fish surveys were not undertaken at sites 2, 5 and 8 where the water level was too low or the sites were dry.

Details of the sites surveyed are presented in Appendix A.

1.2 Data Collection

Fish communities were surveyed using a combination of electrofishing (backpack or boat electrofishing) and baited traps (Table 1.1). All available habitats (e.g. pool, riffle, run and bend) were fished at each site. Electrofishing was conducted in accordance with the *Australian Code of Electrofishing Practice 1997*, using a Smith-Root LR-24 backpack electrofisher. Fish communities were also surveyed with four small (2 millimetre [mm] mesh size) baited traps, which were set at each site for approximately two hours.

The life-history stage, abundance and the apparent health of every fish caught were recorded. Specimens that were unable to be identified in the field were euthanised and returned to the laboratory for identification.

The sampling of fishes was conducted under New South Wales (NSW) Scientific Collection Permit No. P11/0007-1.0, NSW Scientific Licence SL100158 and Animal Research Authority Trim File No.10/2604 issued to frc environmental.

Table 1.1 The electrofishing and trap efforts for fish surveys at each site.

Site	Method	Habitat	Date	Time In	Time Out	Settings	Effort
Sites Upstream of the extent of the proposed West Borehole Seam workings							
4	backpack electrofishing	pool	2011-06-10	1230	1245	400 V 30 Hz 12 ms	184 s
5	–	–	–	–	–	–	–
Sites Within the extent of the proposed West Borehole Seam workings							
6	small bait traps (4)	pool	2011-06-09	0815	1000	–	7 h
	backpack electrofishing			0925	0955	500 V 30 Hz 12 ms	500 s
8	–	–	–	–	–	–	–
Site Downstream the extent of the proposed West Borehole Seam workings							
1	small bait traps (4)	pool	2011-06-09	1250	1415	–	5.7 h
	backpack electrofishing		2011-06-11	1240	1305	400 V 30 Hz 12 ms	507 s
2	–	–	–	–	–	–	–
3	backpack electrofishing	pool	2011-06-11	0915	0940	400 V 30 Hz 12 ms	505 s
7	backpack electrofishing	pool	2011-06-11	1000	1040	500 V 30 Hz 12 ms	501 s

– not surveyed
V volts
Hz hertz
h hours
s seconds
ms milliseconds

1.3 Data Analysis

Fish communities at each site were assessed for the:

- taxonomic richness (total number of species caught at a site)
- total abundance (total number of individuals caught at a site)
- abundance of exotic species, and
- abundance of species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999,* NSW *Threatened Species Conservation Act 1995* or NSW *Fisheries Management Act 1994*.

Data at sites within and downstream of the extent of the proposed West Borehole Seam workings were compared to:

- background data (i.e. data from comparative sites upstream of the extent of the proposed West Borehole Seam workings), and
- results of a previous survey by frc environmental for the nearby Abel Underground Mine, from 24 to 28 May 2010 (frc environmental 2010).

The locations of sites for the frc environmental survey for the nearby Abel Underground Mine are shown in Appendix A.

1.4 Regional and Ecological Perspective

The literature on fish communities in the region was also reviewed, and summarised to provide a context for the results of this survey.

2 Results and Discussion

2.1 Community Composition

Three species of fish were caught at one site during the survey (Table 2.1):

- eastern gambusia (*Gambusia holbrooki*) (Figure 2.1)
- empire gudgeon (*Hypseleotris compressa*) (Figure 2.2), and
- firetail gudgeon (*Hypseleotris galii*) (Figure 2.3).

Figure 2.1

Eastern gambusia, caught at site 1.

Figure 2.2

Empire gudgeon, caught at site 1.

Figure 2.3

Firetail gudgeon, caught at site 1.

The most abundant species caught was the eastern gambusia with a total of 105 individuals. A total of one empire gudgeon and one firetail gudgeon were also caught. All fish were caught at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings) (Table 2.1).

Table 2.1 Abundance of each fish species collected at each site.

Species Name	Common Name	Upstream Sites		Sites within the Extent of the proposed West Borehole Seam workings		Downstream Sites				Total
		4	**5**	**6**	**8**	**1**	**2**	**3**	**7**	
Gambusia holbrooki	eastern gambusia *	0	–	0	–	105	–	0	0	**105**
Hypseleotris compressa	empire gudgeon	0	–	0	–	1	–	0	0	**1**
Hypseleotris galii	firetail gudgeon	0	–	0	–	1	–	0	0	**1**
	Total	**0**	–	**0**	–	**107**	–	**0**	**0**	**107**
	% exotic species	**0%**	–	**0%**	–	**98%**	–	**0%**	**0%**	**98%**

– not surveyed due to low levels or lack of water

* exotic non-indigenous species

2.2 Taxonomic Richness

Three fish species were caught at site 1 (upstream of the extent of the proposed West Borehole Seam workings). The low number of species at site 1 and the absence of fish at other sites indicate substantial impediments to fish passage, and the ephemeral nature of the water bodies surveyed.

The taxonomic richness in the current survey was below that of the Abel Underground Mine survey, where taxonomic richness ranged from one to six species per site (frc environmental 2010). See Section 3.1 for species caught during this survey.

2.3 Abundance

At site 1, the fish abundance (total number of fish caught at a site) was 107. This range is typical of ephemeral waterways; however, exotic eastern gambusia was the predominant species at this site and comprised 98% of the individuals caught. No fish were caught at any other sites.

The fish abundance in the current survey was below that of the Abel Underground Mine survey, in which fish abundance was 1551 across the study area. The exotic eastern gambusia was also the predominant species caught in this survey, and comprised 75% of the individuals caught. Firetail gudgeons were also relatively abundant, with 192 individuals caught at one site (frc environmental 2010).

2.4 Exotic Species

Exotic eastern gambusia (*Gambusia holbrooki*) was caught at site 1. Eastern gambusia is declared as noxious under the *Fisheries Management Act 1994*, and is considered a pest by the NSW Department of Primary Industries.

2.5 Threatened Species

No threatened species were caught in this survey, or in the Abel Underground Mine survey.

3 Regional and Ecological Perspective

3.1 Community Composition

In the Abel Underground Mine survey, eight native fish species were recorded in the Hunter-Central Rivers Catchment; one exotic species was recorded (eastern gambusia, *Gambusia holbrooki*) (frc environmental 2010). Species richness ranged from one to six species per site and abundance was dominated by the eastern gambusia, which comprised 75% of the individuals caught. A high proportion of introduced fish species versus native fish species is typical of the Hunter-Central Rivers Catchment (DECCW 2010).

The condition of fish communities within the region (as of 2010) is relatively poor (DECCW 2010). In the wider Hunter-Central Rivers Catchment, 52 species of finfish (that inhabit freshwater or estuarine systems) have been recorded (DPI 2006). The Hunter-Central Rivers Catchment includes key protected species, such as the threatened black cod (*Epinephelus daemelii*) and estuary cod (*Epinephelus coioides*) (Table 3.1).

The natural flows of the Hunter-Central River Catchment have been severely impeded with over 300 weirs, dams, regulating structures or tidal barriers (other than road crossings) within the area, and have the potential to impact fish movement within the catchment (Thorncraft & Harris 2000; New South Wales Fisheries 2002). Major dams within the Hunter-Central Rivers Catchment include (New South Wales Fisheries 2002):

- Glenbawn
- Glennies Creek
- Lostock
- Chichester
- Liddell, and
- Grahamstown dams.

These form major barriers to fish passage on the waterways where they occur and ultimately impact the community composition within the region.

Table 3.1 Fish species in the Hunter-Central Rivers Catchment.

Family *Species Name*	**Common Name**	**Current Survey**	**frc environmental 2010** [a]	**NSW Rivers Survey (2006 and 2010)** [b]
Anguillidae				
Anguilla australis	short-fin eel	–	yes	yes
Anguilla reinhardtii	marbled eel	–	yes	yes
Atherinidae				
Atherinosoma microstoma	small-mouthed hardyhead	–	–	yes
Ariidae				
Arius graeffei	lesser salmon catfish	–	–	yes
Clupeidae				
Potamalosa richmondia	freshwater herring	–	–	yes
Cyprinidae				
Carassius auratus	common goldfish [c]	–	–	yes
Cyprinus carpio	common carp [d]	–	–	yes
Eleotridae				
Gobiomorphus australis	striped gudgeon	–	yes	yes
Gobiomorphus coxii	Cox's gudgeon	–	–	yes
Hypseleotris compressa	empire gudgeon	yes	yes	yes
Hypseleotris galii	firetail gudgeon	yes	yes	–
Hypseleotris klunzingeri	western carp gudgeon	–	yes	yes
Philypnodon grandiceps	flathead gudgeon	–	yes	yes
Philypnodon macrostomus	dwarf flathead gudgeon	–	yes	–
Philypnodon sp. 1	gudgeon sp.	–	–	yes
Galaxiidae				
Galaxias brevipinnis	climbing galaxias	–	–	yes

Family *Species Name*	**Common Name**	**Current Survey**	**frc environmental 2010** [a]	**NSW Rivers Survey (2006 and 2010)** [b]
Galaxias maculatus	common jollytail	–	–	yes
Galaxias olidus	mountain galaxias	–	–	yes
Gobiidae				
Redigobius macrostoma	large-mouth goby	–	–	yes
Megalopidae				
Megalops cyprinoids	oxeye herring	–	–	yes
Monodactylidae				
Monodactylus argenteus	diamondfish	–	–	yes
Mugilidae				
Mugil cephalus	flathead mullet	–	–	yes
Myxus petardi	freshwater mullet	–	–	yes
Percichthyidae				
Macquaria ambigua	golden perch	–	–	yes
Macquaria novemaculeata	Australian bass	–	–	yes
Plotosidae				
Tandanus tandanus	freshwater catfish	–	–	yes
Poecilidae				
Gambusia holbrooki	eastern gambusia [d]	yes	yes	yes
Pseudomugilidae				
Pseudomugil signifer	Pacific blue eye	–	–	yes
Retropinnidae				
Retropinna semoni	Australian smelt	–	–	yes
Salmonidae				
Oncorhynchus mykiss	rainbow trout [c]	–	–	yes
Salmo trutta	brown trout [c]	–	–	yes

Family *Species Name*	Common Name	Current Survey	frc environmental 2010 [a]	NSW Rivers Survey (2006 and 2010) [b]
Salvelinus fontinalis	brook char [c]	–	–	yes
Scatophagidae				
Scatophagus argus	spotted scat	–	–	yes
Selenotoca multifasciata	banded scat	–	–	yes
Scorpaenidae				
Notesthes robusta	bullrout	–	–	yes
Serranidae				
Epinephelus daemelii	black cod	–	–	yes
Epinephelus coioides	estuary cod	–	–	yes
Terapontidae				
Bidyanus bidyanus	silver perch	–	–	yes
Leiopotherapon unicolor	spangled perch	–	–	yes
Terapon jarbua	crescent perch	–	–	yes
Tetrarogidae				
Notesthes robusta	bullrout	–	–	yes

– not caught
[a] frc environmental (2010)
[b] Department of Primary Industries (2006); Howell & Creese (2010)
[c] exotic non-indigenous species
[d] exotic non-indigenous species, declared noxious under the *Fisheries Regulation 2008*

3.2 Environmental Tolerances

Waterways of the Hunter-Central Rivers Catchment support a wide range of temperate landscape regions including major rivers, wetlands and estuaries (DWE 2009).

Many of the rivers and creeks within the Hunter-Central Rivers Catchment are connected to estuarine habitats; many species can tolerate a wide range in salinity and require the habitats of both fresh and brackish conditions to complete their life cycles (e.g. marbled eel).

The firetail gudgeon is perhaps the hardiest of the species caught in the current survey, and it tolerates:

- pH from 4.4 to 8.9
- water temperatures from 8.4 to 31.2°C, and
- conductivity from 51.0 to 4123.0 microSiemens per cm (µS/cm) (Allen et al. 2002; Pusey et al. 2004).

The empire gudgeon can also tolerate a large range of water quality conditions (Table 3.2).

Table 3.2 Fish species in the current survey and the range of water quality conditions in which they were caught.

Family *Latin Name*	**Common name**	**Water Temp. (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Conductivity (µS/cm)**	**Turbidity (NTU)**
Eleotridae						
Hypseleotris compressa	empire gudgeon [a b]	11.7–31.0	1.7–11.3	4.4–9.1	97.5–2,744.0	0.3–200.0
Hypseleotris galii	firetail gudgeon [a b]	8.4–31.2	0.3–19.5	4.4–8.9	51.0–4,123.0	0.1–331.4
Poecilidae						
Gambusia holbrooki	eastern gambusia	NA	NA	NA	NA	NA

[a] Pusey et al. 2004

[b] environmental data from catches in surveys in south-east Queensland sourced from Pusey et al. (2004)

mg/L = milligrams per litre

NTU = Nephelometric Turbidity Units

NA data not available

3.3 Importance of Flow

Fish dispersal within the Hunter-Central Rivers Catchment is often affected by man-made structures, as the catchment is highly regulated and flow is directly obstructed. The Hunter-Central Rivers Catchment has an average annual rain fall of 1,140 mm in coastal areas (DWE 2009). The highly variable nature of the climate in the Hunter Valley has caused both serious droughts and extensive floods.

In areas where fish passage is commonly obstructed, fish dispersal is often dependent on floodwaters, with most species dispersing over large areas during floods. However, due to the nature of the natural drainage lines (which are limited to a small number of isolated pools) and the high gradient of the streams in the Project area, it is unlikely that fish will disperse very far upstream (i.e. into the Project area) during periods of high rainfall. It is likely that the fish recorded at site 1 (wet area downstream of the extent of the proposed West Borehole Seam workings) are located at the upper limit of their distribution along Surveyors Creek 2 (Figure 1.2 of Aquatic Ecology Assessment).

Species richness is commonly correlated with the size, number and distribution of waterholes along a waterway. Waterways with permanent, large or frequent waterholes tend to be more species-rich than others (Unmack 2001); waterways with small, ephemeral waterholes, such as those in the Project area, tend to be species-poor.

4 Fish Descriptions

4.1 Ecology of Fish in this Survey

Each of the fish species requires some physical in-stream habitat for shelter and reproduction. A variety of physical aquatic habitat (e.g. woody debris and substrate diversity) also supports diverse macroinvertebrate communities, which are prey to many fish in the area.

4.2 Mosquitofish (*Gambusia holbrooki*)

The mosquitofish is a widespread and abundant species whose numbers are in plague proportions in some areas of Australia. It is commonly found in all states of Australia including coastal drainages of NSW, however it is native to north and central America and was introduced into Australia as a mosquito control measure that has proven to have minimal effect (Allen et al. 2002). They prefer warm, still waters and are typically found shoaling at the edges of streams and lakes (Allen et al. 2002).

4.3 Empire gudgeon (*Hypseleotris compressa*)

The empire gudgeon is a widespread species occurring throughout western, northern and eastern Australia (Pusey et al. 2004). This species is found in a variety of habitats including rainforest streams, rivers, wetlands, streams, swamps and dune lake systems (Pusey et al. 2004). This species can tolerate wide ranges of temperatures up to 35 °C, pH from 5.0 to 9.1 and conductivities as saline as found in seawater (Allen et al. 2002). Reproduction occurs in the warmer months and eggs are tended and guarded by the males (Allen et al. 2002).

4.4 Firetail gudgeon (*Hypseleotris galii*)

The firetail gudgeon is a common species in eastern Australia from Water Park Creek in Queensland to Georges River in NSW (Pusey et al. 2004). This species is found in a variety of habitats including streams, ponds, swamps and drains (Allen et al. 2002). Firetailed gudgeons can tolerate wide ranges of temperature from 8 to 31 °C, pH from 4.4 to 8.9, and conductivities as saline as 4,123 µS/cm (Pusey et al. 2004). Reproduction occurs in late winter through to autumn where eggs are laid underneath rocks and guarded by the male (Allen et al. 2002; Pusey et al. 2004).

5 References

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