Aquatic Ecology and Stygofauna Assessment

Springvale Mine Extension Project

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Prepared for
Springvale Coal Pty Limited

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Cover Image: Caddis fly larva from the family Hydrobiosidae, a pollution sensitive taxa present in the hanging swamp habitat. Photographer: Dr Rad Nair, Cardno Ecology Lab.

Executive Summary

Background and Scope of Works

This Aquatic Ecology and Stygofauna Impact Assessment has been prepared by Cardno Ecology Lab, on behalf of Springvale Coal Pty Limited (Springvale Coal), to support the Environmental Impact Statement (EIS) for the Springvale Mine Extension Project (the Project). The scope of works for the assessment was determined by the requirements of the Director General of the NSW Department of Planning and Infrastructure, Commonwealth Department of Sustainability, Environment, Water, Population and Communities and other government agencies. This report includes:

> An overview of Commonwealth and State legislative requirements, policies and guidelines that are relevant to the effects of the Project on aquatic ecology and stygofauna;

> Information on threatened aquatic species, populations, ecological communities, groundwater dependent ecosystems (GDEs) and key threatening processes that could be affected by the proposed mining and associated works;

> Description of the existing aquatic environment and its associated biota and of the stygofauna associated with groundwater aquifers;

> Assessments of the potential impacts of the proposed mine construction, operation, decommissioning and rehabilitation works on aquatic habitats and their biota, particularly threatened species, populations and communities, and GDEs occurring within and immediately downstream of the Project Areas;

> Recommendations on measures to avoid, mitigate or manage potential impacts associated with the extension of mining operations on aquatic ecology of the watercourses within and downstream of the Project Application Area.

The Project

Springvale Coal is seeking approval to extend its longwall mining operations to the east, the southeast and the southwest of its existing workings at Springvale Colliery (Springvale) located 15 km northwest of Lithgow. The Project involves:

> Development of underground access headings and roadways from the existing mining area;

> Secondary extraction of coal from the proposed longwalls LW416 to LW432 and LW501 to LW503;

> Use of existing ancillary surface facilities and infrastructure, crusher and screening plant at the Springvale Pit Top;

> Transfer of coal to offsite locations using the existing overland conveyor system;

> Use of existing ancillary surface infrastructure at the Springvale pit top and on Newnes Plateau for ventilation, electricity, water, materials supply, and communications;

> Installation and operation of two additional dewatering bore facilities (Bores 9 and 10) and associated infrastructure on Newnes Plateau;

> Upgrade of existing and construction of new sections of access tracks to the Bores 9 and 10 facilities;

> Construction of a downcast ventilation borehole at the Bore 10 facility location;

> Establishment of a services borehole area;

> Upgrade of the existing Springvale Delta Water Transfer Scheme (SDWTS) to accommodate a water delivery capacity of up to 50 ML/day;

> Management of mine inflows by transferring water to Wallerawang Power Station (WPS), via the SDWTS, and discharge through Angus Place Colliery’s licensed discharge point LDP001 and Springvale Colliery’s LDP009;

> Progressive rehabilitation of disturbed areas at infrastructure sites no longer required for mining operations.

Relevant legislative requirements, policies and guidelines

The major legislative requirements that are relevant to the Project are the NSW Environmental Planning and Assessment Act 1979 (*EP&A Act*) under which the proposed mine extension will be assessed and the provisions in the Commonwealth Environmental Protection and Biodiversity Conservation Act (*EPBC Act*) 1999, NSW Threatened Species Conservation Act (*TSC Act*)1995 and NSW Fisheries Management Act (*FM Act)* 1994 (including Fisheries Management Amendment Act 1997) that relate to the conservation of threatened species, populations and communities and the Protection of the Environment Operations Act 1997 which regulates the volume and concentration of key pollutants discharged to the aquatic environment.

The Policy and Guidelines for Fish Habitat Conservation and Management Fish (updated 2013) issued by the NSW Department of Primary Industry and NSW Office of Water Guidelines for Controlled Activities are applicable to instream ecology and the riparian zone. The NSW State Groundwater Ecosystem Policy, NSW Aquifer Interference Policy and NSW Office of Water's Risk Assessment Guidelines for Groundwater Dependent Ecosystems are applicable to the swamps and stygofauna occurring within the Mine Extension Area.

Conservation Issues

None of the threatened fish species listed under the *EPBC Act* or *FM Act* identified as potentially occurring within Lithgow Local Government Area are likely to occur within the Project Application Area. One threatened invertebrate species listed under the *TSC Act*, the Giant Dragonfly, is known to occur in some of the swamps. Suitable habitat for the Adam's Emerald Dragonfly, a threatened invertebrate species listed under the *FM* Act, occurs within the Project Application Area. This species has not been recorded in this are but exist.

Two endangered ecological communities, Newnes Plateau Shrub Swamps (Shrub Swamps) and Newnes Plateau Hanging Swamps (Hanging Swamps), occur within and adjacent to the Project Application Area. Both are components of the Temperate Highland Peat Swamps on Sandstone Endangered Ecological Community (EEC) listed under the *EPBC Act*. Newnes Plateau Shrub Swamps in the Sydney Basin Bioregion are also listed as an EEC under the *TSC Act*.

Three Key Threatening Processes listed under the *FM Act* are potentially relevant to the Project:

> Degradation of native riparian vegetation along New South Wales watercourses;

> Instream structures and other mechanisms that alter natural flows;

> Removal of large woody debris from New South Wales rivers and streams (if required).

Two Key Threatening Processes (KTPs) listed under the *TSC Act* may also be relevant:

> Alteration of habitat following subsidence due to longwall mining;

> Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands.

The Project could potentially impact on three groundwater dependent ecosystems: baseflow streams, groundwater dependent wetlands and subsurface phreatic aquifer ecosystems.

Existing Aquatic Environment

Descriptions are provided of the aquatic ecology of the upper reaches of the Coxs River, Wolgan River and Carne Creek, and of the drainages downstream of several Shrub Swamps and Hanging Swamps that could potentially be impacted by the Project. The descriptions are based on information compiled from biannual baseline aquatic ecology surveys of these watercourses undertaken by Marine Pollution Research Pty Ltd (MPR).

Coxs River

Monitoring was undertaken at four sites, CR1, CR2, CR4 and CR5, in the upper reach of the Coxs River above Lake Wallace.

The river channel was generally narrow, incised and flat-bottomed except at CR5 where there were two long broad pools separated by a constricted riffle zone. The stream banks were steep, undercut, unstable and actively eroding in some sections. They were covered by grasses with occasional blackberry bushes. Eucalypt and willow trees were also present at CR5. The substratum consisted of sandy and/or muddy deposits with some pebbles, cobbles and boulders. The riparian and aquatic environments at CR2 and CR4 were in a poorer condition than those at CR1 and CR5.

The electrical conductivity (EC), dissolved oxygen (DO) and pH levels of the water at CR2 and CR5 were frequently outside the ANZECC/ARMCANZ (2000) guidelines, as were the EC levels at CR4 and DO levels at CR1 and CR4. The EC and pH levels exceeded the guidelines, but DO levels were generally below the guidelines, except at CR5, where they occasionally exceeded the upper guideline. Turbidity levels at all four sites were generally within the guidelines.

More aquatic plant taxa were found at CR1 and CR5 than at CR2 and CR4. Filamentous green algae were present at all four sites. Charophytes were recorded at CR1, CR4 and CR5 only.

The aquatic macroinvertebrate fauna was diverse, with a total of 62 taxa recorded across the surveys and total numbers per site ranging from 35 at CR5 to 47 at CR2. The fauna consisted of insects, crustaceans, worms, molluscs, springtails, freshwater mites and leeches. The fauna was either equivalent to or significantly impaired relative to the AUSRIVAS reference condition, with that at CR2 and CR4 being less impaired on average than that at CR1 and CR5. The average SIGNAL2 score, an index of environmental quality based on the sensitivity of macroinvertebrate families to various forms of pollution, indicated the sites were subject to moderate to severe degradation, with CR1 and CR5 being in the poorest condition. The macroinvertebrate assemblages at CR1 and CR2 were fairly distinct from each other and from those at CR4 and CR5.

Two native fish species, Flathead Gudgeon and Mountain Galaxias, and three introduced species, Eastern Gambusia, Goldfish and Brown Trout, were recorded at CR5. The two native species were also recorded at CR2. Eastern Gambusia and Brown Trout were the only species found at CR4. No fish were caught at CR1 however, some (possibly Mountain Galaxias) were observed. Tadpoles were observed at all the sites, but no frogs were found.

From the above it is clear that although the upper Coxs River is degraded it supports a relatively diverse aquatic biota.

Wolgan River Catchment

Monitoring was undertaken at three sites, WRup, WRmd and WRdn, on the Wolgan River and at one site, CCXdn, on its tributary Carne Creek.

The river channel was narrow (≤ 5 m wide), of shallow to moderate depth (≤ 1.5 m) and surrounded by dense riparian vegetation. The substratum varied along the river, with sand and areas of finer sediment present at WRup, bedrock predominating at WRmd but with sand, boulders and cobbles also present and sand being the major feature at WRdn but with gravel and boulders also present. The channel at CCXdn was also narrow, shallow and had a variable substratum consisting of boulders, cobbles, gravel and sand drifts. Orange precipitates (iron floc) were observed only at WRup. The riparian and aquatic habitats in the river had been exposed to small to moderate amounts of disturbance, with WRmd being the least disturbed site. Minimal disturbance was evident at CCXdn.

The DO levels in the river were frequently below the ANZECC/ARMCANZ (2000) guidelines, as were the pH levels at WRmd and WRdn. The EC and turbidity levels in the river were generally within the guidelines. The pH levels at CCXdn were also well below the guidelines and more acidic than in the river, but EC and DO levels were only occasionally below the guidelines.

Two aquatic plants (Swamp Clubrush and Jointed Rush) were recorded in the river, but none were observed at CCXdn. Filamentous green algae and charophytes were observed at WRup, WRmd and WRdn, but not found at CCXdn.

The macroinvertebrate fauna consisted of insects, crustaceans, worms, bivalve molluscs and freshwater mites. The total number of taxa recorded per survey varied from 18-25, 20-25, 19-24 and 19-23 at WRup, WRmd, WRdn and CCXdn, respectively. The average SIGNAL2 score indicated the river sites were degraded but not CCXdn. WRup was the most degraded site. The macroinvertebrate fauna at WRup was significantly impaired relative to the AUSRIVAS reference condition, but that at WRmd and WRdn was either equivalent to or significantly impaired relative to the reference condition. The macroinvertebrate assemblages at Sites CCXdn and WRup were distinct from each other and from those at WRmd and WRdn.

Eastern Banjo Frogs and Spotted Marsh Frogs were heard at WRup, but no frogs were observed at any of the other sites. Tadpoles were found at WRup and WRdn only. An eel (*Anguilla* sp.) was observed at WRmd, but no fish were found at WRup or WRdn. Fish and larvae, most likely Mountain Galaxias, were sighted at CCXdn.

From the above it is clear that the aquatic habitats and quality of water in the Wolgan River catchment are generally in a better condition than that in the Coxs River catchment, but the aquatic biota is less diverse.

Drainages Downstream of Swamps

Monitoring was undertaken at:

> Sites CC1-4 situated respectively on drainages downstream of the Sunnyside East, Carne West, Gang Gang and Barrier Swamps in the northern part of the proposed workings area;

> Sites MC1, PC1, BC1 and BCN2 situated respectively on drainages downstream of Marrangaroo, Paddys Creek, Pine and Nine Mile Swamps in the southern part of the proposed workings area;

> Site SSWdn on the drainage below Sawyer Swamp Creek adjacent to LW502-503.

The drainage channels below CC1-4 were narrow, shallow and overgrown with dense vegetation. The channel at these sites was similar, consisting of cascades over bedrock, pools with exposed bedrock and accumulations of sandy and muddy sediment. Fallen logs and moss were common throughout CC1. The drainage channel at MC1 was similar to those at CC1-4. The substratum at MC1 consisted of bedrock with some boulders and cobbles and sand accumulations and silt in some pools. The riparian habitat and drainage channels at CC1-4 and MC1 were minimally disturbed. The drainage channels at PC1, BC1 and BCN2 were in a poorer condition, with that at PC1 being the most disturbed. The drainage channel at PC1 had shallow incisions, but with some steep areas with undercut banks and had a substratum consisting mainly of mobile sand with some pebbles and cobbles. The drainage channel at BC1 was incised into the surrounding valley floodplain and had steep sides and a substratum consisting of firm sand with localised deposits of clay-like sediments. The drainage channel at BCN2 consisted of a broad soak with multiple flow paths and had a mostly sandy substratum that was covered in silt in Spring 2012, with some iron precipitation also evident. The substratum at SSWdn consisted mostly of sand, but with some boulder outcrops and sandstone rock fragments. The submerged surfaces at SSWdn were covered with iron precipitation. SSWdn was subject to small to moderate amounts of disturbance.

The EC and pH levels of the water in the drainages were generally below and DO levels mostly below the ANZECC/ARMCANZ (2000) guidelines. Turbidity levels were either within or above the guideline default trigger values.

Aquatic macrophytes were recorded at all the sites except BC1. The identity of the macrophytes is unclear, because the name recorded at CC1-CC4 and MC1 has changed over time from an unidentified member of the Cyperaceae to Bulbous Rush to Swamp Clubrush. Bulbous Rush was also recorded at PC1 and BCN2. Small amounts of filamentous green algae were found at all of the sites except PC1 and BCN2. Charophytes were recorded only at CC1 and MC1. Algal mats were also observed at MC1 and BC1.

The aquatic macroinvertebrate fauna consisted of insects, crustaceans, worms and freshwater mites. The fauna was less diverse than that at the Coxs River and Wolgan River sites. The fauna at CC1, CC3 and CC4 was the most diverse and that at BC1, BCN2 and SSWdn the least diverse. The macroinvertebrate assemblages at BC1, BCN2 and SSWdn were distinct from each other and from those at the other sites. The assemblages at MC1 and PC1 were similar to those at CC1-4. The macroinvertebrate fauna at the sites in the northern part of the proposed workings area (i.e. CC1-4) was less degraded than that at the sites in the southern part, with that at SSWdn and BC1 being the most degraded.

No frogs were observed or caught at any of the sites. Tadpoles were found only at BC1. Mountain Galaxias was the only species of fish found, but was recorded only at MC1 in spring. Larval fish were also observed at MC1 and at PC1.

Stygofauna

In May 2012, MPR conducted a pilot survey of the invertebrates associated with boreholes targeting the groundwater system below individual swamps and the near-surface aquifer in the Banks Wall Sandstone to determine whether any stygofauna were present. Samples from the swamp boreholes contained four likely stygofauna taxa (cyclopoid copepods, harpacticoid copepods, copepod nauplii and bathynellid syncarids) and three possible stygofauna taxa (Rotifera, Tardigrada and phreatoicid isopods). The boreholes at Sunnyside East Swamp yielded the greatest number of likely and possible stygofauna taxa, but also yielded more water than the other swamp boreholes. One likely (Cyclopoid copepod) and two possible stygofauna taxa (Acarina and Rotifera) were found in the boreholes that targeted the shallow unconfined aquifer.

Potential Impacts and Mitigation Measures

Construction Phase

In the absence of mitigation measures the construction works associated with the Project could have the following effects:

> Runoff from areas of land that are disturbed and soil that is stockpiled during construction of the dewatering borehole facilities, downcast ventilation borehole and pipeline infrastructure could increase the sediment and contaminant load in the watercourses and swamps which, in turn, could have adverse impacts on water quality, availability of aquatic habitat and associated biota, including stygofauna associated with the shallow perched aquifer system;

> The upgrade and extension of the existing access tracks to the dewatering boreholes could lead to changes in the pattern of water flow, disturbance and erosion of stream banks and bed, removal of instream and riparian vegetation and if flow is obstructed affect movement of aquatic biota;

> Clearing of riparian vegetation at sites where the dewatering borehole facilities, downcast ventilation borehole and pipeline infrastructure will be installed could have indirect impacts on abundance, distribution and health of aquatic biota that use the vegetation as a habitat, refuge or source of food.

> Accidental release of lubricating oils, hydraulic fluids and fuel into watercourses and their infiltration into the shallow perched aquifer system via runoff could have ecotoxic effects on aquatic biota and stygofauna;

> Construction of dewatering boreholes could lead to discharge of groundwater to the surface and changes to the quantity and quality of surface water and contamination of water with drilling muds/fluids, drilling additives, oils and lubricants which may be toxic to aquatic biota and stygofauna;

Impacts associated with general construction could be minimised by:

> Limiting the area of riparian zone and aquatic habitat disturbed;

> Using measures specified in the Erosion and Sediment Control Plan to protect aquatic habitats and biota immediately downstream of the construction area;

> Establishing a bunded area for storage of fuels, oils, refuelling and appropriate maintenance of vehicles and mechanical plant.

Impacts associated with construction of dewatering boreholes would be minimised by selecting sites where environmental disturbance would be minimal, using biodegradable drilling muds, containing and removing any water discharged during drilling and bore development, equipping drilling rigs with spill response kits and training staff in spill response management.

Mining Operations

The extraction of the longwall panels will result in vertical and horizontal ground movements which could in turn cause a variety of physical impacts on watercourses and swamps. The information that is available on likely ground movements and physical impacts indicates there are unlikely to be any significant impacts on aquatic habitats and biota in the Wolgan River, Carne Creek or drainage lines. Fracturing of stream beds may occur, but this would be minor, shallow and isolated in nature (MSEC 2013). This could lead to drainage of overlying pools, loss of aquatic habitat and associated biota and loss of connectivity between pools. Such losses would not be important in ephemeral drainage lines, as aquatic habitat would be present only during flow events and for a short time thereafter. Weathering of freshly exposed fractures could result in increases in salinity and concentrations of some metals and reductions in dissolved oxygen levels. These impacts are expected to be localised and temporary persisting until the cracks are infilled and overtopping of flows is resumed. Increases in iron staining could result in smothering of the substratum and sessile biota, but this would extend only a short distance downstream from where the water re-emerges.

Longwall extraction can also affect groundwater discharge to and recharge from streams and their baseflows. Hydrogeological modelling indicates impacts would be smaller than the seasonal variation in baseflow. It is therefore highly unlikely that there would be any measurable effects on aquatic ecology.

Stygofauna could potentially be impacted by changes in groundwater availability and quality and physical disruption of aquifers during mining. The machinery used to construct underground roadways is likely to compact sediment, which could in turn reduce the size of interstitial spaces and voids in the underlying strata where stygofauna live and mobilise fine sediment. Hydrogeological modelling suggests that stygofauna associated with different aquifers will be subject to different forms of disturbance, with impacts being greater on those associated with deep aquifers, if such animals are present.

The proposed longwalls have been set back at least 460 m from the centreline of the Wolgan River to minimise the potential for subsidence. Impacts that do arise would be managed by:

> Periodic inspection of the watercourses and drainage lines for evidence of subsidence-induced impacts;

> Regular monitoring of the condition of aquatic habitats, quality of water and diversity of aquatic biota at potential impact sites and reference sites during and after mining

> A Trigger Action Response Plan for surface water and groundwater that would prompt studies of impacts on aquatic ecology if thresholds were exceeded;

> Remediation measures, such as grouting, would be used in areas where fracturing of stream or swamp beds leads to protracted diversion of stream flow and/or drainage of pools.

Mine Water Make Disposal

The water that accumulates in the underground mine workings will be managed by transferring it to the SDWTS and by discharge into the Coxs River via LDP009. The transfer of water to the SDWTS will result in a significant reduction in the potential impact of any discharges into the Coxs River. The discharge from LDP009, however, would increase during the life of the mine, with the largest volumes being released between 2019 and 2025.

The peak discharges would have moderate to significant effects on low flows, small to moderate effects on low to moderate flows and minimal to small effects on high flows. The changes in discharges before 2019 and after 2025 would be small and would thus have minimal impacts on river flow. The marked increase in discharge between 2019 and 2025 could exacerbate the existing erosion of the stream bank and channel and could lead to further downstream transport of sediment. Such impacts are likely to be short-lived and would be negligible relative to those that occur naturally during high flow events. The increase in dilution resulting from the greater flow may counteract the increase in turbidity and potential for flow-on effects on aquatic biota.

The peak discharges would result in a small to moderate increases in the availability of instream habitat, connectivity along the river and connection with adjoining riparian habitats during low and medium flows, but negligible changes during high flows. Continuous releases during low flow periods would increase the stability of aquatic habitats and make them more conducive for growth of aquatic macrophytes. Sudden increases in flow rate during low flow conditions could flush away potential instream habitat, but such impacts would be negligible relative to that which occurs naturally during high flow events. The change in the flow regime could potentially decrease the diversity and abundance of aquatic macroinvertebrates. The magnitude of change would depend on the volume and variability in the discharge and sensitivity of the taxa to flow.

The release of mine water make via LDP009 would change the quality of the water in the river at and downstream of the discharge point. EC, total dissolved solids, aluminium levels in the river would be increased. The greatest changes in salinity and hence potential for impact on aquatic biota would occur at the beginning and during the middle of the Project. The impacts would be greater if the SDWTS is upgraded, as this would result in more discharge to the river. The changes in salinity will not mimic those that occur naturally, with increases being more rapid and sustained and decreases being as sharp as some natural declines but sustained for longer. The aquatic biota will thus be exposed to salinity conditions they have not previously experienced. These may result in direct toxic effects on some organisms and indirect effects on others through modification of species composition of the ecosystem. In Australian freshwater systems direct adverse biological effects are unlikely to occur unless EC levels exceed 1,500 µS/cm. Although this suggests that the aquatic biota in the river is unlikely to be impacted by the salinities resulting from the discharge, the rapidity of the changes may be problematic.

Disposal of mine water make could also result in direct loss of any stygofauna inhabiting the water that accumulates in the mine workings and would reduce the volume of saturated sediments and the amount of potential habitat available to any remaining stygofauna.

The impact of the discharge of mine water make on instream ecology would be minimised by ensuring it meets the conditions specified in the Springvale's Environment Protection Licence 3607. It is also recommended that:

> Appropriate measures be used to minimise the potential for erosion and sedimentation at the licenced discharge point and on the Coxs River downstream thereof and that extent of erosion should be monitored regularly;
> Effects of changes in the quality of all constituents that are ecotoxic to aquatic biota and temperature of the receiving water should be taken into consideration;
> A literature review be undertaken to determine the likely impacts of abrupt and sustained changes in salinity and an aquatic ecology monitoring programme be implemented to determine their actual impact on aquatic flora and fauna.

Decommissioning and Rehabilitation Phases

During rainfall events, the aquatic biota in streams and drainages and stygofauna associated with the perched groundwater system could be impacted by runoff laden with sediment and contaminants such as fertilisers and herbicides. Sediment input into watercourses would be minimised by implementing temporary erosion and sediment controls measures specified in the Erosion and Sediment Control Plan. Runoff from rehabilitated areas may also be directed to sediment control retention ponds for treatment.

Aquatic biota could potentially be impacted when the existing water management structures (e.g. dams and ponds are dismantled, rehabilitated and natural drainage patterns restored. These structures would be decommissioned using procedures described in the Mine Closure Strategy for Springvale that would be prepared several years before mining ceased. Boreholes would be permanently sealed in accordance with the Minimum Construction Requirements for Water Bores in Australia.

Impacts on Threatened Species

The assessment of the significance of impacts indicated that if viable populations of Adams Emerald Dragonfly were present within the proposed workings area they could be subject to temporary, localised, minor impacts. It is consequently highly unlikely that the proposed mining would have a significant impact on this threatened species.

Cumulative Impacts

The headwaters of the Wolgan River have been disturbed by past mining activities at Angus Place and Springvale Collieries. The previous mining, however, did not result in significant fracturing or surface water flow diversions along the river and it is unlikely that extraction of the proposed Springvale and Angus Place workings will do so.

The headwaters and swamps along Carne Creek have not been disturbed by past or recent mining activities, but would be undermined by some of the proposed longwalls in the northern part of the proposed workings area. The creek could potentially be impacted by some construction activities associated with the Project and could in the future be affected by mine decommissioning and rehabilitation. Available information and the mitigation measures that will be implemented during decommissioning and rehabilitation phases indicate these activities are unlikely to have a significant impact on the instream ecology of Carne Creek.

These watercourses, their swamps and drainage lines could also have been impacted by forestry-based activities and public recreational activities that take place in Newnes State Forest. The magnitude and geographic extent of impacts arising from such activities is unknown and cannot therefore be assessed relative to that due to mining activities. The most likely source of impact is erosion and sediment-laden runoff which could reduce the quality of the water.

The discharge of mine make water into Coxs River could potentially result in further degradation of a system that has already been impacted by clearing of land, mining operations, urban and industrial development and construction of impoundments. The predicted peak outflow from the Springvale Mine would occur after completion of other mining projects in the Coxs River catchment, so the potential for cumulative impact is small.

Stygofauna associated with the perched surficial groundwater system could also have been impacted by past mining-related activities, including discharge of mine water and construction of roads and access paths, and by other activities that take place in Newnes State Forest. Past and present mining activities have also had a considerable impact on the level of water in the deep groundwater system, particularly in the Lithgow Seam, AQ1 and AQ4 and could therefore have had an impact on stygofauna, if any occur at these depths. Drawdown of the other bores that exist within 5 km and 10 km of the centre-point of the Project could have also had a cumulative impact on some aquifers. There is insufficient information available to determine the likelihood or magnitude of such impacts.

Conclusion

The aquatic ecology assessment indicates the extraction of coal would not have any significant impacts on aquatic habitats, aquatic flora or aquatic fauna, provided that appropriate measures to avoid, minimise and manage impacts for each phase of the Project are implemented. The discharge of mine water make will result in more rapid and sustained changes in salinity than occur naturally. Although the salinity level in the Coxs River would be below that likely to have adverse effects on aquatic biota, the rapidity and sustained nature of the changes may be problematic. The assessment of potential impacts on stygofauna is limited by the lack of information on their occurrence in the aquifers within the Project area, their response to environmental perturbations and likely conservation significance.

Table of Contents

Tables

Figures

Appendices

Glossary

Angus Place	Angus Place Colliery
ANZECC	Australia and New Zealand Environment and Conservation Council
aquatard	A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water
aquifer	A geological structure or formation that is permeated with water or is capable of being permeated with water.
AUSRIVAS	Australian River Assessment System (http://ausrivas.canberra.edu.au)
Catchment	The area of land upstream a point on a waterway from whence the passing water is derived. This includes all relevant main channels and tributaries as well as all surrounding land where water enters defined pathways. Where catchment is preceded by a creek/river name, the area is defined by the most downstream point on that named creek/river before the confluence with another named creek/river.
DEC	The former NSW Department of Environment and Conservation
DECCW	The former NSW Department of Environment, Climate Change and Water
DPI	NSW Department of Primary Industries
DSEWPAC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
EC	Electrical conductivity - a measure of the concentration of dissolved salts in water
EEC	Endangered ecological community
EIS	Environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2000 (NSW)
EPA	NSW Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). Provides for the protection of the environment, especially matters of national environmental significance and provides a national assessment and approvals process.
EPL	Environment Protection Licence
FM Act	Fisheries Management Act 1994 (NSW)
FMA Act	Fisheries Management Amendment Act 1997 (NSW)
I&I NSW	The former division of Industry and Investment NSW
LDP	A Licenced Discharge Point where wastewater is released in accordance with conditions specified within the site Environment Protection Licence.
LGA	Local government area
Macroinvertebrate (aquatic)	An animal without a backbone that spends all or part of its

	life in water that can be seen with the naked eye.
Mixing Zone	A region in a receiving water immediately adjacent to a licensed discharge point where concentrations are allowed to exceed water quality objectives so long as those objective are met outside of that region
MNES	Matters of national environmental significance. Refers to the eight matters of national environmental significance protected under the *EPBC Act* including wetlands of international importance and threatened flora, fauna and ecological communities
MPR	Marine Pollution Research Pty Ltd
NOW	NSW Office of Water
NTU	Nephelometric turbidity unit
OEH	NSW Office of Environment and Heritage
ORP (mV)	Oxidation Reduction Potential; a measure of a water system's capacity to release or gain electrons in chemical reactions
% sat	Percent saturation, a measure of the relative amount of dissolved oxygen in water
Percentile	The value of a variable (e.g. river flow) below which a certain percent of observations fall.
pH	A measure used to represent the acidity or alkalinity of an aqueous solution.
Phreatic	Relating to or denoting underground water in the zone of saturation (beneath the water table)
Project Application Area	Area within the red line in Figure 1-1 that includes all activities proposed as part of the Springvale Mine Extension Project
Project	The Springvale Mine Extension Project
Proposed Workings	Footprint of the area below which mining will occur
RBGS	Royal Botanic Garden, Sydney
RCE	Riparian, Channel and Environmental inventory
SDWTS	Springvale – Delta Water Transfer Scheme
SIGNAL2	Stream Invertebrate Grade Number Average Level (Version 2)
Springvale	Springvale Mine
Taxon (singular) Taxa (plural)	A taxonomic category or group, such as a family or a species
Threatened species	Includes all species with legislative protection under state and federal Acts, including threatened, vulnerable, endangered and critically endangered species under the FM act, TSC Act and EPBC Act
TSC Act	Threatened Species Conservation Act 1995 (NSW)
Turbidity	A measure of the clarity (turbidity) of water
µS/cm	Micro Siemens per cm; a common measure of electrical conductivity (the concentration of dissolved salts in the water)

1 Introduction

1.1 Purpose of the Report

Springvale Coal Pty Limited (Springvale Coal) proposes to extend its longwall mining operations to the east, the southeast and the southwest of its existing workings at Springvale Colliery (Springvale) located 15 km northwest of Lithgow. The location of the Springvale Pit Top, Project Application Area and proposed Mine Extension Area are shown in **Figure 1-1**.

The Springvale Mine Extension Project (referred to hereafter as the Project) is considered a State Significant Development in accordance with Clause 8 and Schedule 1 (Item 5) of State Environmental Planning Policy (State and Regional Development) 2011. Approval for The Project is being sought under Part 4 Division 4.1 of the Environmental Planning and Assessment Act 1979 (*EP&A Act*). The Director General of the Department of Planning and Infrastructure (DP&I) has indicated that an Environmental Impact Statement (EIS) is required to support the Development Application and the requirements for this were issued on 6 November 2012. The following assessment focuses on the potential impacts of the Project on the aquatic ecological attributes of streams and drainages downstream of swamps and on stygofauna (i.e. animals that are dependent on subterranean groundwater). The assessment has been prepared in support of the EIS being prepared by Golder Associates.

1.2 Project Overview

The Project will:

> Continue to extract up to 4.5 million tonnes per annum (Mtpa) of run of mine (ROM) coal from the Lithgow Seam.

> Develop underground access headings and roadways from the current mining area.

> Undertake secondary extraction by longwall mining of the proposed longwalls LW416 to LW432 and LW501 to LW503.

> Continue the use of existing ancillary surface facilities at the Springvale pit top.

> Continue to manage the handling of ROM coal through a crusher and screening plant at the Springvale pit top, and the subsequent loading of the coal onto the existing overland conveyor system for despatch to offsite locations;

> Continue to operate and maintain the existing ancillary surface infrastructure for ventilation, electricity, water, materials supply, and communications at the Springvale pit top and on Newnes Plateau;

> Install and operate two additional dewatering bore facilities (Bores 9 and 10) on Newnes Plateau and the associated power and pipeline infrastructure, and upgrade the existing and construct two new sections of access tracks to Bores 9 and 10 facilities;

> Construct a downcast ventilation borehole at the Bore 10 facility location;

> Establish a services borehole area;

> Upgrade the existing Springvale Delta Water Transfer Scheme (SDWTS) comprising construction of new sections of the trenched pipelines to increase the water delivery capacity of SDWTS from the existing 30 ML/day to up to 50 ML/day;

> Manage mine inflows using a combination of direct water transfer to the Wallerawang Power Station, via the SDWTS, and discharge through Angus Place Colliery's licensed discharge point LDP001 and Springvale Colliery's LDP009;

> Continue to undertake existing and initiate new environmental monitoring programs;

> Continue to operate 24 hours per day seven days per week;

> Continue to provide employment to a full time workforce of up to 310 persons;

> Progressively rehabilitate disturbed areas at infrastructure sites no longer required for mining operations;

> Undertake life-of-mine rehabilitation at the Springvale pit top and the Newnes Plateau infrastructure disturbance areas to create final landforms commensurate with the surrounding areas and the relevant zonings of the respective areas;

> Transfer the operational management of coal processing and distribution infrastructure to the proposed Centennial Western Coal Services Project.

The Project would extend the mine life by approximately 13 years.

A more detailed description of the Project is presented in Chapters 1 and 2 of the EIS (Golder Associates 2013).

1.3 Project Location

The Springvale Colliery Pit Top (Springvale) is located within the Lithgow Local Government Area (LGA) and is situated approximately 15 km north-west of the City of Lithgow (Springvale Coal 2012). The underground longwall mine is situated below a sandstone plateau of undulating bushland which is part of Newnes State Forest. Springvale is situated on the border of the upper catchment of the Wolgan River and the catchment of the Coxs River, which in turn are part of the Hawkesbury–Nepean and Sydney Catchment areas, respectively.

Springvale is bordered by Angus Place Colliery (Centennial Angus Place Pty Limited) to the north, various abandoned mines to the south and west, and by Newnes State Forest to the east. The land in the vicinity of Springvale Pit Top is used for residential purposes, pastoral farming, open cut and underground coal mining, power generation and commercial forestry.

1.4 Project Application Area

The Project Application Area encompasses:

> Springvale Pit Top and surface infrastructure situated off the Castlereagh Highway at Lidsdale;

> The existing workings and supporting infrastructure located directly below a sandstone plateau within an area of Newnes State Forest in the central northern portion;

> The proposed workings to the west of the existing workings.

1.5 Proposed Underground Workings

The proposed workings have been defined as the surface area that is likely to be affected by the extraction of the proposed LW416 to LW432 and LW501 to LW503 in the Lithgow Seam (MSEC 2013). The area includes the 26.5 degree angle of draw line from the extents of proposed LW416 to 432 and LW501 to 503 and the predicted 20 mm subsidence contour resulting from the extraction of the proposed longwalls.

The proposed workings are bordered by the existing Springvale Colliery longwalls (LW401-415) and abandoned State Mine Colliery and New State Mine Colliery to the east and by Newnes State Forest to the north and west. The proposed Angus Place Mine Extension Area would be located to the north-west.

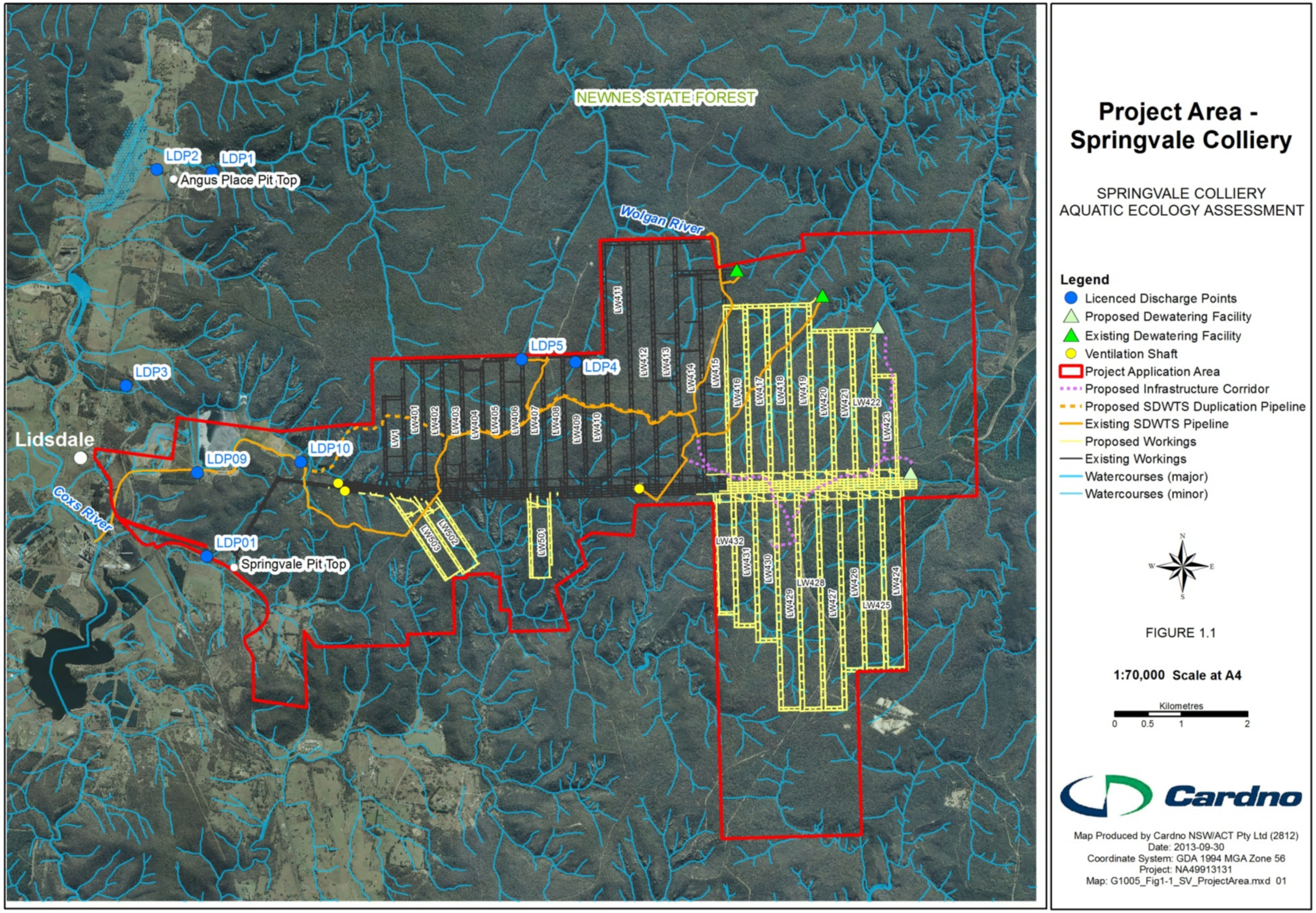

Figure 1-1 Map showing the location of the pit top, existing and proposed underground workings within the Springvale Project Application Area.

1.6 Scope of Works

The scope of works for the Aquatic Ecology and Stygofauna Assessment was determined by the requirements the Director General (DP&I) NSW Office of Water (NOW) and NSW Office of Environment and Heritage (OEH). The specific issues identified by the government agencies and the sections in this report where these are addressed are summarised in **Tables 1-1 - 1.3**.

Table 1-1 Director General's (DP&I) requirements pertinent to this assessment

Assessment Requirements	Relevant Section of this Report
Description of the existing environment, using sufficient baseline data.	4.2-4.7, 5.2-5.5 and 6.2-6.4
Assessment of the potential impacts of all stages of the development, including any cumulative impacts.	7.1-7 and 8.1-8.4.
Assessment of impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including GDEs and environmental flows.	7.1-7 and 8.1-8.4.
Detailed assessment of potential impacts of the development on aquatic threatened species or populations and their habitats, endangered ecological communities and GDEs	7.4
Description of measures that would be implemented to avoid, minimise and, if necessary, offset the potential impacts of the development.	7.1-7.7. and 8.1-8.4
Measures that would be taken to avoid, reduce or mitigate impacts on biodiversity, particularly that associated with Temperate Highland Peat Swamps;	7.1.-7.7 and 8.1-8.4
Offset strategy to ensure that the development maintains or improves aquatic biodiversity values of the region in the medium to long term.	None required

Table 1-2 NSW Office of Environment and Heritage's (OEH) requirements pertinent to this assessment

Assessment Requirements	Relevant Section of this Report
Identification and assessment of Matters of National Environmental Significance	3.1
Identification of national and state-listed threatened species that could potentially occur on the site and their conservation status	3.1-3.2
Description of survey methodology	4.1, 5.1, 6.2, 6.2.2
Likely impacts on biodiversity, native vegetation and habitat	7.1-7 and 8.1-8.4
Impact of quality, temperature and quality of discharged water on aquatic biodiversity	7.2.1.3
Impact of changes to groundwater levels	7.2 and 8.2
Likely impacts on threatened biodiversity	7.4
Measures to avoid, mitigate and manage impacts	7.1-7.7. and 8.1-8.4

Table 1-3 NSW Office of Water's (NOW) requirements pertinent to this assessment

Assessment Requirements	Relevant Section of this Report
Identification of potential groundwater-dependent ecosystems (GDEs)	3.3
Baseline monitoring of all groundwater and surface water dependent ecosystems within and adjacent to mining operation	4-6
Assessment of GDEs for condition and water quality and quantity requirements for aquatic ecosystems (macroinvertebrate, macrophytes, stygofauna)	4.6
Assessments of impacts on groundwater and surface water dependent ecosystems within and adjacent to mining operation	7.1-7 and 8.1-8.4
Mitigation measures to address impacts on groundwater and surface water dependent ecosystems during and after mining operations	7.1.-7.7 and 8.1-8.4
Monitoring to enable comparison with ongoing monitoring	7.2.2.1

1.7 Structure of the Report

This report is structured as follows:

> Section 2 - Legislative requirements, policies and guidelines that are relevant to the assessment of the potential effects of the Project on aquatic ecology and stygofauna;

> Section 3 - Conservation issues – identification of threatened species, populations and communities of national and state significance that may occur and groundwater-dependent ecosystems that do occur within the Project area;

> Section 4 - Existing Environment - Instream Ecology – description of aquatic habitats, water quality, aquatic plants and algae, aquatic macroinvertebrates and fish found at study sites in the Coxs River and Wolgan River catchments;

> Section 5 – Existing Environment – Aquatic Ecology of Drainages Downstream of Swamps – description of aquatic habitats, water quality, aquatic plants and algae, aquatic macroinvertebrates and fish found at study sites downstream of swamps located in the northern and southern parts of the proposed underground workings

> Section 6 – Existing Environment - Subterranean Aquatic Ecosystems – description of groundwater systems in the vicinity of the Project, and results of groundwater quality and stygofauna sampling undertaken in these systems;

> Section 7 - Potential Impacts on Aquatic Ecology and Avoidance, Mitigation and Management Measures - description of the magnitude and nature of possible direct, indirect and cumulative impacts arising during the construction, operational, decommissioning and rehabilitation phases of the Project and measures that could be taken to avoid, minimise or manage such impacts.

> Section 8 - Potential Impacts on Stygofauna and Management Measures

> Section 9 - Conclusions about the effect of the Project on aquatic ecology and stygofauna;

> Section 10 - Literature Cited – a list of the reports, scientific publications and other documents used to support statements made.

2 Legislative Requirements, Guidelines and Policies

2.1 Legislative Requirements

2.1.1 Development Applications

The Project has been declared a State Significant Development and will therefore be assessed under Division 4.1, Part 4 of the *EP&A Act*. The development application must be accompanied by an Environmental Impact Statement (EIS) that addresses the issues specified in the Director-General's Requirements (DGRs) issued on 6 November 2012. One of the requirements relevant to the ecological studies supporting the EIS is that specific factors and assessment guidelines must be taken into account when deciding whether the Project is likely to have a significant effect on threatened species, populations or ecological communities, as defined under the Threatened Species Conservation Act (*TSC Act*) 1995 and the Fisheries Management Act 1994 (*FM Act)*. The factors to be considered are specified in Section 5A of the *EP&A Act* and constitute what was previously known as the 8-part test, but is now referred to as the Assessment of Significance. The factors relevant to consideration of effects on threatened species, for example, are:

1. Whether the proposed action is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction;
2. The extent to which the species habitat is likely to be removed or modified as a result of the action proposed, whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and whether the habitat to be removed, modified, fragmented or isolated is important to the long-term survival of the species in the locality;
3. Whether the proposed action is likely to have an adverse effect on critical habitat (either directly or indirectly;
4. Whether the proposed action is consistent with the objectives or actions of a recovery plan or threat abatement plan;
5. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

Similar factors need to be considered when assessing effects on threatened populations and ecological communities.

Division 4.1, Part 4 of the *EP&A Act* also indicates some of the authorisations required under other Acts do not apply to State Significant Developments. These include provisions under the *FM Act* with respect to permits for dredging and reclamation work, harm to marine vegetation and no blockage of fish passage. The controlled activity approval under Section 91 of the Water Management Act 2000 that confers a right on its holder to carry out a specified controlled activity at a specified location in, on or under waterfront land, is also not required. An aquifer interference approval that confers a right on its holder to carry out one or more specified aquifer interference activities at a specified location, or in a specified area, in the course of carrying out specified activities, however, may be required.

2.1.2 Threatened Species, Populations and Communities

Threatened freshwater species, populations and communities are listed under the Environmental Protection and Biodiversity Conservation Act 1999 (*EPBC Act*) administered by the Federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC), the NSW Threatened Species Conservation Act 1995 (*TSC Act*) administered by the NSW Office of Environment and Heritage (NSW OEH), and NSW Fisheries Management Act (*FM Act*) 1994 (including Fisheries Management Amendment Act 1997), administered by the NSW Department of Primary Industries NSW (DPI).

The *EPBC Act* provides a legal framework for the protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places. It also includes provisions for nationally threatened species of plants, fish, birds, frogs, reptiles, mammals and other animals. These conservation assets are referred to collectively as Matters of National Environmental Significance (MNES). DSEWPAC is also responsible for the development and implementation of recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the *EPBC Act*.

The *TSC Act* provides for the conservation of species, populations and ecological communities of animals and plants in NSW that are threatened with extinction. This Act also contains provisions for the preparation of recovery plans for listed threatened species, populations and ecological communities, the declaration and mapping of habitats that are critical to their survival and threat abatement plans to manage key threatening processes. The *TSC Act* also provides for the facilitation of the appropriate assessment, management and regulation of actions that may damage critical or other habitat or significantly affect threatened species, populations and ecological communities. It also contains provisions related to Biodiversity Banking and offsets. The provisions of this act apply to algae, aquatic plants, invertebrates and all the major vertebrate groups except fish.

The *FM Act* contains provisions for the conservation of fish stocks, key fish habitat, biodiversity, threatened species, populations and ecological communities of fish and marine vegetation and the development and sharing of the fishery resources of NSW for present and future generations.

2.1.3 Key Threatening Processes

Key Threatening Processes (KTPs) that threaten or may threaten the survival or evolutionary development of threatened species, population or ecological community are listed under the *EPBC Act*, *TSC Act* and *FM Act*.

2.1.4 Protected Species

Native fauna and flora are also protected under the NSW National Parks and Wildlife Act 1974 (*NP and W Act*) administered by the Office of Environment and Heritage (OEH).

2.1.5 Critical Habitat

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations and ecological communities. Registers of critical habitats are maintained by OEH and DPI.

2.1.6 Key Fish Habitat

One of the objectives of the *FM Act* is to conserve key fish habitats. These are defined as aquatic habitats that are important to the sustainability of recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species. In freshwater systems, most permanent and semi-permanent rivers, creeks, lakes, lagoons, billabongs, weir impoundments and impoundments up to the top of the bank are considered key fish habitats. Small headwater creeks and gullies that flow for a short period after rain and farm dams on such systems are excluded, as are artificial waterbodies except for those that support populations of threatened fish or invertebrates.

The DPI NSW map showing the distribution of key fish habitats within the Lithgow LGA indicates the reaches of the Coxs River, Wolgan River, Kangaroo Creek and Carne Creek that traverse the Project Application Area are considered key fish habitats.

2.1.7 Discharges to the Aquatic Environment

The release of discharges from Springvale Mine to the aquatic environment via Licenced Discharge Points (LDPs) is regulated through Environment Protection Licence (EPL) No. 3607 issued under the Protection of the Environment Operations Act 1997 (*POEO Act*). The objectives of the *POEO Act* are to protect, restore and enhance the quality of the environment. These objectives are achieved by reducing pollution at source, monitoring and reporting of environmental quality. An EPL is a means by which the impact of a scheduled activity on the environment is regulated. The EPL identifies the type of discharge point and their location and specifies volume/mass limits for each discharge point and concentration limits for specific pollutants at each LDP. The EPL also specifies monitoring frequency and methods that should be used to monitor the key pollutants, and pollution studies and reduction programs that must be implemented. The latest version of the EPL issued on 21 May 2013 indicates discharges to the aquatic environment may occur through LDP001, LDP004, LDP005, LDP006, LDP007, LDP009 and LDP010. LDP001 is the main discharge point of the pit top facilities (**Figure 1-1**). LDP004 and LDP005 are emergency discharge points from dewatering bores to an unnamed creek that drains into the Wolgan

River. LDP006 and LDP007 are situated outside of the Project Area. LDP009 is Centennial's Springvale Water Transfer System (WTS) bypass point east of Kerosene Vale Ash Dam. LDP010 is for emergency/maintenance discharge from Centennial's Springvale Water Transfer Scheme upstream of the settling ponds.

2.2 Guidelines and Policies

2.2.1 NSW Office of Water Guidelines for Controlled Activities

Approval is required under the Water Management Act 2000 (*WM Act*) for certain types of developments and controlled activities that are carried out in or near a river, lake or estuary. Four types of controlled activities are recognised:

- Erection of a building or the carrying out of a work (within the meaning of the Environmental Planning and Assessment Act 1979); or
- Removal of material or vegetation from land, by way of excavation or other means;
- Deposition of material on land as a result of landfill operations or other means;
- Carrying out any other activity that affects the quantity or flow of water in a water source.

The NSW Office of Water, the agency responsible for administering the *WM Act*, has developed guidelines to assist applicants who are considering carrying out controlled activities on waterfront land (i.e. the land within 40 m of the highest bank of the river, lake or estuary). These guidelines provide information on the design and construction of a controlled activity, and other mechanisms for the protection of waterfront land. The following guidelines are relevant to the potential effects of the proposed pipeline on aquatic ecology:

- Laying pipes and cables in watercourses (NSW Office of Water 2010a);
- Riparian corridors (NSW Office of Water 2011a);
- In-stream works (NSW Office of Water 2010b); and
- Outlet structures (NSW Office of Water 2010c).

The controlled action guidelines are government policy and will be promoted by the NSW Office of Water within any assessment process, and hence the assessment of the Springvale Mine Extension Project will require consideration of NSW Office of Water guidelines.

2.2.2 NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management

The DPI Policy and Guidelines for Fish Habitat Conservation and Management (2013) is an update of the Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (NSW Fisheries 1999). The new document also incorporates the requirements of the former Fisheries NSW Policy and Guidelines for Fish Friendly Waterway Crossings (2003) and two Fish Habitat Protection Plans No. 1 (General) and 2 (Seagrasses), which are in the process of being revoked.

The aims of the updated policies and guidelines are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species, in marine, estuarine and freshwater environments. The updated document assists developers, their consultants and government and non-government organisations ensure their actions comply with the legislation, policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed or offset. The policies and guidelines outlined in this document are taken into account when NSW DPI assesses proposals for developments and other activities that affect fish habitats.

The document contains:

> Background information on aquatic habitats and fisheries resources of NSW;

> An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitats in NSW;

> General policies and classification schemes for the protection and management of fish habitats and outlines the information that NSW DPI requires be included in development proposals that affecting fish habitats;

> Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish around in-stream structures and barriers;

> Specific policies and guidelines for foreshore works and waterfront developments;

> Specific policies and guidelines for the management of other activities affecting waterways.

The document indicates NSW DPI will consider the ‘sensitivity’ of any key fish habitats that will be affected by the Project. The term ‘sensitivity’ refers to the importance of the habitat to survival of the fish and its ability to withstand disturbance. In freshwater ecosystems, instream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, and native aquatic plants, and areas known or expected to contain threatened and protected species are considered to be highly sensitive key fish habitats. Other freshwater habitats plus weir pools and dams across natural waterways are considered to be moderately sensitive key fish habitats. Ephemeral aquatic habitat that does not support native aquatic or wetland vegetation is considered to be of minimal sensitivity. It is important to note that aquatic habitats within first and second order streams on gaining streams, sections of stream that have been concrete-lined or piped (but excluding waterway crossings) and artificial ponds are not regarded as key fish habitat unless they support listed threatened species, population or ecological community or ‘critical habitat’. NSW DPI may in addition assess development proposals in relation to waterway class (i.e. their ability to provide habitat that is suitable for fish).

The general policies and /or guidelines and sections that are likely to be relevant to the current Project include:

> Riparian and freshwater aquatic vegetation (Section 3.2.4.2);

> Snag management (Section 3.2.5.2);

> Habitat rehabilitation and environmental compensation (Section 3.3.3.2);

> Maintaining and enhancing the free passage of fish in NSW waters (Section 4.1.2);

The specific policies and guidelines that may be relevant include:

> Design and construction of waterway crossings (Section 4.2.2);

> Temporary instream structures (e.g. coffer dams, construction pads, sediment erosion booms) (Section 4.5.2);

> Instream rehabilitation works (Section 4.6.2);

> Instream structure removal (Section 4.7.2);

> Minimizing water pollution (Section 6.5.2).

2.2.3 NSW State Groundwater Dependent Ecosystems Policy

The NSW Groundwater Dependent Ecosystems Policy (DLWC 2002) is designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of their dependent ecosystems are maintained or restored, for the benefit of present and future generations. The document provides guidance on the protection and management of groundwater-dependent ecosystems (GDEs) and includes information on:

> The location of groundwater systems in NSW;

> Different types of GDEs;

> Value of and threats to GDEs;

> The principles that underpin the management of GDEs;

> Policies and legislation relating to management of GDEs, including how policy will be implemented and reviewed.

The species composition and natural ecological processes within some ecosystems (e.g. wetlands, red gum forests, limestone caves, springs, hanging valleys and swamps) are dependent on water that has filtered down below the surface of the earth and is held in rocks, gravel and sand. In NSW, groundwater often provides the base flows in rivers and streams after rainfall events that appears as springs or as diffuse flows from saturated sediments or rock underlying the watercourse or its banks.

2.2.4 NSW Aquifer Interference Policy

The Aquifer Interference Policy (Policy) explains the role and requirements of the Minister administering the *WM Act* in the water licensing and assessment processes for aquifer interference activities under the *WM Act* and other relevant legislative frameworks (NSW DPI 2012a). The term aquifer interference as defined under the *WM Act* refers to the following:

> Penetration of an aquifer;

> Interference with water in an aquifer;

> Obstruction of the flow of water in an aquifer;

> Taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and

> Disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The Policy is applicable to all aquifer interference activities but has been specifically developed to address high risk activities. Mining operations such as open cut voids, underground mine workings and the disposal of water taken from an aquifer including water taken as part of coal seam gas extraction are considered high risk activities. The Policy outlines the requirements under NSW Legislation for obtaining water licences for aquifer interference activities, explains how development applications under Part 4, Division 4.1 and Part 5.1 of the *EP&A Act* will be assessed and specifies the factors that must be taken into consideration when assessing the potential effects of groundwater interference activities on an aquifer and its dependent assets, including ecosystems.

The framework for assessing the impacts of aquifer interference activities on water resources indicates the proponent will need to:

> Demonstrate their ability to obtain the necessary licences in order to account for the take of water from any relevant water source or that appropriate mitigation or avoidance strategies would be used to reduce the take of water to a point where it can be accounted for;

> Indicate adequate arrangements will be implemented to ensure that the minimal impact considerations specified in the policy can be met;

> Propose remedial actions for impacts greater than those that were predicted as part of the relevant approval.

Minimal impact considerations have been developed for impacts on each of the highly productive and less productive groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users. Two levels of minimal impact considerations have been specified. Predicted impacts that are less than the Level 1 minimal impact considerations will be considered to be acceptable. Predicted impacts that exceed the Level 1 thresholds by no more than the accuracy of an otherwise robust model, will be considered within the range of acceptability, provided that extra monitoring and mitigation or remediation is undertaken if required. In this case, appropriate conditions may be imposed to ensure the impacts of the activity are acceptable. If the predicted impacts exceed the Level 1 minimal impact considerations by more than the accuracy of an otherwise robust model, additional studies will be required to fully assess the predicted impacts. If the subsequent assessment shows that the predicted impacts would not prevent the long-term viability of the relevant water-dependent asset, the impacts will be considered to be acceptable.

The policy also describes the information the proponent would need to supply to enable the aquifer interference activity to be assessed against the minimal impact considerations. This includes:

> Establishment of baseline groundwater conditions including depth, quality and flow based on sampling of all existing and future bores in the area potentially affected by the activity;

> Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;

> Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;

> Potential for river bank instability, or high wall instability or failure to occur.

The policy also indicates the likely conditions of approval for projects and that a security deposit may be required to cover the costs of remediation works for unforseen impacts or ongoing post-closure activities.

2.2.5 NSW Office of Water's Risk Assessment Guidelines for GDEs

NOW and OEH have developed comprehensive risk assessment guidelines to manage the effects of land and water use activities on GDEs. These guidelines are available in four volumes:

Volume 1 - Risk assessment guidelines for groundwater dependent ecosystems – the conceptual framework;

Volume 2 – Risk assessment guidelines for groundwater dependent ecosystems. Worked examples for seven pilot coastal aquifers;

Volume 3 – Identification of high probability groundwater dependent ecosystems on the Coastal Plains of NSW and their ecological value;

Volume 4 – The ecological value of groundwater sources on the Coastal Plains of NSW and the risk from groundwater extraction.

The conceptual framework (Serov *et al.* 2012) provides the following:

> Definitions of groundwater, GDEs and high priority GDEs;

> A classification of different types of GDEs;

> An description of the relevant policy and legislative framework;

> Information on ecological valuation and risk assessment process and activities that threaten aquifers and/or their associated GDEs;

> A method for determining the ecological value of an aquifer and associated GDEs to assist in reporting against the state-wide Target for Groundwater;

> A method for assessing the risk of an activity to the ecological value of an aquifer and associated GDEs;

> A method for developing management strategies for aquifers and identified GDEs based on a Risk Matrix Approach;

The accompanying appendices contain background information, including:

> A method to identify the type and location of GDEs within an aquifer or defined area;

> A method for inferring the groundwater dependency of identified ecosystems;

> A description of surface and subsurface activities that threaten aquifers and associated GDEs.

This Volume 4 of the guidelines is the most relevant to the Project. The others show how the framework has been applied to groundwater resources and GDEs on the Coastal Plain.

3 Conservation Issues

In this section, threatened aquatic species, populations and communities of national and state significance that may occur in the Project area are identified. Information on the occurrence of threatened amphibians, terrestrial fauna and flora and migratory species and assessments of potential impacts on these are presented in the report prepared by the specialist terrestrial consultant (RPS 2013a).

The potential impacts of the construction, operation, decommissioning and rehabilitation phases of the Project and measures for avoiding, minimising and managing such impacts on threatened aquatic species, populations and communities are discussed in Section 7.

3.1 Matters of National Environmental Significance

3.1.1 Methods

The Protected Matters Search Tool, a database maintained by DSEWPAC, was used to identify threatened aquatic species and communities of national environmental significance that occur or may occur in the Lithgow LGA. A search was undertaken over the entire LGA to ensure that mobile, threatened species that may periodically move into the Project Application Area were taken into consideration.

3.1.2 MNES identified and their Likelihood of Occurrence

3.1.2.1 Threatened Species

The Protected Matters Search Tool indicated that three threatened fish species listed under the *EPBC Act* may occur or suitable habitat for them may occur within the Lithgow LGA. Two of these species, Australian Grayling (*Prototroctes maraena*) and Murray Cod (*Maccullochella peelii*) are considered to be vulnerable to extinction, whilst the third, Macquarie Perch (*Macquaria australasica*), is endangered.

The Australian Grayling occurred historically in coastal streams from the Grose River, west of Sydney, southwards through NSW and Victoria (DSEWPAC 2013). The Australian Grayling is diadromous and requires access to freshwater, estuarine and marine habitats to complete its life cycle. The construction of dams, weirs and other barriers to fish passage has had a major impact on their populations in some river systems. It is currently found in streams and rivers, on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria (NSW DPI 2006a). The records on the NSW DPI Record Viewer indicate that this species does not occur north of Wollongong. Its identification by the Protected Matters Search Tool therefore probably reflects its historical distribution.

Murray Cod are endemic to the Murray-Darling River system, but both hatchery-bred and wild-caught individuals have been translocated and stocked outside this natural distribution range. This species has been recorded in the Hawkesbury-Nepean Catchment, but the records are all from coastal rivers and represent stocked fish (NSW DPI 2006b). This species has been found in flowing and standing waters, including small, clear, rocky streams on the inland slopes and uplands of the Great Diving Range, to large, turbid, meandering slow-flowing rivers, creeks, anabranches, and lakes and larger billabongs, of the inland plains of the Murray Darling Basin (National Murray Cod Recovery Team 2010). Murray Cod are usually found in association with large rocks, large snags and smaller structural woody habitat, undercut banks and over-hanging vegetation, but also frequent the main river channel and larger tributaries and anabranches.

The NSW DPI Fish Record Viewer indicates Macquarie Perch has been recorded in the Capertee River, Colo River, lower Coxs River, Warragamba Dam and other parts of the Hawkesbury-Nepean River system. NSW DPI has also caught this species in the Wolgan River (Cumberland Ecology 2006), but this is not reflected on Record Viewer. The 2010 Audit of the Sydney Drinking Water Catchment indicates Macquarie Perch have also been recorded in the mid Coxs River (DECCW 2010). Macquarie Perch are found in rivers and lakes, but particularly the upper reaches of rivers and their tributaries. This species prefers clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (DSEWPAC 2010). They spawn in spring or summer and lay their eggs in shallow, fats-flowing water over stones and gravel in shallow upland streams or flowing parts of rivers. The impoundments at Lake Lyell and Lake Wallace would prevent fish in the lower and mid Coxs River from accessing the upper reach of the river adjacent to the Project Application Area.

The current distribution ranges of Murray Cod, Australian Grayling and Macquarie Perch indicate they are highly unlikely to occur in the Project Application Area. The cascades between the Newnes Plateau and Wolgan Valley would also pose a formidable barrier to upstream passage of these species if they were present in the lower Hawkesbury-Nepean Catchment. The watercourses overlying the Project Application Area do not contain the sorts of habitats that are preferred by these species and are unlikely to contain sufficient prey for an apex predator like Murray Cod. In view of this, the preparation of assessments of the significance of impacts for these species is considered unnecessary.

3.1.2.2 Endangered Ecological Communities

Two plant communities, Newnes Plateau Shrub Swamps (Shrub Swamps) and Newnes Plateau Hanging Swamps (Hanging Swamps) found within and adjacent to the proposed workings are components of the Temperate Highland Peat Swamps on Sandstone Endangered Ecological Community (EEC) listed under the *EPBC Act*. Activities that are likely to have a significant impact on the endangered ecological communities protected under the *EPBC Act* must be referred to the DSEWPAC Minister for assessment and approval.

Shrub Swamps are narrow, elongated swamps found primarily in the shallow headwaters of Triassic Narrabeen sandstone catchments on the Newnes Plateau at altitudes varying from around 900 m to 1200 m (OEH 2011). These swamps have deep sandy organic sediments that are permanently to periodically waterlogged. The vegetation is dominated by shrubs such as *Baeckea linifolia*, *Boronia deanei*, *Grevillea acanthifolia*, *Epacris* sp. and *Leptospermum* sp. The understorey is composed mainly of sedges, particularly *Baloskion australe*, *Empodisma minus*, *Lepyrodia scariosa* and *Lepidosperma limicol*a. Pouched Coral Fern (*Gleichenia dicarpai*) and Button Grass (*Gymnoschoenus sphaerocephalus*) are sometimes found around the drainage lines and Spiny-headed Mat Rush (*Lomandra longifolia*) may be common around the edge of the swamp. Shrub Swamps have low gradients and typically have low velocity surface water flows and high water retention (Centennial Coal October 2012). This community is sustained by direct rainfall recharge and/or rainfall interflow which is prevented from infiltrating deep into the sandstone sediments by underlying low permeability clay /siltstone beds, bands and lenses (RPS 2013b).

Hanging Swamps are found at the head of gullies and ridge top sites at altitudes ranging from 900 - 1170 m where the groundwater that percolates through Triassic Narrabeen sandstone is forced outwards by impermeable shale layers (DEC 2006). The soils associated with these swamps consist of permanently saturated peat and humic loams. They support a variety of swamp heath plants, with the uppermost stratum including sparse and often stunted mallee, tea tree and banksias and lowest stratum being characterised by a dense, almost impenetrable mixture of coral fern (*Gleichenia*), umbrella fern (*Sticherus*) and large saw-sedge (*Gahnia sieberiana*). This community is sustained by the continuous seepage of water from the rock. The base of Hanging Swamps is generally steeper so they retain less water than Shrub Swamps (RPS 2013ba).

RPS (2013a) indicates 8 Shrub Swamps and 22 Hanging Swamps occur within the area encompassed by the proposed workings. Four Shrub Swamps associated with the headwaters of Carne Creek occur within the northern part of the proposed workings: Sunnyside East Swamp, Carne West Swamp, Gang Gang Swamp South West and Gang Gang Swamp East. Six Shrub Swamps occur within or adjacent to the southern part of the proposed: Marrangaroo Creek Swamp, Marrangaroo Upper Swamp, Paddys Creek Swamp, Pine Swamp Upper and Pine Swamp. Paddys Creek, Pine and Nine Mile Swamp extend beyond the eastern boundary of the Mine Extension Area. There are also several Shrub Swamps situated just outside the proposed workings, including Carne Central Swamp and Barrier Swamp to the east of the northern part and Sunnyside Swamp to the west.

3.2 Matters of State Conservation Significance

3.2.1 Methods

A search for information regarding records and distribution of threatened and protected species of fish in the Lithgow LGA and Hawkesbury-Nepean CMA was undertaken using the online Record Viewer developed by the Threatened Species Unit of the former I&I NSW.

A second online search facility, NSW BioNet managed by OEH's Wildlife Unit, was used to search for records of flora and fauna sightings within Lithgow LGA held in the Atlas of NSW Wildlife. This Atlas contains records of plants, mammals, birds, reptiles, amphibians, some fungi, some invertebrates (such as insects and snails listed under the *TSC Act* and some fish). The Atlas was also searched for information on known and predicted distributions of vegetation communities, endangered populations and key threatening processes listed under the TSC Act occurring within the Lithgow LGA.

3.2.2 Threatened Species and their Likelihood of Occurrence

According to Record Viewer, the Macquarie Perch is the only threatened fish species listed under the *FM Act* to have been recorded in the Lithgow LGA. This record is for a specimen caught in the Capertee River in 2006. A search for records of this species over the entire Hawkesbury-Nepean Catchment Management Area revealed it had been found in Warragamba Dam and the lower Coxs River in 1994 and in the Colo River in 2007. The 2010 Audit of the Sydney Drinking Water Catchment indicates Macquarie Perch have also been recorded in the mid Coxs River (DECCW 2010). The wider geographic search indicated that two other threatened fish species (Silver Perch and Trout Cod) listed under the *FM Act* have been recorded in the Hawkesbury-Nepean catchment, however, these records are all from coastal rivers and represent stocked fish (NSW DPI 2006b). The current distribution ranges of Murray Cod, Australian Grayling and Macquarie Perch indicate they are highly unlikely to occur in the Project Application Area. The cascades between the Newnes Plateau and Wolgan Valley would also pose a formidable barrier to upstream passage of these species if they were present in the lower Hawkesbury-Nepean Catchment. The impoundments at Lake Lyell and Lake Wallace would also prevent the Macquarie Perch occurring in the lower Coxs River from accessing the upper reach of the river adjacent to the Project Application Area. The watercourses overlying the Project Application Area do not contain the sorts of habitats that are preferred by these species and are unlikely to contain sufficient prey for an apex predator like Murray Cod. In view of this, the preparation of assessments of the significance of impacts for these species is considered unnecessary.

The expected distribution ranges of Adams Emerald Dragonfly (*Archaeophya adamsi*) and Sydney Hawk Dragonfly (*Austrocordulia leonardi*), listed as endangered species under the *FM Act,* include the Hawkesbury-Nepean catchment. Both dragonflies are extremely rare having been collected from only a few localities, suggesting that their distribution is highly localised. The Sydney Hawk Dragonfly is known to occur at three locations between Audley and Picton to the south of Sydney and in the Hawkesbury-Nepean, Georges River and Port Hacking drainages (NSW DPI 2007). The predicted distribution range of this species, however, does not extend much beyond Penrith (NSW DPI 2007), so it is highly unlikely to occur in the Project Area. The Adams Emerald Dragonfly has been collected from four localities near Sydney: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Tunks Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains and Hungry Way Creek in Wollemi National Park. The larvae of this species have been found in narrow, shaded riffle zones with moss and abundant riparian vegetation in small creeks with gravel or sandy bottoms (NSW DPI 2012b). As the macroinvertebrate surveys undertaken in the Project Application Area are limited in frequency, spatial extent, duration and intensity but suitable habitats for this species are present, the possibility of Adams Emerald Dragonfly being present cannot be discounted. An Assessment of Significance has therefore been prepared as a precautionary measure (see Section 7.5).

The search undertaken using NSW Bionet showed that one endangered semi-aquatic invertebrate species, the Giant Dragonfly (*Petalura gigantea*), listed under the *TSC Ac*t has been recorded in the Lithgow LGA. The Giant Dragonfly is considered to be an obligate groundwater dependent mire (peat-forming wetland) dwelling species, because its breeding success is dependent on sites with a groundwater regime that provides enough surface moisture to minimise desiccation of eggs and early larval instars, supports peatland soils suitable for burrowing by larvae, and that have a water table height that allows larvae to access or extend their burrows (Benson and Baird 2012). This species is typically found in permanent swamps and bogs containing some free water and open vegetation (NSW Scientific Committee, 2004). The Giant Dragonfly has been recorded in a number of swamp or mire types in the Blue Mountains region, including the Newnes Plateau Shrub Swamps (Baird 2012). This species has been recorded in several Shrub Swamps within the Project Application Area, including Carne West, Gang Gang West and Gang Gang East Swamps (Benson and Baird 2012). It has also been recorded in Long Swamp on the upper Coxs River (Baal Bone Colliery 2012). Potential habitat for this dragonfly has been identified in other swamps within the area, including Carne Central and Sunnyside East. RPS (2013a) concluded that the Giant Dragonfly is likely to occur within the proposed workings but has prepared an Assessment of Significance for this species.

3.2.3 Threatened Populations

Three threatened populations of freshwater fish are listed under the *FM Ac*t. The distribution range of these populations does not include the watercourses that traverse the Project Application Area. No threatened populations of aquatic organisms are listed under the *TSC Act*.

3.2.4 Threatened Communities

Newnes Plateau Shrub Swamps in the Sydney Basin Bioregion is the only EEC listed under the *TSC Act* that is present within the Project Application Area. Eight Shrub Swamps are located within the area of the proposed workings (see Section 3.1.2.2 for more details).

The distribution range of the four EECs listed under the *FM Act* does not include the watercourses that traverse the Project Application Area.

3.2.5 Key Threatening Processes

The Key Threatening Processes (KTPs) listed under the *FM Act* that may be relevant to the effects of the Project on aquatic ecology are:

> Degradation of native riparian vegetation along New South Wales watercourses;

> Instream structures and other mechanisms that alter natural flows;

> Removal of large woody debris from New South Wales rivers and streams (if required).

The following KTPs listed under the *TSC Act* may also be relevant:

> Alteration of habitat following subsidence due to longwall mining;

> Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands.

None of the KTPs listed under the *EPBC Ac*t are relevant to the Project.

3.2.6 Protected Species

Australian Grayling, one of the threatened fish species listed under the *EPBC Act* as potentially occurring in the Lithgow LGA, is listed as a protected species under the *FM Act*. The information on its current distribution range presented in Section 3.1.2.1 indicates this species is highly unlikely to occur within the Project Application Area.

The search of the Bionet website for the Atlas of NSW Wildlife indicated that two semi-aquatic mammals, the platypus (*Ornithorhynchus anatinus*) and water rat (*Hydromys chrysogaster*), that are listed as protected under the *NP&W Act* occur within the Lithgow LGA. There are, however, no records of either species occurring within the Project Application Area or Newnes State Forest.

3.2.7 Wild Rivers

Wild Rivers are rivers that are in near-pristine condition in terms of animal and plant life and water flow, and are free of the unnatural rates of siltation or bank erosion that affect many of Australia's waterways. In NSW, Wild Rivers may be declared within national parks and other reserves that are protected under the *NP&W Act*. The declaration of 'wild rivers' ensures that their high conservation values are maintained and that Aboriginal objects and places associated with them are identified, conserved and protected. The Colo River and its four sub-catchments (Wolgan, Capertee, Colo, Wolgan and Wollemi) is one of the river systems declared a Wild River in 2008 (DECCW 2008). The Colo Wild River Assessment, however, recommended that only the section of the Wolgan River to its intersection with (and including) Rocky Creek and their tributaries be declared a Wild River. This section of the river is downstream of the Project Application Area.

3.2.8 Critical Habitat

None of the critical aquatic habitats listed under the *TSC Act* or *FM Act* are found within the Project Application Area.

3.3 Groundwater Dependent Ecosystems

The definition and classification of GDEs adopted in this report are those from the *Risk Assessment Guidelines for GDEs* produced by the NSW Office of Water (Serov *et al. 2012*). GDES are ecosystems in which the species composition and natural ecological processes are wholly or partially determined by groundwater. The classification scheme recognises three broad types of GDEs associated with underground ecosystems:

- Karst and caves;
- Subsurface phreatic aquifer ecosystems;
- Baseflow stream (hyporheic or subsurface water ecosystems);

and four broad types of GDES associated with above ground ecosystems:

- Groundwater dependent wetlands;
- Baseflow streams (surface water ecosystems);
- Estuarine and near shore marine ecosystems; and
- Phreatophytes – Groundwater dependent terrestrial ecosystems.

Each of these GDE types comprises a number of distinct subtypes.

The Project could potentially impact on three GDEs: baseflow streams, groundwater dependent wetlands and subsurface phreatic aquifer ecosystems.

4 Existing Environment – Aquatic Ecology of Streams

In this section, information is presented on the physical setting and aquatic ecology of the three watercourses, Wolgan River, Carne Creek and Coxs River, that could potentially be impacted by the Springvale Mine Extension Project. The section of the Wolgan River situated to the west of the proposed workings and three headwater sub-catchments of ones of its tributaries, Carne Creek, situated above the proposed workings have been included in this assessment because they may experience valley related movements and could be sensitive to such movements (MSEC 2013). The Wolgan River catchment has in the past received inflows from two emergency discharge points (LDP004 and LDP005) which are situated on an unnamed tributary. The section of the Coxs River situated to the east of the Project Application Area and above Lake Wallace has been included because some of the water that accumulates in the proposed underground workings may be released into it via Springvale's Licenced Discharge Point LDP009, if it cannot be transferred to Wallerawang Power Station (WPS) via the SDWTS.

The information presented on the aquatic ecology of the sections of these watercourse within and adjacent to the Project Application Area has been compiled from a series of reports on the outcomes of the baseline aquatic ecology monitoring program undertaken by MPR (2010, 2011a and 2011b; 2012a and 2012b, 2013). A brief outline of the sites and methods used in the baseline monitoring program has been included in Section 4.1 to assist the reader. The aquatic ecology of the monitoring sites in the Coxs River and Wolgan River catchments are described in Sections 4.2 and 4.3, respectively. A brief description of the results of the Springvale and Angus Place water quality monitoring in Coxs River and the Wolgan River is presented in Section 4.4. Additional information on the aquatic ecology of the lower reaches of the Wolgan River obtained from Cumberland Ecology (2006) and DECCW (2008) and of the Upper Coxs River sub-catchment derided from SCA (2010) is presented in Section 4.5. The aquatic ecological attributes of the monitoring sites situated on drainages downstream of the swamps in the northern and southern part of the proposed workings are described in Section 5.

4.1 Overview of the Baseline Aquatic Ecology Monitoring

The baseline aquatic ecology monitoring sites that are relevant to this assessment are Sites CR1, CR2, CR4 and CR5 situated on the Coxs River above Lake Wallace, Sites WRup, WRmd and WRdn on the Wolgan River and Site CCXdn on Carne Creek. The location of these sites is shown in **Figure 4-1** and their geographic coordinates and a brief description of their location are presented in **Table 4-1**.

Table 4-1 Geographic coordinates and locality description of the baseline aquatic ecology monitoring sites in the Coxs River and Wolgan River catchments.

Site Code	Catchment	Easting	Northing	Description
CR1	Coxs River	229809	6307337	Upstream site located 700 m upstream from Angus Place LDP confluence.
CR2		228691	6305324	Site at the haul road crossing, approximately 1km downstream of Angus Place LDP
CR4		228361	6302773	Midstream site located at Maddox Lane road crossing.
CR5		228529	6300752	Midstream site located at Main St crossing, Wallerawang.
WRup	Wolgan River	237495	6305114	Wolgan River upstream site located above the Angus Place LDP6 and Springvale LDP4/5 emergency release sub-catchment confluences with Wolgan River
WRmd		236420	6306880	Wolgan River midstream site located 1km downstream from junction of Narrow Swamp tributary and Wolgan River.
WRdn		235388	6309805	Wolgan River downstream site located at Fire Trail No. 5 road crossing and Wolgan River.
CCXdn	Carne Creek	240473	6305884	Carne Creek site below confluence of upper catchment tributaries draining CC1 and CC2-CC3.

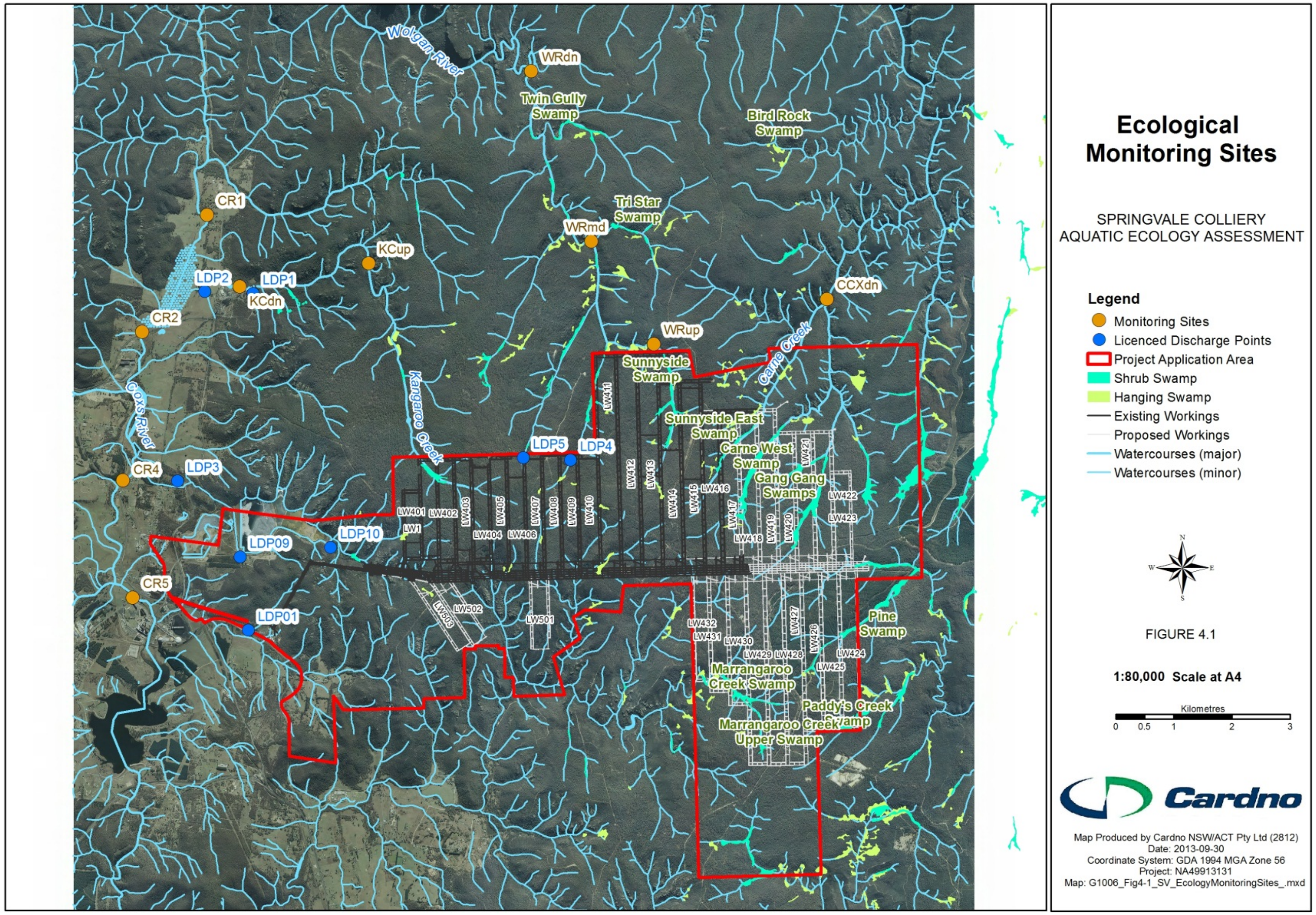

Figure 4-1 **Map showing the location of the aquatic ecology monitoring sites in the Coxs and Wolgan catchments relative to the proposed longwalls in the Project Application Area.**

The baseline monitoring is a biannual event that commenced in Autumn 2010 at Sites CR2, CR5, WRup and WRdn, in Spring 2010 at Sites CR1, CR4 and WRdn and in Autumn 2012 at Site CCXdn. The last monitoring event for all sites occurred in Spring 2012.

The baseline monitoring methodology included:

> Assessment of the condition of the aquatic habitat using a version of the Riparian, Channel and Environmental Inventory (RCE) modified for Australian conditions by Chessman *et al.* (1997).

> Measurement of temperature, electrical conductivity (EC) , salinity, pH, dissolved oxygen (DO) and turbidity just below the surface of the water column and at depth where sufficient water was available;

> Recording the occurrence of aquatic macrophytes;

> Sampling, sorting and identification of aquatic macroinvertebrates associated with pool edge habitat in accordance with the Australian Rivers Assessment System (AUSRIVAS) protocols (Turak *et al.* 2004);

> Sampling of fish and frogs using a combination of overnight and spot bait trapping, dip netting and visual observation.

The RCE assessment involves evaluating and assigning a score of 1-4 to 13 separate descriptors of the riparian zone, stream bank, channel and bed. The RCE score for a site is calculated by summing the scores for each descriptor, with total values varying from 13 for a highly modified channelled stream lacking riparian vegetation to 52 for a site exhibiting little or no obvious physical disruption. In this assessment, total RCE scores of 39-52, 26-39 and 13-26 are considered respectively to indicate small-, moderate- and large-scale disturbance of stream channel and adjacent features.

The EC, DO, pH and turbidity measurements were compared with the upper and lower default trigger values (DTVs) for slightly disturbed rivers in south-east Australia (ANZECC/ARMCANZ 2000). The trigger values provide an indication of the risk to environmental value, with measurements within the upper and lower DTV range indicative of a low risk and those outside the range indicating that the environmental value may not be protected,

It should be noted that the identification of aquatic macrophytes is problematic in the field and that plants bearing reproductive structures are necessary for reliable identification. In some cases it is not clear whether there has been a change in the occurrence of plants or a change in their identification. This hinders the interpretation of the baseline data.

The SIGNAL2 score (Stream Invertebrate Grade Number Average Level), a biotic index that uses information on the sensitivity of macroinvertebrate families to various forms of pollution, was used as an indicator of water quality (Chessman 2003). Average SIGNAL2 scores that are >6, 5-6, 4-5 and < 4 indicate a site is subject to no, mild, moderate and severe degradation, respectively.

Cardno has also included an assessment of the health of the sites on Coxs River and Wolgan River that was obtained by using the AUSRIVAS predictive modelling software to analyse information on the presence/absence of the aquatic macroinvertebrate taxa and physico-chemical environmental characteristics (Coysh *et al.* 2000). These analyses were restricted to the 2011 and 2012 datasets, because alkalinity, one of the physical chemical variables required was not measured in 2010 and that alkalinity measures for WRmd and CR4 were derived from the average values for the two adjacent sites. The total alkalinity measures for Sites CR2, CR4 and CR5 measured prior to the spring sampling events were also reduced to 190 milligrams per litre of calcium carbonate (mg/L CaCO3) so that they met the parameters of the AUSRIVAS model.

The AUSRIVAS software compares the macroinvertebrates collected at a site (i.e. Observed) to those predicted to occur (i.e. Expected) at undisturbed reference sites with similar environmental characteristics.

Two of the indices generated by the AUSRIVAS model were examined:

> OE50 Taxa Score - This is the ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50 % probability of occurrence. OE50 taxa values range from 0 to 1 and provide a measure of the impairment of macroinvertebrate assemblages at

each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.

> Overall Bands derived from OE50 Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as follows:

Band X = Richer invertebrate assemblage than reference condition;

Band A = Equivalent to reference condition;

Band B = Sites below reference condition (i.e. significantly impaired);

Band C = Sites well below reference condition (i.e. severely impaired);

Band D = Impoverished (i.e. extremely impaired).

Cardno has provided information on differences in the multivariate structure of the macroinvertebrate assemblages obtained by calculating the Bray-Curtis similarity coefficients for each pair of samples and then using an ordination technique known as non-metric Multi-Dimensional Scaling (MDS) to produce a graphical representation of the assemblages based on their similarity within and among places or times sampled (Clarke 1993). In MDS plots, samples which have similar sets of organisms are grouped closer together than ones containing different sets of organisms.

4.2 Coxs River Catchment

4.2.1 Overview

The Coxs River is a major tributary of the Hawkesbury-Nepean River system and is part of the Sydney Water Catchment Area. The river is perennial and approximately 155 km long. It originates at Gardiners Gap, about 6 km east of Cullen Bullen, and flows generally south and then east, before entering Lake Burragorang, the largest of Sydney's water-supply reservoirs. The upper Coxs River is a second order stream that receives inflows from numerous tributaries, with Pipers Flat Creek, Neubecks Creek, Sawyer Swamp Creek, Lambs Creek and Kangaroo Creek all being situated upstream of Lake Wallace. The upper Coxs River also receives water from numerous licensed discharge points (LDPs), including Angus Place Colliery, Coal Services site, Springvale Colliery, Enhance Place, Mt Piper and Wallerawang Power Stations and Wallerawang Sewage Treatment Plant. There are two large impoundments on the upper Coxs River; Lake Wallace at Wallerawang and Lake Lyell approximately 12 km further downstream.

The land in the upper river catchment is used primarily for grazing, forestry and coal mining, with the coal being used in electricity generation at the Wallerawang and Mt Piper Power Stations. A large proportion of the water in the upper Coxs River is also used in these power stations, with that used by the Wallerawang Power Station either being extracted directly from the Coxs River / Lake Wallace water supply reservoir or indirectly via the Springvale Delta Water Transfer System (SDWTS) and that used by the Mt Piper Power Station being transferred from Lake Lyell via Thompsons Creek Dam. Lake Wallace also supplies drinking water to the Wallerawang township.

4.2.2 Site CR1

Site CR1 is located on a broad bend of the Coxs River downstream of the confluence with Lambs Creek and approximately 700 m upstream of its confluence with Kangaroo Creek, the waterway into which AP_LDP001 discharges (**Figure 4-1**).

4.2.2.1 Aquatic and Riparian Habitat

Site CR1 was surrounded by grazing pasture. The river channel was narrow (maximum and average widths of 5 m and 2 m, respectively) and shallow (with maximum depth of the pool varying from 0.6 m to 1.3 m). During several surveys, water was observed seeping out of the eastern riparian bank into the channel.

The riparian corridor was narrow and uniform, consisting of native woody vegetation and small amounts of blackberry. The banks were mostly stabilised by grasses and eucalypts, but there were localised areas of erosion resulting from cattle accessing the water. River buttercup (*Ranunculus inundatus*), emergent sedges, submerged grasses, charophytes and trailing bank vegetation were present along the pool edge.

Detritus, woody debris and logs were abundant throughout the instream area of the site. In Autumn 2011, it was noted that some of the instream and riparian logs had been scoured.

In Spring 2010 and Autumn 2011, the substratum consisted of firm sand with some areas of gravel, pebbles and fine muddy sediment. However during subsequent surveys, it consisted of fine soft muddy sediments, with some sections of sand. The substratum and submerged surfaces (plants and detritus) were often covered in a layer of silt.

The total RCE score ranged from 33 to 34 and indicated the stream channel and adjacent features were moderately disturbed. The variation in the RCE score was due to fluctuations in the amount of filamentous green algae.

4.2.2.2 Water Quality

The baseline surface water quality measurements for CR1 presented in **Table 4.2** show that:

> Electrical conductivity levels were relatively low, ranging from 92-186 µS/cm, but within the guidelines (30 – 350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during the first three surveys, within the guidelines in Autumn 2012, but above the upper DTV (110% saturation) in Spring 2012;

> pH levels were within the guidelines (6.5-8.0 units) for slightly disturbed upland rivers in south-east Australia during four surveys, but below the lower DTV (6.5 units) in Autumn 2012;

> Turbidity were within the default trigger value range (2-25 NTU) during three surveys, but above in Spring 2011 and below in Autumn 2012.

Table 4-2 Surface water quality measurements recorded during baseline surveys undertaken at Site CR1 on Coxs River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
28/10/2010	10:27	14.6	186	65.1	6.96	8.6
09/06/2011	13:03	5.3	141	73.3	7.11	4.5
02/11/2011	09:50	15.1	182	67.1	6.73	48.7
31/05/2012	14:32	8.2	92	92.3	6.23	1.6
21/11/2012	14:49	19.3	99	115.5	7.07	23.4

4.2.2.3 Aquatic Plants and Algae

The following aquatic macrophytes were recorded at CR1 during the course of the baseline monitoring program: River Buttercup (*Ranunculus inundatus*), River Clubrush (*Schoenoplectus validus*), Spikerush (*Eleocharis* spp.), Tall spikerush (*Eleocharis sphacelate)*, Jointed Rush (*Juncus articulatus*), Starwort (*Callitriche* spp.) and *Carex gaudichaundiana*. River Buttercup is the only macrophyte species to have been found during all five surveys. *Carex gaudichaundiana* was not identified until Spring 2012.

Filamentous green algae were present throughout the site, with amounts varying across surveys from small to abundant. Charophytes were recorded during each survey.

4.2.2.4 Aquatic Macroinvertebrates

A total of 43 macroinvertebrate taxa were collected during the baseline surveys, 32 of which were insect families (**Appendix A**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Cladocera (water fleas), Cyclopidae (copepods), Parastacidae (freshwater crayfish/yabbies), Ostracoda (seed shrimps), Oligochaeta (freshwater worms), Ancylidae (freshwater limpets), freshwater snails of the families Lymnaeidae, Planorbidae and Physidae, and Dugesiidae (flatworms). The number of taxa collected per event varied from 23 to 35 (**Table 4.3**). Nine taxa (Dytiscidae, Baetidae, Leptophlebiidae, Corixidae, Notonectidae, Notonemouridae, Hydroptilidae and Leptoceridae were recorded every survey, but seven taxa were recorded once (**Appendix A**).

In 2011 and Autumn 2012, the macroinvertebrate fauna at Site CR1 was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 25% and 34% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4.3**). The sample collected in Spring 2012 lacked only 17% of the expected families and was rated equivalent to the AUSRIVAS reference condition.

The average SIGNAL2 scores for most surveys were ≥ 4, indicating the site was moderately degraded. The score for Spring 2012, however, was marginally less than 4.0 and also considerably smaller than that during the previous survey, suggesting that there had been a reduction in environmental quality (**Table 4.3)**. Twenty-eight taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant to a variety of environmental conditions, including common forms of water pollution. Five taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-3 Number of macroinvertebrate taxa recorded at Site CR1 on Coxs River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA = not analysed).

Indicator	Survey Date				
	28/10/2010	09/06/2011	02/11/2011	31/05/2012	21/11/2012
Number of taxa	26	23	24	28	35
SIGNAL2 score	4.0	4.1	4.2	4.4	3.9
OE50 Taxa Score	NA	0.75	0.75	0.66	0.83
AUSRIVAS Bands	NA	B	B	B	A

4.2.2.5 Fish and Frogs

No fish were caught during the surveys, but a small fish and several larval fish were observed in Spring 2012. Tadpoles were observed during the spring surveys, but there is no indication that frogs were present.

4.2.3 Site CR2

Site CR2 is located on Coxs River below its confluence with Kangaroo Creek and just downstream of Long Swamp, a broad swale with ill-defined channels that are dry most of the time (MPR 2010) (**Figure 4-1**). The inflows from Kangaroo Creek, including the release from AP_LDP001, are therefore likely to be the major contributor to the flow observed at CR2. Monitoring was conducted in main flow channel located on the eastern side of the floodplain and upstream and downstream of the culverts on the Mt Piper Haul Road.

4.2.3.1 Aquatic and Riparian Habitat

There were no trees in the riparian zone. The river banks were covered in grasses with occasional blackberry bushes. The banks were steep and undercut and had slumped into the river in some places. Increased levels of undercutting and erosion were noted during the Spring 2011 survey. There was evidence of cattle access along the entire site with animals being present on several occasions. Their presence would have contributed to the destabilisation of the river bank and degradation of the channel.

The drainage channel was narrow, with an average width of approximately 2 m and maximum width of 5 m and shallow, with maximum depths of 0.8-1.0 m during the first three surveys and 1.3-1.4 m in the latter two surveys. MPR noted that there was a high flow event between the Spring 2011 and Autumn 2012 surveys and that this overtopped the bank by 1.5 m. The edge habitat consisted of grasses, detritus, submerged rushes, curly pondweed and stands of Cumbungi. The substratum varied, with unconsolidated sandbanks being present in the main channel and muddy deposits in low flow areas and adjacent to the road culverts.

In Spring 2011, localised infilling of pools and the coverage of most submerged surfaces in a layer of silt were noted. In Autumn 2012, rubble and cobbles were observed at the road crossing.

The RCE value varied from 21.5 to 22, indicating the stream channel and adjacent features at CR2 were subject to large-scale disturbance. Scores for all RCE descriptors other than channel form and aquatic vegetation were low.

4.2.3.2 Water Quality

The baseline surface water quality measurements for CR2 presented in **Table 4.4** show that:

> Electrical conductivity levels ranged from 542-944 µS/cm and exceeded the upper DTV (350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during four surveys, but within the guidelines in Spring 2011 and Autumn 2012;

> The pH levels were alkaline and exceeded the upper DTV (8.0 units) for slightly disturbed upland rivers in south-east Australia during five surveys and was just below this limit in Autumn 2012;

> Turbidity levels during all surveys were within the default trigger value range (2-25 NTU).

Table 4-4 Surface water quality measurements recorded during baseline surveys undertaken at Site CR2 on Coxs River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
07/06/2010	15:29	06.31	944	83.7	9.33	13.9
27/10/2010	11:06	12.93	560	84.8	8.26	13.9
09/06/2011	15:46	05.38	749	72.4	8.41	02.8
01/11/2011	15:37	15.77	939	95.9	8.27	13.9
29/05/2012	16:01	07.69	542	92.2	7.99	02.9
22/11/2012	07:50	12.38	891	88.8	8.51	12.1

4.2.3.3 Aquatic Plants and Algae

Four aquatic macrophyte species were recorded during the course of the baseline monitoring program: Tall spikerush (*Eleocharis sphacelate),* Jointed Rush (*Juncus articulatus)*, Curly pondweed (*Potamogeton crispus*) and Cumbungi (*Typha* spp).

Filamentous green algae were present throughout the baseline surveys, with amounts varying from small in Spring 2010 to abundant and covering most submerged surfaces in Autumn and Spring 2011 and Autumn 2012. No charophytes were observed.

4.2.3.4 Aquatic Macroinvertebrates

A total of 47 macroinvertebrate taxa were collected during the baseline surveys, 34 of which were insect families (**Appendix B**). The insects included representatives from nine orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Lepidoptera (moths and butterflies), Mecoptera (scorpionflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa included springtails, copepods, freshwater shrimps, freshwater crayfish/yabbies, seed shrimps, freshwater worms, molluscs and worms. The number of taxa collected per event varied from 20 to 30 (**Table 4.5**). Eight taxa (Chironominae, Tanypodinae, Simuliidae, Tipulidae, Baetidae, Caenidae, Corixidae and Leptoceridae) were recorded every survey, but 11 taxa were recorded once (**Appendix B**).

In 2011, the macroinvertebrate fauna at Site CR2 was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 23% and 30% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4.5**). The samples collected in Autumn and Spring 2012 lacked 13% and 4% of the expected families respectively and were rated equivalent to the AUSRIVAS reference condition.

The average SIGNAL2 score for the initial survey was less than 4.0, which is indicative of severe degradation, but was ≥ 4.0 in subsequent surveys, suggesting that it was moderately degraded (**Table 4.5)**. Twenty-six taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant to a variety of environmental conditions, including common forms of water pollution. Nine taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-5 Number of macroinvertebrate taxa recorded at Site CR2 on Coxs River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA = not analysed).

Indicator	Survey Date					
	07/06/2010	27/10/2010	09/06/2011	01/11/2011	29/05/2012	22/11/2012
Number of taxa	29	29	20	25	23	30
SIGNAL2 score	3.6	4.0	4.7	4.4	4.3	4.6
OE50 Taxa Score	NA	NA	0.70	0.77	0.87	0.96
AUSRIVAS Bands	NA	NA	B	B	A	A

4.2.3.5 Fish and Frogs

Two native species of fish, Flathead gudgeon (*Philypnodon grandiceps*) and Mountain galaxias (*Galaxias olidus*), were caught, but only during one of the surveys. Tadpoles were observed during all surveys except that in Autumn 2012, but no frogs were found.

4.2.4 Site CR4

Site CR4 was located where Maddox Lane crosses Coxs River. The flow at this point is piped under the crossing. This site is situated downstream of the river's confluence with Neubecks Creek.

4.2.4.1 Aquatic and Riparian Habitat

The riparian zone lacked woody vegetation. The river banks were steep, undercut, unstable and actively eroding in areas where they were not held together by pasture grasses. The river channel was narrow (2-3 m in width), incised and flat-bottomed, except at the road crossing where the width increased to 8 m. The channel was shallow (with a maximum depth of 1.0-1.2 m during the first three surveys increasing to 1.4 m in Autumn and Spring 2012). There was evidence that the water level had been 1.8 m higher during the high flow event that occurred between Spring 2011 and Autumn 2012.

The edge habitats included trailing bank vegetation, grasses, charophytes, sedges and detritus. The substratum consisted of a mixture of cobbles and boulders, with varying amounts of sandy and muddy deposits in areas of lower flow. Moderate amounts of silt were observed in Autumn and Spring 2012. In Autumn 2012, the substratum and submerged surfaces in the lower flow sections of the pools were covered by a cream- coloured flocculant which appeared to emanate from Sawyers Swamp Creek. This was not evident during the subsequent survey.

The RCE score varied from 29 to 30, suggesting the stream channel and adjacent features were moderately disturbed. The low score reflected the lack of instream structure and poor state of the riparian vegetation and stream corridor.

4.2.4.2 Water Quality

The baseline surface water quality measurements for CR4 presented in **Table 4.6** show that:

> Electrical conductivity levels ranged from 640-930 µS/cm and exceeded the upper DTV (350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during three surveys but within the guidelines in Spring 2011 and Autumn 2012;

> pH levels were within the guidelines (6.5-8.0 units) for slightly disturbed upland rivers in south-east Australia during four surveys, but above the upper DTV in Spring 2012

> Turbidity levels during all surveys were within the default trigger value range (2-25 NTU).

Table 4-6 Surface water quality measurements recorded during baseline surveys undertaken at Site CR4 on Coxs River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
27/10/2010	13:07	17.90	666	74.5	7.84	6.4
08/06/2011	15:51	06.38	930	76.0	8.02	5.3
01/11/2011	18:16	19.82	853	101.2	7.99	5.9
30/05/2012	15:11	08.57	640	90.9	7.15	11.6
20/11/2012	07:52	16.40	837	73.2	8.33	4.4

4.2.4.3 Aquatic Plants and Algae

Four aquatic macrophyte species were recorded during the course of the baseline monitoring program: Spiny Rush (*Juncus* sp.), Jointed Rush (*Juncus articulatus*), Common Reed (*Phragmites australis*) and Cumbungi (*Typha* spp). Common Reed was observed during all surveys, but the rushes were found during three surveys only, while Cumbungi was recorded only in Autumn 2011.

In Spring 2010, the substratum was covered in an algal mat. Filamentous green algae were present throughout the baseline surveys, with amounts varying from small in Autumn 2012 to abundant in Spring 2011. Charophytes were also observed during all five surveys.

4.2.4.4 Aquatic Macroinvertebrates

A total of 46 macroinvertebrate taxa were collected during the baseline surveys, 32 of which were insect families (**Appendix C**). The insects included representatives from ten orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Lepidoptera (moths and butterflies), Mecoptera (scorpionflies), Megaloptera (dobsonflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa comprised freshwater mites, water fleas, copepods, freshwater shrimps, freshwater crayfish/yabbies, seed shrimps, freshwater worms, molluscs and worms. The number of taxa collected per event varied from 20 to 33 (**Table 4.7**). Four taxa (Simuliidae, Baetidae, Gomphidae and Leptoceridae) were recorded every survey, but 10 taxa were recorded once (**Appendix C**).

In 2011 and Autumn 2012, the macroinvertebrate fauna at Site CR4 was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 33% and 47% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4.7**. The sample collected in Spring 2012 lacked only 4% of the expected families and was rated equivalent to AUSRIVAS reference condition.

The average SIGNAL2 scores for four surveys were > 4, indicating the site was moderately degraded (**Table 4.7)**. The score for the Spring 2012 survey was considerably smaller than that for the Spring 2011 and Autumn 2012 surveys, suggesting there had been a decline in the quality of the environment. Twenty-seven taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant to a variety of environmental conditions, including common forms of water pollution. Six taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-7 Number of macroinvertebrate taxa recorded at Site CR4 on Coxs River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA = not analysed).

Indicator	Survey Date				
	27/10/2010	08/06/2011	01/11/2011	30/05/2012	20/11/2012
Number of taxa	26	21	22	20	33
SIGNAL2 score	4.1	4.1	4.6	4.6	3.9
OE50 Taxa Score	NA	0.53	0.67	0.59	0.96
AUSRIVAS Bands	NA	B	B	B	A

4.2.4.5 Fish and Frogs

Two introduced fish species were recorded, with Eastern Gambusia (*Gambusia holbrooki*) being caught on four occasions and Brown Trout (*Salmo trutta*) observed twice. Tadpoles were observed during the spring surveys, but no frogs were heard or observed.

4.2.5 Site CR5

Site CR5 is located below and upstream of where Main Street, Wallerawang crosses the Coxs River. This site is above Wallerawang Power Station.

4.2.5.1 Aquatic and Riparian Habitat

At the upstream end of the site there was a long broad pool, below which there was a constricted flow channel that drained into another long pool situated below and downstream of the road bridge. This pool was approximately 10 m wide and had a maximum depth that varied from 1.3 m to 1.5 m during the baseline surveys.

The riparian vegetation consisted mostly of eucalypt trees and occasional willow trees, grasses and blackberry bushes. The river banks were steep, undercut and eroding in some areas. Substantial changes in riparian and aquatic vegetation were observed during the baseline monitoring, with blackberry bushes on the eastern bank under the road bridge and cumbungi stands throughout the site having been scoured out by the time of the Autumn 2011 survey, further die-back of blackberry bushes, cutting back and poisoning of willow trees evident in Spring 2011 and scouring out of cumbungi and river clubrush apparent in Autumn 2012.

The substratum consisted of soft mud in the pool upstream of the bridge and of a mixture of bedrock, boulder, cobble and rock fragments at the downstream end. In Autumn 2011, the substratum and submerged surfaces were covered by a cream-coloured flocculant, as was that at CR4.

The RCE score varied from 31 to 33, indicating the stream channel and adjacent features were moderately disturbed.

4.2.5.2 Water Quality

The baseline surface water quality measurements for CR2 presented in **Table 4.8** show that:

> Electrical conductivity levels ranged from 558-860 µS/cm and exceeded the upper DTV (350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during two surveys and exceeded the upper DTV (110% saturation) on two occasions, but were within the guidelines in Spring 2012;

> pH levels exceeded the upper DTV (8.0 units) for slightly disturbed upland rivers in south-east Australia during four surveys, but were within the DTV range in Spring 2010 and Autumn 2012;

> Turbidity levels exceeded the upper DTV (25 NTU) in Autumn 2012, but were within the default trigger value range during the other surveys.

Table 4-8 Surface water quality measurements recorded during baseline surveys undertaken at Site CR5 on Coxs River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
8/06/2010	12:52	09.53	829	115.0	9.24	12.9
28/10/2010	08:09	14.80	558	63.3	7.97	10.7
07/06/2011	12:56	07.23	860	83.9	8.47	03.7
02/11/2011	12:39	19.51	764	171.2	8.67	15.2
28/05/2012	15:05	9.61	704	98.2	7.13	27.2
22/11/2012	14:25	21.74	817	106.2	8.36	15.4

4.2.5.3 Aquatic Plants and Algae

Ten aquatic macrophyte species were recorded during the course of the baseline monitoring program, but only River Clubrush (*Schoenoplectus validus*), Curly Pondweed (*Potamogeton crispus*) and Cumbungi (*Typha* spp) were present each survey. Spiny Rush (*Juncus* sp.), Common Reed (*Phragmites australis*), Water Primrose (*Ludwigia peploides*) and Blue Water Speedwell (*Veronica anagallis-aquatica*) were observed once. Jointed Rush (*Juncus articulatus*), Blunt Pondweed (*Potamogeton ochreatus*) and Watercress (*Nasturtium officinale*) were found twice.

Filamentous green algae were present and abundant during each survey. Mat-like algae were observed on the substratum in Autumn 2011 and Spring 2011. Charophyte algae were recorded in Spring 2010 only.

4.2.5.4 Aquatic Macroinvertebrates

A total of 35 macroinvertebrate taxa were collected during the baseline surveys, 19 of which were insect families (**Appendix D**). The insects included representatives from six orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Odonata (dragonflies) and Trichoptera (caddis flies). The number of taxa collected per event varied from 18 to 25 (**Table 4.9**). The other taxa comprised freshwater mites, water fleas, copepods, freshwater shrimps, freshwater crayfish/yabbies, seed shrimps, leeches, hydra, freshwater worms, molluscs and worms. Ten taxa (Chironominae, Orthocladiinae, Tanypodinae, Baetidae, Caenidae, Leptophlebiidae, Corixidae, Atyidae, Oligochaeta and Physidae) were recorded every survey, but 11 taxa were recorded once (**Appendix D**).

In 2011, the macroinvertebrate fauna at Site CR5 lacked between 9% and 18% of the families expected to occur at reference sites with similar physical chemical characteristics and was therefore rated as equivalent to the AUSRIVAS reference condition (**Table 4.9**). The samples collected in Autumn and Spring 2012 lacked 22% and 18% of the expected taxa and were considered to be significantly impaired.

Table 4-9 Number of macroinvertebrate taxa recorded at Site CR5 on Coxs River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA = not analysed).

Indicator	Survey Date					
	8/06/2010	28/10/2010	7/06/2011	2/11/2011	28/05/2012	22/11/12
Number of taxa	20	32	23	23	23	23
SIGNAL2 score	4.0	4.3	4.0	3.9	3.9	3.7
OE50 Taxa Score	NA	NA	0.82	0.91	0.78	0.82
AUSRIVAS Bands	NA	NA	A	A	B	B

The average SIGNAL2 scores for the initial three surveys were ≥ 4, indicating the site was moderately degraded (**Table 4.9)**. The scores for the subsequent surveys ranged from 3.7 to 3.9, suggesting there had been a decline in the quality of the environment. Twenty-five taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant to a variety of environmental conditions, including common forms of water pollution. Six taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

4.2.5.5 Fish and Frogs

Two native species of fish, Flathead Gudgeon (*Philypnodon grandiceps*) and Mountain Galaxias (*Galaxias olidus*), and three introduced species of fish, Eastern Gambusia (*Gambusia holbrooki*), Goldfish (*Cassius auratus*) and Brown Trout (*Salmo trutta*), were recorded. Eastern Gambusia and Flathead Gudgeon were found on five and four occasions, respectively. Brown Trout were recorded twice, but Mountain Galaxias and Goldfish were only present on one occasion, with a large school of the latter ranging in size from 5-7cm observed below the bridge in Autumn 2010. Tadpoles were observed during the first two surveys, but there is no indication that any frogs were present.

4.3 Wolgan River Catchment

4.3.1 Overview

The Wolgan River is an approximately 64 km long perennial stream that originates above Springvale on the Newnes Plateau about 9 km East by North of Wallerawang. The river then flows in a north to easterly direction before joining with the Capertee River, below Mount Morgan, east of Glen Davis to form the Colo River, which drains into the Hawkesbury-Nepean River system. The watershed on the Newnes Plateau consists of sandstone catchments within Newnes State Forest. The vegetation within these catchments is relatively undisturbed, except where it has been cleared for fire and access roads and for Angus Place and Springvale mine surface infrastructure. The elevation of the river declines from 1070 m at its source to 550 m at its confluence with Carne Creek in the Wolgan Valley approximately 12 km from its headwaters and then to 178 m at its confluence with the Capertee River.

There has been minimal clearing of vegetation except for fire and access roads, and Angus Place and Springvale mine surface infrastructure. The Wolgan River valley to the west of the proposed longwalls is steep (approximately 80 metres high) and composed of cliffs, pagodas and talus slopes.

The base surface water flows are small and derived from shrub swamps and perched aquifers (MSEC 2013). The river used to receive periodic inflows of mine water make from borehole 940 via emergency discharge point LDP006 and Narrow Swamp North, however, use of this LDP has now ceased. It also received periodic discharges from two emergency discharge points (LDP004 and LDP005) associated with Springvale Mine situated on an unnamed creek that drained into the river.

The Wolgan River bed consists of surface soils derived from the Burralow Formation of the Triassic Narrabeen Group, with sandstone bedrock outcropping in some locations. The natural gradient of the upper reaches of the river adjacent to the Extraction Area ranges from 25 mm/m to 200 mm/m, with an average natural gradient of approximately 75 mm/m (MSEC 2013).

The upper reaches of the Wolgan River have been undermined by the existing longwalls of Springvale and the centreline of the river is situated up to 150 m away from the previously extracted longwalls at Angus Place Colliery. The proposed longwalls within the Project Application Area would be situated to the east of the upper reaches of the river (**Figure 4-1**). An approximately 0.9 km stretch of the river would be situated within 600 m of the proposed Springvale longwalls, with the closest longwall (LW416) being 460 m east of the river (MSEC 2013). A 3 km reach of the river is situated within 600 m of the proposed Angus Place longwalls.

Carne Creek is an approximately 19.5 km long stream that rises 2.5 km northwest by west of Bungleboori on the Newnes Plateau and flows in a generally North-North-Westerly direction before cascading down the plateau and draining into the Wolgan River in the lower part of the Wolgan Valley. The headwaters of Carne Creek consist of at least six separate sub-catchments, five of which are located within sections of Newnes State Forest, where there has been minimal clearing of vegetation except for fire and access roads (MPR 2010). These sub-catchments support Shrub Swamps. The eastern most sub-catchment of Carne Creek has been cleared for pine plantation and this extends down towards the upper limits of Barrier Swamp. The channel valleys downstream of the swamps are incised and bordered by steep sandstone escarpments, which increase in depth and frequency with increasing distance downstream (MPR 2010). The drainage lines in the northern part of the Project Application Area flow into Carne Creek (MSEC 2013).

Four of the proposed longwalls (LW416 to LW419) would be located directly below an approximately 2.0 km reach of Carne Creek that is largely confined within Sunnyside East Swamp (MSEC 2013). The creek upstream of the swamp is ephemeral, but that downstream has small base surface water flows. The beds of the creek and drainage lines consist of surface soils derived from the Burralow Formation of the Triassic Narrabeen Group, with sandstone bedrock outcropping in some locations. In the drainage lines, there are also debris accumulations which include loose rocks and tree branches. The natural gradients along the reach of the creek directly above the proposed longwalls ranges from 25 mm/m to 100 mm/m, with an average gradient of around 50 mm/m (MSEC 2013). The drainage lines downstream of the shrub swamps have small base surface water flows, but those elsewhere are mostly ephemeral, except where there are groundwater seeps from perched aquifers. The natural gradient of the drainage lines above the proposed longwalls varies from 25 mm/m to 300 mm/m.

4.3.2 Wolgan River Upstream site (WRup)

WRup is located upstream of the Angus Place LDP006 and Springvale LDP004-5 emergency release sub-catchment confluences within Wolgan River and close to the downstream limits of Sunnyside Swamp and upstream of a fire trail crossing.

4.3.2.1 Aquatic and Riparian Habitat

The river channel at the upstream end of the site was narrow (average width of 1.0 m), shallow (mostly less than 10 cm depth) and surrounded by dense riparian vegetation. Below this there was a broad (up to 5 m), deep (1.2 - 1.5 m) pool caused by the damming effect of the crossing. The channel downstream of the road crossing was similar to that upstream. The flow at the upstream and downstream ends of the site was more natural than that within the pool, where flow was piped under the road via a culvert. In Autumn 2012, it was noted that a high flow event resulting in a 0.8 to 1 m increase in water level had occurred.

The riparian habitat was dense and overhung the river throughout the site. It consisted of sedges, sword grass, coral ferns, heath shrubs and trees. Despite the dense riparian vegetation, undercutting of the banks and some erosion of bends and exposed banks were evident. The pool edge habitats included edge rushes, sedges, trailing bank vegetation, eucalypt detritus, undercut banks and logs. The pool substratum consisted mostly of sand, but with some isolated areas of clay-like sediments. Orange precipitates (iron flocs) were observed along some areas of the river banks in Autumn 2010, covered submerged surfaces in isolated areas of the pool in Autumn 2012 but smothered most of the submerged surfaces at the site in Spring 2012.

The total RCE score ranged from 38.5 to 39 and indicated the stream channel and adjacent features were moderately disturbed.

4.3.2.2 Water Quality

The baseline surface water quality measurements for WRup presented in **Table 4.10** show that:

> Electrical conductivity (EC) levels were low, ranging from 42-51 µS/cm, but within the guidelines (30 – 350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (DO) (% saturation) levels were below the lower default trigger value (DTV) (90% saturation) during all the surveys, except that in Autumn 2012 when it was within the ANZECC/ARMCANZ 2000 guidelines;

> pH levels were within the guidelines (6.5-8.0 units) for slightly disturbed upland rivers in south-east Australia during four surveys, but below the lower DTV (6.5 units) in Spring 2011 and Autumn 2012;

> Turbidity levels during all surveys were within the default trigger value range (2-25 NTU).

4.3.2.3 Aquatic Plants and Algae

Over the course of the baseline monitoring program, three different aquatic macrophytes have been reported to occur at WRup. The first plant observed in Autumn 2010 was tentatively identified as a member of the family Cyperaceae (sedge). In Autumn 2011, the Royal Botanical Gardens Sydney (RBGS) indicated this was in fact Bulbous Rush (*Juncus bulbosus*). This species was recorded in all the subsequent surveys. In Spring 2013, an unidentified Baumea-like rush was found, but this has yet to be positively identified.

Filamentous green algae were recorded during each survey, with amounts varying from small to moderate. In Spring 2011 and 2012, it was reported that most of the substratum and submerged surfaces were smothered by algal mats. Charophyte algae were recorded for the first time in Spring 2012.

Table 4-10 Surface water quality measurements recorded during baseline surveys undertaken at Site WRup on the Wolgan River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
09/06/2010	13:20	5.7	44	76.0	7.49	19.3
10/11/2010	07:34	13.4	51	64.7	6.84	ND
25/05/2011	10:18	6.7	47	82.4	7.01	17.1
15/11/2011	16:42	17.5	51	88.1	6.33	21.7
23/05/2012	16:01	6.1	42	90.0	5.94	6.6
27/11/2012	15:38	16.24	ND	77.4	6.83	9.0

4.3.2.4 Aquatic Macroinvertebrates

A total of 43 macroinvertebrate taxa were collected during the baseline surveys, 37 of which were insect families (**Appendix E**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Cladocera (water fleas), Cyclopidae (copepods), Phreatoicidae (isopods), Oligochaeta (freshwater worms) and Dugesiidae (flatworms). The number of taxa collected per event varied from 18 to 25 (**Table 4.11**). Ten taxa (Dytiscidae, Ceratopogonidae, Chironominae, Tanypodinae, Baetidae, Corixidae, Notonectidae, Hemicorduliidae, Lestidae and Leptoceridae) were recorded every survey, but 18 taxa were recorded once (**Appendix E**).

The average SIGNAL2 scores for the initial three surveys were <4, indicating the site was severely degraded (**Table 4.11)**. The scores for the subsequent surveys ranged from 4.1 to 4.9, suggesting there had been an improvement in the quality of the environment. Twenty-two taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant to a variety of environmental conditions, including common forms of water pollution. Eight taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-11 Number of macroinvertebrate taxa recorded at Site WRup on the Wolgan River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA, not analysed).

Indicator	Survey Date					
	09/06/2010	08/11/2010	25/05/2011	15/11/2011	23/05/2012	27/11/2012
Number of taxa	19	18	20	22	21	25
SIGNAL2 score	3.84	3.50	3.79	4.05	4.85	4.44
OE50 Taxa Score	NA	NA	0.55	0.72	0.78	0.72
AUSRIVAS Bands	NA	NA	B	B	B	B

4.3.2.5 Fish and Frogs

No fish were caught or observed during the aquatic ecology surveys. The Eastern Banjo Frog (*Lymnodynastes dumerilii grayi*) and Spotted Marsh Frog (*Lymnodynastes tasmaniensis*) were heard in November 2010, but not in subsequent surveys. Unidentified tadpoles were observed in November 2011.

4.3.3 Wolgan River Midstream site (WRmd)

WRmd is located approximately 1 km downstream from the junction of Narrow Swamp tributary and Wolgan River.

4.3.3.1 Aquatic and Riparian Habitat

The river channel at this site was narrow (average width less than 1.0 m) and meandering, with bedrock races intersecting short sandy pools. The maximum depth varied from 0.2 m – 0.8 m across surveys.

The site was surrounded by dense native heath and eucalypt woodlands. Instream bank vegetation was prominent throughout the site with a high degree of cover over the waterbody and consisted mostly of sword grass (*Gahnia* sp.), and coral ferns (*Gleichenia* sp). The aquatic habitats along the pool edge included trailing bank vegetation, eucalypt detritus, undercut banks and logs. The substratum consisted mostly of bedrock, but with boulder/cobble sized sandstone fragments and some sand accumulations at the downstream end. In Spring 2010 and Autumn 2011, burrows (presumed to be yabby holes) were observed along the river banks. In Spring 2012, moderate amounts of silt were observed on the substratum.

The total RCE score (44) was consistent across surveys and indicated the stream channel and adjacent features were subject to small levels of disturbance.

4.3.3.2 Water Quality

The baseline surface water quality measurements for WRmd presented in **Table 4.12** show that:

> Electrical conductivity levels were low, ranging from 30-38 µS/sec, but within the guidelines (30 – 350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during three surveys, but within the guidelines in Spring 2011 and Autumn 2012;

> pH levels were within the guidelines (6.5-8.0 units) for slightly disturbed upland rivers in south-east Australia during the first two surveys, but below the lower DTV (6.5 units) during subsequent surveys;

> Turbidity levels were slightly in excess of the upper DTV (25 NTU) in Autumn 2011, but within the guidelines in subsequent surveys.

Table 4-12 Surface water quality measurements recorded during baseline surveys undertaken at Site WRmd on the Wolgan River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
09/11/2010	11:41	12.5	38	75.3	6.57	ND
23/05/2011	12:39	8.8	33	86.1	6.71	25.7
16/11/2011	12:48	12.3	30	99.4	5.86	10.3
21/05/2012	12:21	8.1	35	96.0	5.97	12.4
26/11/2012	13:35	16.45	ND	82.8	6.38	16.9

4.3.3.3 Aquatic Plants and Algae

Four different aquatic macrophytes were recorded during the baseline monitoring. The first plant observed in Spring 2010 was tentatively identified as a member of the family Cyperaceae (sedge). This was subsequently identified as Bulbous Rush (*Juncus bulbosus*) and was recorded in all the other surveys, except that in Spring 2012. An introduced species, the Jointed Rush (*Juncus articulatus*), was found in Autumn 2012, but not during the subsequent survey. In Spring 2012, another macrophyte was found and subsequently identified as Swamp Clubrush (*Isolepis inundatus*) by RBGS. MPR (2013) indicates this species may previously have been recorded as Bulbous Rush.

Filamentous green algae were absent in Spring 2010, but present in small to moderate amounts in subsequent surveys. Charophytes were present during all surveys.

4.3.3.4 Aquatic Macroinvertebrates

A total of 33 macroinvertebrate taxa were collected during the baseline surveys, 30 of which were insect families (**Appendix F**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies), as was the case at Site WRup. The other taxa were Oligochaeta (freshwater worms), Sphaeriidae (pea shells) and Dugesiidae (flatworms).

The number of taxa collected per event varied from 20 to 25 (**Table 4.13**). Twelve taxa (Dytiscidae, Gyrinidae, Ceratopogonidae, Chironominae, Tanypodinae, Baetidae, Leptophlebiidae, Synthemistidae, Telephlebiidae, Gripopterygidae, Leptoceridae and Philorheithridae) were sampled during every survey, but 10 taxa were recorded once (**Appendix F**).

In 2011, the macroinvertebrate fauna at Site WRmd was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 18% and 22% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4.13**). The samples collected in 2012 were rated as equivalent to the AUSRIVAS reference condition and lacked between 10% and 14% of expected taxa.

The average SIGNAL2 scores varied from 5.1 to 5.5 and were thus indicative of mild degradation (**Table 4.13)**. Twelve taxa had SIGNAL2 scores ≤ 4, indicating they were tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix F**). Fourteen taxa had SIGNAL2 scores ≥ 7, indicating they were sensitive to pollution.

Table 4-13 Number of macroinvertebrate taxa recorded at Site WRmd on the Wolgan River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey.

Indicator	Survey Date				
	09/11/2010	23/05/2011	16/11/2011	21/05/2012	26/11/2012
Number of taxa	21	21	20	25	20
SIGNAL2 score	5.48	5.05	5.50	5.28	5.25
OE50 Taxa Score	NA	0.78	0.82	0.86	0.90
AUSRIVAS Bands	NA	B	B	A	A

4.3.3.5 Fish and Frogs

An eel (*Anguilla* sp.) was observed in November 2010, but no fish were caught or observed during the subsequent surveys (MPR 2011a and b, 2012 a and b). There is no indication that any frogs were heard or observed.

4.3.4 Wolgan River Downstream Site (WRdn)

WRdn is situated in a narrow steep sided valley bordered by vertical cliffs upstream of Fire Trail No. 5.

4.3.4.1 Aquatic and Riparian Habitat

The flow was piped under the road at the lower crossing. The channel meandered and an irregular sequence of shallow sandy constricted higher-flow zones alternated with deeper backwater pools. The maximum in-stream channel width was 3 m and maximum depth varied from 1.0 to 1.5 m. There was evidence that flow events had increased water levels by 1.0 -1.5 m and 1.5 to 2 m between the first and second and third and fourth surveys, respectively.

The riparian vegetation was dense and overhung the stream banks throughout the site. The aquatic habitats along the pool edge included trailing bank vegetation, eucalypt detritus, charophytes, undercut banks and logs. The substratum throughout the site was sandy, with gravel and boulder fragments also present at the road crossings. Deepening of channel beds and erosion at the lower trail crossing was noted between the first and second surveys, while deepening and infilling of pools areas were noted between the third and fourth surveys. In Spring 2012, detritus was abundant throughout the site.

The total RCE score (42) was consistent across surveys and indicated the stream channel and adjacent features were subject to small levels of disturbance.

4.3.4.2 Water Quality

The baseline surface water quality measurements for WRdn presented in **Table 4.14** show that:

> Electrical conductivity levels were low, ranging from 33-57 µS/cm, but within the guidelines (30 – 350 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during four surveys, but within the guidelines in Spring 2011 and Autumn 2012;

> pH levels were below the lower DTV (6.5 units) during four surveys, but within the guidelines in Autumn 2010 and 2011;

> Turbidity levels were within the guidelines (2-25 NTU).

4.3.4.3 Aquatic Plants and Algae

Three different aquatic macrophytes were recorded during the baseline monitoring. The first plant observed in Spring 2010 was tentatively identified as a member of the family Cyperaceae (sedge). This was subsequently identified as Bulbous Rush (*Juncus bulbosus*) and was recorded in Spring 2011, but not subsequently. The third macrophyte was found in Spring 2012 and identified as Swamp Clubrush (*Isolepis inundatus*) by RBGS. MPR (2013) indicates this species may previously have been recorded as Bulbous Rush.

Small amounts of filamentous green algae were observed during all the surveys, except that in Autumn 2012. Charophytes were recorded in all the surveys except those undertaken in Autumn 2010 and 2011.

Table 4-14 Surface water quality measurements recorded during baseline surveys undertaken at Site WRdn on the Wolgan River (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
9/06/2010	10:44	6.67	57	75.9	7.86	18.2
9/11/2010	8:27	12.89	46	69.5	6.27	ND
26/05/2011	9:16	6.62	40	73.5	7.30	12.3
17/11/2011	15:00	13.54	33	91.1	6.15	11.6
24/05/2012	9:56	5.10	36	92.6	5.94	2.1
27/11/2012	13:36	16.64	ND	73.5	6.29	21.1

4.3.4.4 Aquatic Macroinvertebrates

A total of 39 macroinvertebrate taxa were collected during the baseline surveys, 35 of which were insect families (**Appendix G**). The insects included representatives from the seven orders sampled at Sites WRup and WRmd plus two additional orders, the Mecoptera (scorpionflies) and Megaloptera (dobsonflies). The other taxa were Cyclopidae (copepods), Ostracoda (seed shrimps), Oligochaeta (freshwater worms) and Sphaeriidae (pea shells). The number of taxa collected per event varied from 19 to 24, with more collected during the first two surveys than subsequently (**Table 4.15**). Eleven taxa (Dytiscidae, Gyrinidae, Chironominae, Tanypodinae, Tipulidae, Baetidae, Leptophlebiidae, Synthemistidae, Synlestidae, Gripopterygidae and Leptoceridae) were found during all six surveys ((**Appendix G**). Nine taxa were recorded once.

In Autumn 2011 and 2012, the macroinvertebrate fauna at Site WRdn was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 19% and 27% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4.15**). Samples collected during the Spring surveys lacked between 6% and 14% of expected taxa but were rated as equivalent to the AUSRIVAS reference condition.

The average SIGNAL2 scores varied from 4.8 to 5.5 and were thus indicative of either moderate or mild degradation (**Table 4.15**). The scores for the autumn surveys were greater than those for spring surveys, suggesting that there may be a seasonal change in quality of the environment. Eleven taxa were tolerant of a variety of environmental conditions, including common forms of water pollution (i.e., had SIGNAL2 scores ≤ 4) (**Appendix G**). Twelve taxa were considered to be sensitive to pollution (i.e. had SIGNAL2 scores ≥ 7).

Table 4-15 Number of macroinvertebrate taxa recorded at Site WRdn on the Wolgan River and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey.

Indicator	Survey Date					
	9/11/2010	26/05/2011	17/11/2011	24/05/2012	27/11/2012	9/06/2010
Number of taxa	20	24	23	20	19	21
SIGNAL2 score	4.72	5	5.52	4.75	5.26	5.95
OE50 Taxa Score	NA	NA	0.81	0.86	0.73	0.94
AUSRIVAS Bands	NA	NA	B	A	B	A

4.3.4.5 Fish and Frogs

No fish were caught or observed during the aquatic ecology surveys. No frogs were heard or observed, but tadpoles were found in November 2012.

4.3.5 Carne Creek Site CCXdn

Site CCXdn is situated below the confluence of the two upper catchment tributaries that drain sites CC1 and CC2/ CC3, midway along the Newnes Plateau section of Carne Creek around 5.5 km from the headwaters of the catchment (**Figure 4-1**). This site was added to the monitoring program in Autumn 2012 and was surveyed again in the following spring.

4.3.5.1 Aquatic and Riparian Habitat

Site CCXdn was situated in a greatly incised valley bordered by steep sandstone escarpment supporting native vegetation. The creek channel was incised below the surrounding valley floor by 3 m and was steep and undercut in parts, and generally straight, but with some slight bends and constrictions. The channel had a maximum width of 5 m, an average width of 3.5m, a maximum depth of 0.9 m and average depth of 0.4 m. There was evidence that the water level was at least 2 m higher during high flow events.

Boulder outcrops, numerous fallen logs and dense vegetation, consisting mostly of ferns, were present long the banks of the channel. The rocks and logs were covered with mosses. The channel substratum consisted of sandstone fragments, ranging in size from gravel to cobble, long sand drifts and boulder outcrops. The edge habitats sampled consisted of undercut banks, trailing bank vegetation and detritus.

A total RCE score of 49 was recorded, indicating the stream channel and adjacent features were subject to minimal disturbance.

4.3.5.2 Water Quality

The baseline surface water quality measurements for CCXdn presented in **Table 4.16** show that:

> Electrical conductivity level in Autumn 2012 was below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were within guidelines in Autumn 2012, but below the lower DTV (90% saturation) in Spring 2012;

> pH was acidic and well below the lower DTV (6.5 units) during both surveys;

> Turbidity levels were within the guidelines during both surveys.

Table 4-16 Surface water quality measurements recorded during baseline surveys undertaken at Site CCXdn on Carne Creek (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded.

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
7/06/2012	14:57	8.07	24	91.8	4.35	4.1
28/11/12	12:11	12.91	ND	83.0	4.99	14.7

4.3.5.3 Aquatic Plants and Algae

No macrophytes, charophytes or filamentous green algae were recorded during either survey.

4.3.5.4 Aquatic Macroinvertebrates

A total of 25 macroinvertebrate taxa were collected during the two baseline surveys, 23 of which were insect families (**Appendix H)**. The insects included representatives from six orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites) and Oligochaetes (freshwater worms).

More taxa were collected in Spring than in Autumn 2012 (**Table 4.17**), however, 17 of these were common to both surveys (**Appendix H**).

The average SIGNAL2 scores were ≥6.0, indicating the water was not degraded. Seven taxa had SIGNAL2 scores (≤ 4), indicating they were tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix H**). Ten taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-17 Number of macroinvertebrate taxa recorded each survey at Site BCN2 downstream of Nine Mile Swamp and their average SIGNAL2 score.

Indicator	Survey Date	
	6/06/2012	29/11/2012
Number of taxa	19	23
SIGNAL2 score	6.47	6.00

4.3.5.5 Fish and Frogs

No frogs or tadpoles were observed. Fish and larval fish, most likely Mountain galaxias, were observed in Spring 2012.

4.4 Surface Water Quality Monitoring Programs

The Angus Place and Springvale Surface Water Quality Monitoring Programs provide information on the variation in a number of water quality parameters at sites upstream and downstream of discharge influences on the Coxs River and Kangaroo Creek and at sites on the Wolgan River that are not subject to discharges. RPS (2013 c and d) has compared the results from these monitoring programs with the ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in south-east Australia.

At the upstream monitoring site on the Coxs River, the following guideline exceedances were noted: EC, pH, total suspended solids (TSS), Aluminium and Nitrite as N occasionally and Nickel, Filtered Zinc, Total Nitrogen and Total Phosphorus frequently. More exceedances were evident at the downstream monitoring site on the Coxs River, with those for pH, Manganese, Turbidity, Aluminium, Boron, Cadmium and Nitrite as N occurring occasionally, while those for EC, Filtered Zinc, Total Nitrogen as N and Total Phosphorus were frequent.

The data also suggest that the discharge from LDP001 elevates the pH, EC, total dissolved solids, barium, calcium, magnesium, potassium, sodium, Total Sulphur and alkalinity (carbonate, bicarbonate and total) levels at the downstream monitoring sites on Kangaroo Creek and the Coxs River. There is also a marked increase in the levels of total nitrite as N and total Nitrogen as N between the upstream and downstream monitoring site on Coxs River. This does not appear to be linked with the discharge and is most likely due to farming activities.

At the downstream monitoring site on the Wolgan River, the following exceedances of DTVs were noted: pH and Nitrate as N occasionally, Total Nitrogen as N and Total Phosphorus sometimes and Aluminium frequently. At the upstream site on the Wolgan River, the exceedances were slightly different with that for pH, electrical conductivity, turbidity and Nitrate as N being occasional, those for Zinc, Total Nitrogen as N and Total Phosphorus occurring sometimes and those for Aluminium and Iron being more frequent. RPS (2013c) also noted that the water at both sites had elevated bicarbonate, carbonate, sulphate, sodium, calcium and potassium concentrations, reflecting the origin of the water from swampy areas.

4.5 Additional Sources of Information

4.5.1 Upper Coxs River Catchment

The condition of the Upper Coxs River sub-catchment (i.e. the section extending from the river's origin to just below Lake Lyell) over the period 1 July 2007 to 30 June 2010 has been audited by the Sydney Catchment Authority (SCA) (2010). The sub-catchment was found to be under a high level of stress, due to inflows from the sewage treatment plants, inflows of urban stormwater, runoff from roads and grazing lands, regulation of flows by dams, extraction of surface and ground water, occurrence of barriers to fish passage, geomorphological disturbance from past and present mining and licenced discharges from Wallerawang Power Station and coal mine operations.

The audit noted that the median total nitrogen (0.8 mg/L), total phosphorus (0.09 mg/L), and conductivity (676 µS/cm) levels in the section of the Coxs River between Sawyers Swamp Creek and Pipers Flat Creek was above the guidelines for upland rivers in south-east Australia (ANECC/ARMCANZ 2000). The median total nitrogen (0.335mg/L), total phosphorus (0.019mg/L) and conductivity 40 (µS/cm) levels were considerably lower in the Coxs River upstream of Kangaroo Creek.

In 2009, the aquatic macroinvertebrate fauna at a site on the river upstream of the confluence with Lambs Creek and at most sites on the river downstream of the confluence with Neubecks Creek was significantly impaired relative to the AUSRIVAS reference conditions, whereas that at the site closest to the confluence with Neubecks Creek and at sites on Neubecks Creek and Sawyers Swamp Creek was severely impaired. The macroinvertebrate fauna at a site on the river situated approximately half way between its confluences with Neubecks Creek and Pipers Flat Creek has been assessed annually from 2001 to 2009 and been found to fluctuate between similar to AUSRIVAS reference condition and significantly Impaired.

Several different types of wetland occur in the Upper Coxs River sub-catchment, but information on their condition is limited. Some swamps have been impacted by longwall mining, mine water discharges and water transfers to the Farmers Creek Dam water supply. Many areas of Long Swamp in the upper reaches of the river are still in good condition, but some are experiencing increased desiccation. Long Swamp has been impacted by mine water discharges and 4WD tracks and could be impacted if longwall mining alters groundwater levels adjacent to the swamp (Aurecon 2009). The perched aquifer in Kangaroo Creek Swamp in the upper reaches of Kangaroo Creek has been impacted by longwall mining (Centennial Coal 2009). Flows from the Clarence Water Transfer Scheme are believed to have contributed to gullying in the upper part of Farmers Creek Swamp (DECCW 2010).

The NSW Office of Water Gauging Station No. 212054 situated on the Coxs River above Lake Wallace has monitored flows and salinity daily since 1992. The data from this station indicate the 5th percentile, 50th percentile (median) and maximum flows are 2.9 ML/d, 12.2 ML/d and 5,321 ML/d, respectively and that salinities greater than 600 µS/cm have prevailed for more than 20 years (RPS 2013c). The data also show a trend of increasing salinity between 1992 and 2007 followed by a marked reduction in salinity after 2010. A maximum salinity level of 1,704 µS/cm was recorded in January 2013.

4.5.2 Wolgan River Catchment

In May 2005, AUSRIVAS macroinvertebrate samples were collected from edge habitats in the upper reaches of Wolgan River as part of a study to determine whether the Colo River and its sub-catchments met the wild river criteria (DECCW 2008). Samples collected from sites within Wollemi National Park were similar to the AUSRIVAS reference condition, however, those from Newnes Plateau, just outside the park, and Wolgan Gap gave mixed results, with some indicating slight impairment relative to the reference condition and others a slightly more diverse fauna. The overall results indicated that this section of river was in good condition with high aquatic biodiversity and that the condition of the river improved as it entered Wollemi National Park.

The Public Environment Report submitted to the OEH in relation to potential impacts from the proposed Emirates Wolgan Valley Resort included a general description of aquatic flora and fauna within the sections of the Wolgan River and Carne Creek that traverse that site (Cumberland Ecology 2006). The major findings were:

> Both streams had been highly modified as a result of vegetation clearing, erosion and grazing;

> The creek and river were heavily eroded and the channel beds had a heavy sediment deposition in many areas;

> Aquatic vegetation was sparse;

> Woody debris and submerged timber provided habitat for aquatic macroinvertebrates and fish in the upper reaches of Carne Creek and lower sections of the Wolgan River;

> NSW DPI has recorded seven native and two alien fish species within the Wolgan River;

> Fish habitat had been degraded by clearing and cattle grazing and impacted by the spread of alien species;

> The diversity and abundance of fish is also likely to have been impacted by weirs and other constructed damming structures on the Wolgan River towards Newnes.

4.6 Summary

4.6.1 Aquatic Habitat

4.6.1.1 Coxs River Catchment

The channel at Sites CR1, CR2 and CR4 consisted of a narrow incised, flat-bottomed drainage. The stream banks were steep, undercut, unstable and actively eroding in some sections. The banks supported grasses and isolated blackberry bushes, but there was no woody riparian vegetation at the three upstream sites. Eucalypt trees and sparse willow trees, however, were present at the downstream site (CR5), as were grasses and blackberry bushes. The substratum at all four sites consisted of sandy and/or muddy deposits with some pebbles, cobbles and boulders. There was also a riffle zone at CR5. The riparian and aquatic environments at the sites situated downstream of the confluence with Kangaroo Creek (CR2) and with AP_ LDP003 (CR4) were in the poorest overall condition.

4.6.1.2 Wolgan River Catchment

The monitoring sites on Wolgan River were surrounded by dense, overhanging riparian vegetation. The river channel was fairly narrow, varying in width from 1-5 m, and water levels were shallow to moderate, with maximum depths varying from 0.2-1.5 m. The substratum was variable, consisting mostly of sand but with areas of finer sediments at the upstream site, being composed mostly of bedrock, but with some sandy pools, boulders and cobbles also present at the midstream site and being mostly sandy but with some gravel and boulder fragments at the downstream site. The aquatic habitats in the river had been exposed to small to moderate amounts of disturbance, with the midstream site being in a slightly better condition than the other two sites. Orange precipitates (iron floc) were present at the upstream site only.

The creek channel at the site on Carne Creek was incised below the surrounding valley floor, generally straight, fairly narrow and shallow. Dense vegetation and moss-covered boulders and logs were present along the banks. The channel substratum was variable and comprised sandstone fragments, ranging in size from gravel to cobble, long sand drifts and boulder outcrops. The site had been subject to minimal disturbance.

4.6.2 Water Quality

4.6.2.1 Coxs River Catchment

The water at Site CR1 was in a better overall condition than that at the other sites. The electrical conductivity levels at Sites CR2, CR4 and CR5 exceeded the upper DTV (350 µS/cm) for slightly disturbed upland rivers in south-east Australia, but were below the level that poses a threat to aquatic life (approximately 1,562 µS/cm). The conductivity levels at Site CR1 were within the DTV range. The dissolved oxygen levels at all of the sites, except CR5, were generally below the guidelines. The pH of the water at Sites CR2 and CR5 was more alkaline than the upper DTV (8.0 units), while that at CR1 and CR4 was generally within the guidelines. The turbidity levels at the sites in the Coxs River catchment were generally within the guidelines.

4.6.2.2 Wolgan River Catchment

The conductivity of the water in the Wolgan River was within the ANZECC/ARMCANZ (2000) guidelines, but the measurement taken in Carne Creek was below the lower DTV. The dissolved oxygen levels at all the sites were generally below the guidelines. The pH of the water at Sites WRmd, WRdn and CCXdn was generally acidic and below the below the lower DTV, as was that at WRup on occasion. The water in the creek was more acidic than in the river. The turbidity levels at all sites were within the guidelines, except at WRmd on one occasion.

4.6.3 Aquatic Plants and Algae

4.6.3.1 Coxs River Catchment

More aquatic plant taxa were found at CR1 and CR5 than at CR2 and CR4. Jointed Rush and Cumbungi were the most widespread plants. Filamentous green algae were found at all four sites. Charophytes were absent from CR2, but present at the other sites.

4.6.3.2 Wolgan River Catchment

The information on occurrence of aquatic macrophytes is difficult to interpret, because of the lack of consistency in their identification over time and absence of diagnostic features in the form of flowers and fruit required for identification. Bulbous Rush has been recorded at all the riverine sites, but now appears to have been identified as Swamp Clubrush. Jointed Rush has also been recorded but only at the midstream site on one occasion. No macrophytes or algae were observed at the site on Carne Creek.

4.6.4 Aquatic Macroinvertebrates

4.6.4.1 Coxs River Catchment

The sites on the Coxs River supported a diverse range of aquatic macroinvertebrate fauna, with a total of 62 taxa being recorded across the surveys and total numbers per site ranging from 35-47. The fauna consisted of 44 insect families, five crustacean taxa (Cladocera, Cyclopidae, Atyidae, Parastacidae and Ostracods), four different worm taxa (Oligochaeta, Nemertea, Temnocephalidae and Dugesiidae), six mollusc taxa (Corbiculidae, Sphaeriidae, Ancylidae, Lymnaeidae, Physidae and Planorbidae) and one taxon each of springtails (Collembola), freshwater mites (Hydracarina) and leeches (Erpobdellidae). Fewer taxa were recorded per survey, with numbers varying from 23-35, 20-30, 20-33 and 20-32 at CR1, CR2, CR4 and CR5, respectively. The proportion of the taxa recorded every survey varied from 8.7% at CR4 to 23.3% at CR5.

The fauna at the sites in Coxs River was either significantly impaired or equivalent to the AUSRIVAS reference conditions, with that at CR2 and CR4 being less impaired on average than that at CR1 and CR5. The average SIGNAL2 scores indicated the condition of the Coxs River sites varied from moderately to severely degraded, with Sites CR1 and CR5 being in the poorest condition.

The MDS plot below shows similarity of macroinvertebrate fauna at Sites CR1, CR2, CR4 and CR5 on Coxs River, and indicates that macroinvertebrate assemblages at CR1 and CR2 were fairly distinct from each other and from those at CR4 and CR5 on the Coxs River (**Figure 4-2**).

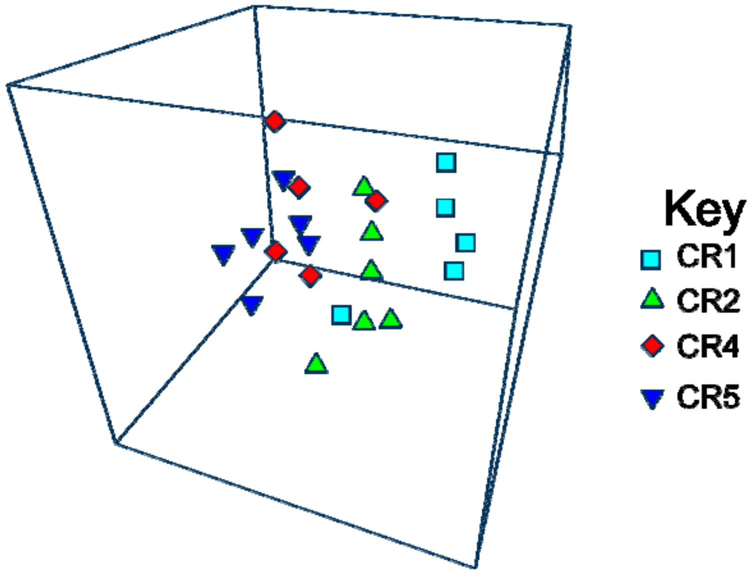

Figure 4-2 Multi-dimensional scaling plot comparing the multivariate structure of the aquatic macroinvertebrate assemblages at sites on the Coxs River.

4.6.4.2 Wolgan River Catchment

The Wolgan River sites supported a diverse range of aquatic macroinvertebrate fauna, with a total of 57 taxa being recorded across the surveys and total numbers per site ranging from 33-43. The fauna consisted of 49 insect families, four crustacean taxa (Cladocera, Cyclopidae, Ostracods and Isopoda), two different types of worms (oligochaetes and flatworms) and one taxon each of bivalves (Sphaeriidae) and freshwater mites (Hydracarina). Fewer taxa were recorded per survey, with numbers varying from 18-25, 20-25 and 19-24 at the upstream, midstream and downstream sites, respectively. The proportion of the taxa recorded every survey declined from 41.9% at the upstream site to 36.4% at the midstream site and 28.3% at the downstream site. The macroinvertebrate fauna at the Carne Creek site was less diverse, with a total of 25 taxa recorded and numbers per survey varying from 19 to 23.

The macroinvertebrate fauna at the upstream river site was significantly impaired relative to the AUSRIVAS reference conditions during both of the 2011 and 2012 surveys, but that at the midstream site and downstream were impaired only in 2011 and spring, respectively. During the other surveys, the fauna at these sites was equivalent to the reference conditions.

The average SIGNAL2 scores indicated that the upstream riverine site was in the poorest condition, varying from severely to moderately degraded, the downstream site varied from moderately to mildly degraded, while the midstream site was classed as mildly degraded during all surveys. The average score for the Carne Creek site indicated it was not polluted.

The macroinvertebrate assemblages at Sites CCXdn and WRup were distinct from each other and from those at WRmd and WRdn (**Figure 4-3**). The dispersion of the symbols in the ordination indicates the fauna at WRup was more variable over time than that at the other sites.

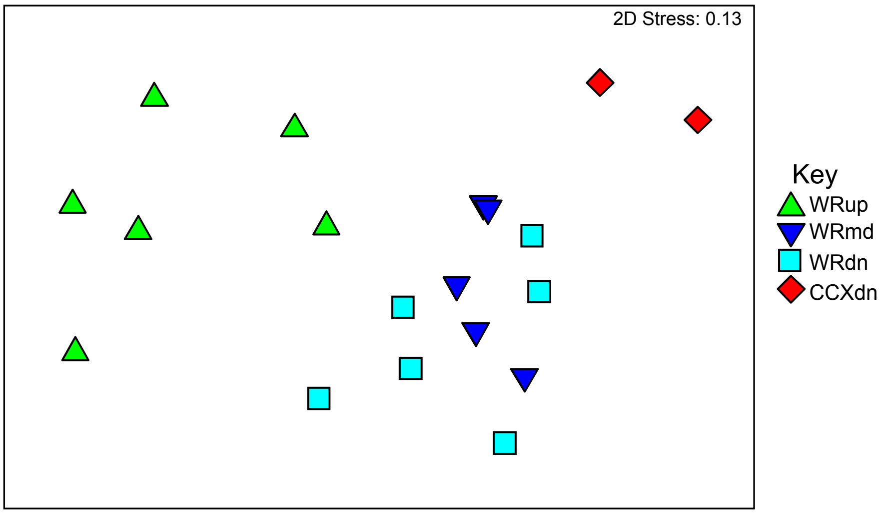

Figure 4-3 Multi-dimensional scaling plot comparing the multivariate structure of the aquatic macroinvertebrate fauna at Sites WRup, Wrmd and WRdn on the Wolgan River and Site CCXdn on Carne Creek.

4.6.5 Fish and Frogs

4.6.5.1 Coxs River Catchment

Two native species of fish, Flathead Gudgeon and Mountain Galaxias, and three introduced species of fish, Eastern Gambusia, Goldfish and Brown Trout were recorded at CR5. The two native species were the only fish recorded at CR2 and Eastern Gambusia and Brown Trout the only species found at CR4. No fish were caught at CR1 however, some (possibly Mountain Galaxias) were observed. Tadpoles were observed at all the sites, but no frogs were found.

4.6.5.2 Wolgan River Catchment

Eastern Banjo Frogs (*Lymnodynastes dumerilii grayi*) and Spotted Marsh Frogs (*Lymnodynastes tasmaniensis*) were heard, but only at WRup on one occasion. Tadpoles were present at WRup and WRdn, but only in Spring 2012. An eel (*Anguilla* sp.) was caught at the midstream site in Spring 2010, but no other fish species were caught or observed in the river. Fish and larvae, most likely Mountain Galaxias, were sighted in Carne Creek in Spring 2012.

4.7 Conclusions

The biannual baseline monitoring undertaken in the Coxs River, Kangaroo Creek and Wolgan River provides some information on within and between year variation in aquatic habitat, water quality and occurrence of aquatic plants and algae, aquatic macroinvertebrates and fish observed over a 2.5 to 3 year period. The information collected at Site CCXdn, however, is less representative as monitoring at that site commenced only in Autumn 2012. The monitoring program has shown that the condition of the aquatic habitats and quality of water in the Coxs River catchment is generally poorer than that in the Wolgan River catchment, but the aquatic biota is more diverse. It has also shown that there are marked differences in the aquatic ecology of sites upstream and downstream of licenced discharge points.

5 Existing Environment - Aquatic Ecology of Drainages Downstream of Swamps

As characterised by RPS (2013a), there are 12 Newnes Plateau Shrub Swamps (Shrub Swamps) and 55 Newnes Plateau Hanging Swamps (Hanging Swamps) in the immediate vicinity of the proposed workings. The Shrub Swamps are situated in low slope headwater valleys on the Newnes Plateau. The nature of the Shrub Swamps varies, with some being permanently waterlogged (Type C), others periodically waterlogged (Type A) and many exhibiting both characteristics (RPS 2013b. In the latter, the upper section is usually fed primarily by surface water while the lower section is predominantly groundwater fed. The base of the Shrub Swamps has a low gradient resulting in low velocity surface water flows and high water retention. The Hanging Swamps are subject to infrequent waterlogging and are supported by water from perched groundwater systems, direct and indirect rainfall recharge. The sub-catchment channel valleys downstream of the swamps are incised and bordered by steep sandstone escarpments, that increase in depth and frequency with increasing distance downstream (MPR 2012c). The Shrub Swamps in the Carne Creek catchment are considered to be primarily groundwater dependent systems and have a permanently high water table maintained by groundwater aquifers (Benson and Baird 2012). Carne West Swamp, however, has recently been classified as an ephemeral rather than a perennial system (Adhikary and Wilkins 2013). None of these swamps has been undermined or exposed to mine discharge previously.

In this section, the aquatic habitats, water quality, aquatic flora and fauna found at nine monitoring sites situated downstream of key swamps within or adjacent to the northern and southern parts of the proposed workings and of proposed LW502-LW503 are described. The description of the aquatic ecological attributes of the monitoring sites downstream of the swamps has been compiled from information presented in a series of reports on the outcomes of the baseline aquatic ecology monitoring program undertaken by MPR (2010, 2011a and b; 2012 a and b, 2013). A brief outline of the monitoring methodology was given in Section 4.1.

5.1 Overview of the Baseline Aquatic Ecology Monitoring

The location of the monitoring sites is shown in **Figure 5-1** and their geographic co-ordinates are presented in **Table 5.1**. Sites CC1, CC2 and CC3 are located respectively at the downstream ends of the Sunnyside East, Carne West and Gang Gang Shrub Swamps, in the headwater sub-catchments of Carne Creek within the northern part of the proposed workings. Site CC4 is situated downstream of Barrier Swamp, a Hanging Swamp located to the east of the proposed workings. Monitoring of the aquatic ecological attributes at Sites CC1-4 commenced in Autumn 2010. Sites MC1 in Marrangaroo Creek, BC1 in Bungleboori Creek and PC1 in Paddys Creek are situated downstream of swamps within the southern part of the proposed workings. An additional site (BCN2) is situated downstream of Nine Mile Swamp in the Bungleboori Creek catchment to the east of the proposed workings. Site SSWdn is situated on Sawyers Swamp Creek, a tributary of Coxs River, downstream of LW502-LW503. This site is located above the Kerosene Vale Ash Dam in a narrow valley downstream of the Newnes Plateau. Monitoring of the aquatic ecological attributes at BC1 and MC1 commenced in Spring 2010, but that at BCN2, PC1 and SSWdn only began in Autumn 2012.

Note that the AUSRIVAS predictive software has not been used to analyse the macroinvertebrate data. Spatial differences in the multivariate structure of the macroinvertebrate assemblages, however, have been examined using non-metric Multi-Dimensional Scaling (MDS) (Clarke 1993) (See Section 4.1 for more details).

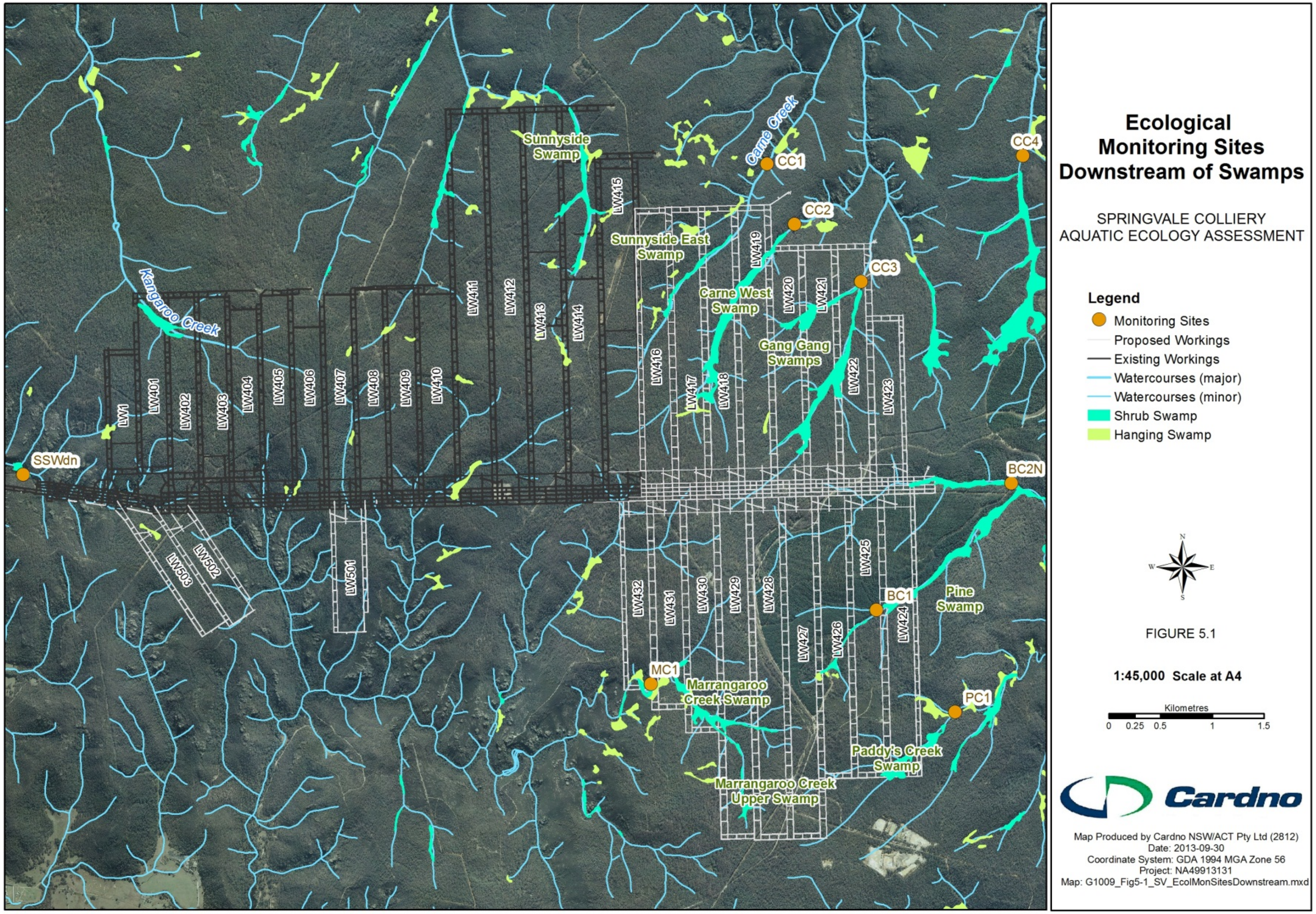

Figure 5-1 Map showing the location of the aquatic ecology monitoring sites downstream of swamps relative to the proposed longwalls in the Project Application Area.

Table 5-1 Geographic coordinates and locality descriptions for monitoring sites on the drainages downstream of swamps located above or in the vicinity of the proposed workings.

Site Code	Catchment	Easting	Northing	Description
CC1	Carne Creek	239574	6304405	Site located downstream of Sunnyside East Swamp.
CC2		239839	6303820	Site located at the downstream end of Carne West Swamp.
CC3		240484	6303265	Site located at the downstream end of Gang Gang swamp, below the confluence of two swamp flow channels.
CC4		242049	6304485	Site located at the downstream end of a hanging swamp adjacent to Barrier Swamp.
MC1	Marrangaroo Creek	238448	6299375	Site located in upper Marrangaroo Creek.
BC1	Bungleboori Creek	240633	6300089	Site on Pine Swamp Upper in the upper Bungleboori Creek catchment.
BC2N		241938	6301314	Site on the northern unnamed drainage to Bungleboori Creek tributary that drains Pine Swamp.
PC1	Paddys Creek	241393	299103	Site located midway along Paddys Creek below two swamps.
SSWdn	Sawyers Swamp Creek	232266	6301445	Site on Sawyers Swamp Creek located above Kerosene Vale Ash dam.

5.2 Swamps in or near the Northern Part of the Proposed Workings

5.2.1 Sunnyside East Swamp - Site CC1

The southern half of Sunnyside East Swamp is generally dry and channelized, but the northern half appears to be permanently wet. The vegetation is dominated by *Gleichenia dicarpa*, *Leptospermum grandifolium*, *Baumea rubiginosa* and *Gahnia sieberiana* (Springvale Coal 2012b). Site CC1 is situated downstream of Sunnyside East Swamp and the headwaters of the western branch of Carne Creek along which there are several Hanging Swamps and is just outside the area of the proposed workings.

5.2.1.1 Aquatic and Riparian Habitat

The channel substratum consisted of bedrock and boulders with few areas where sand or water could accumulate. Unconsolidated sand and gravel deposits, however, were present in plunge pools and there was a build-up of fine silt on the substratum at the lower end of the site. The channel was densely overgrown with ferns, shrubs and sedges and as a result very little sunlight penetrated through to the water. Fallen logs were common throughout the site. Moss was common on rocks and logs along the entire study area. The edge habitat comprised trailing bank vegetation, bedrock overhangs and detritus. The water was generally very shallow (less than 5 cm deep) and the maximum water depth was 0.5 m. The RCE score (49) indicated the stream channel and adjacent features were minimally disturbed.

5.2.1.2 Water Quality

The baseline surface water quality measurements for CC1 presented in **Table 5.2** show that:

> Electrical conductivity levels were very low, ranging from 16-24 µS/sec, which is below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were within the guidelines during two surveys but below the lower DTV (90% saturation) during the other baseline surveys;

> pH levels were below the lower DTV (6.5 units), except during the first survey;

> Turbidity levels were within the default trigger value range (2-25 NTU).

5.2.1.3 Aquatic Plants and Algae

In Autumn 2010, no macrophytes were observed. In Spring 2010 and Autumn 2011, the plunge pool at the lower end of the site was reported to contain charophytes and some ‘sedges’. In Spring 2011 and Autumn 2012, Bulbous Rush and charophytes were observed. In Spring 2012, a reduction in the abundance of charophytes was noted and swamp clubrush (*Isolepis inundatus*) was reported. No filamentous green algae were observed.

Table 5-2 Surface water quality measurements recorded during baseline surveys undertaken at Site CC1 downstream of Sunnyside East Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
10/06/2010	10:36	8.93	23	77.1	6.89	16.1
08/11/2010	13:59	11.30	23	80.2	ND	ND
25/05/2011	12:19	9.75	19	78.0	5.63	10.6
14/11/2011	13:57	12.14	16	106.0	5.67	13.4
22/05/2012	09:16	8.90	24	94.1	5.31	1.2
28/11/2012	09:31	12.12	ND	85.2	5.50	15.5

5.2.1.4 Aquatic Macroinvertebrates

A total of 32 macroinvertebrate taxa were collected during the baseline monitoring events, 28 of which were insect families (**Appendix F**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Mecoptera (scorpionflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Parastacidae (freshwater crayfish/yabbies), Oligochaeta (freshwater worms) and Gordioidea (hair worms).

The number of taxa collected per event varied from 14 to 21 (**Table 5.3**). The samples collected in spring yielded more taxa than those in the preceding autumn. Six taxa (Gyrinidae, Ceratopogonidae, Tanypodinae, Leptophlebiidae, Gripopterygidae and Leptoceridae) were found every survey, but nine taxa were recorded only once (**Appendix F**).

Table 5-3 Number of macroinvertebrate taxa recorded at Site CC1 downstream of Sunnyside East Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date					
	10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012
Number of taxa	14	18	16	20	16	21
SIGNAL2 score	5.50	5.72	4.97	5.40	5.38	6.10

The average SIGNAL2 scores varied from 5.0 to 6.1 and were thus indicative of mild to no degradation (**Table 5.3**). Eleven taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix F**). Eleven taxa had SIGNAL2 scores ≥ 7 and are considered to be sensitive to pollution.

5.2.1.5 Fish and Frogs

No fish or amphibians were observed or caught during the baseline aquatic ecology monitoring events.

5.2.2 Carne West Swamp - Site CC2

Carne West Swamp is a permanently wet, groundwater swamp dominated by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Leptospermum grandifolium*, *Gleichenia dicarpa*, *Xyris gracilis* ssp. *gracilis* and *Baeckea linifolia (*Springvale Coal 2012b). Site CC2 is situated downstream of a road crossing at the downstream end of Carne West Swamp and is just outside the proposed workings area.

5.2.2.1 Aquatic and Riparian Habitat

The channel was narrow (generally less than 1 m), sinuous and surrounded by a dense overgrowth of riparian shrubs, sedges and trees. There was a series of regular rocky cascades approximately 50-75 m downstream of the road crossing. The channel substratum consisted mostly of exposed bedrock but with some sandy and muddy accumulations. The average and maximum depth were 0.1 and 0.3 m, respectively. The pool edge habitat consisted of trailing bank vegetation, detritus and an unidentified Cyperaceae species. The RCE score (49) indicated the stream channel and adjacent features were minimally disturbed.

5.2.2.2 Water Quality

The baseline surface water quality measurements for CC2 presented in **Table 5.4** show that:

> Electrical conductivity levels were very low, ranging from 15-24 µS/cm, which is below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during three of the baseline surveys, but within the guidelines during the others;

> pH levels were below the lower DTV (6.5 units);

> Turbidity levels were within the default trigger value range (2-25 NTU) during two surveys, but exceeded the upper DTV in Spring 2011 and 2012.

RPS (2013c) compared the water quality measurements from Carne West Swamp taken by Centennial Coal with the appropriate ANZECC/ARMCANZ (2000) guidelines and noted that Zinc, Aluminium and Total Suspended Solids levels consistently exceeded their respective DTVs, pH levels did so frequently, while Iron, Total Nitrogen as N and Total Phosphorus did so occasionally. They suggested that low flows combined with decomposition of organic matter and local geology probably contributed to the acidity of the water and this, in turn, may have caused the leaching of aluminium from soils. RPS (2013b) also noted that the water was more acidic between January 2011 and June 2011 and attributed this to the accumulation of acid sulphates resulting from drying out of the swamp soils during a low flow/dry period.

Table 5-4 Surface water quality measurements recorded during baseline surveys undertaken at Site CC2 downstream of Carne West Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
10/06/2010	12:12	6.09	20	79.2	6.08	ND
08/11/2010	11:46	13.43	17	96.9	ND	ND
25/05/2011	14:03	7.69	18	75.1	5.09	17.9
14/11/2011	15:43	13.19	15	98.5	4.51	53.3
22/05/2012	11:31	6.13	24	95.8	4.41	7.2
28/11/2012	13:54	12.60	ND	82.3	4.92	30.3

5.2.2.3 Aquatic Plants and Algae

Three different aquatic macrophytes were recorded during the baseline monitoring. The first plant observed in Autumn 2010 was tentatively identified as a member of the family Cyperaceae (sedge). In Spring 2011 and Autumn 2012, Bulbous Rush (*Juncus bulbosus*) was recorded. The third macrophyte, swamp clubrush (*Isolepis inundatus*), was found in Spring 2012.

Very small amounts of filamentous green algae were reported in Spring 2010, but none were observed during other surveys. No charophytes were reported.

5.2.2.4 Aquatic Macroinvertebrates

A total of 24 macroinvertebrate taxa were collected during the baseline monitoring events, 22 of which were insect families (**Appendix G**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Mecoptera (scorpionflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Parastacidae (freshwater crayfish/yabbies) and Oligochaeta (freshwater worms).

The number of taxa collected per event varied from 10 to 18, with fewer taxa being collected during the first three surveys (**Table 5.5**). Six families (Tipulidae, Leptophlebiidae, Synthemistidae, Gripopterygidae, Leptoceridae and Philorheithridae) were found each survey, but six were sampled once (**Appendix G**).

The average SIGNAL2 scores varied from 5.3 to 6.6 and were thus indicative of mild or no degradation (**Table 5.5**). Eight taxa had low SIGNAL2 scores (≤ 4), indicating they were tolerant to a variety of environmental conditions, including pollution (**Appendix G**). Tex taxa had SIGNAL2 scores (≥ 7) indicative of sensitivity to pollution.

Table 5-5 Number of macroinvertebrate taxa recorded at Site CC2 downstream of Carne West Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date					
	10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012
Number of taxa	14	10	13	16	18	18
SIGNAL2 score	5.50	6.30	5.77	5.84	5.28	6.56

5.2.2.5 Fish and Frogs

No fish or amphibians were observed or caught during the baseline aquatic ecology monitoring events.

5.2.3 Gang Gang Swamp - Site CC3

Gang Gang Swamp is a permanently wet, groundwater fed system with channelised flows and is dominated by *Leptospermum grandifolium*, *Lepidosperma limicola*, *Boronia deanei* and *Gleichenia dicarpa* (Springvale Coal 2012b). Site CC3 is located above a road crossing downstream of the confluence of the Gang Gang Swamp South West and Gang Gang Swamp East flow channels and above proposed Longwall 422.

5.2.3.1 Aquatic and Riparian Habitat

This site was situated above a road crossing downstream of the confluence of two separate swamp flow channels, with the eastern arm having significantly more flow than the western arm. At the upstream end of the site, the two arms of the swamp converged into a waterfall and cascade. There were short, steep cascading waterfalls downstream of the site. The flow path was covered by extensive (100%) riparian vegetation. There was also abundant edge and trailing bank vegetation. The maximum water depth was 0.4 m, but the depth was generally less than 0.1 m. The substratum consisted of bedrock in the cascade sections and fine sandy deposits, with fine muddy silt present in backwater areas where there was minimal flow. The RCE score (49) indicated the stream channel and adjacent features were minimally disturbed.

5.2.3.2 Water Quality

The baseline surface water quality measurements for CC3 presented in **Table 5.6** show that:

> Electrical conductivity levels were very low, ranging from 17-22 µS/sec, which is below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during four surveys, but within the guidelines during the others;

> pH levels in all surveys were below the lower DTV (6.5 units);

> Turbidity levels were slightly above the upper DTV (25 NTU) on three occasions, but within limits otherwise.

Table 5-6 Surface water quality measurements recorded during baseline surveys undertaken at Site CC3 downstream of Gang Gang Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
09/06/2010	15:56	7.49	20	77.2	6.20	25.6
08/11/2010	11:53	12.56	17	79.7	ND	ND
25/05/2011	15:20	8.82	20	75.5	5.45	26.0
15/11/2011	14:53	14.92	17	105.2	4.69	23.2
22/05/2012	13:43	7.78	22	95.9	4.42	14.2
28/11/2012	15:41	13.94	ND	86.7	5.47	28.9

5.2.3.3 Aquatic Plants and Algae

Three different aquatic macrophytes were recorded during the baseline monitoring. The first plant observed in Spring 2010 was tentatively identified as a member of the family Cyperaceae (sedge). During the subsequent survey rushes were reported and in Spring 2011 and Autumn 2012 these were identified as Bulbous Rush (*Juncus bulbosus*). The third macrophyte, swamp clubrush (*Isolepis inundatus*), was found in Spring 2012. Small amounts of filamentous green algae were found during most surveys, but no charophytes were reported.

5.2.3.4 Aquatic Macroinvertebrates

A total of 31 macroinvertebrate taxa were collected during the baseline monitoring events, 26 of which were insect families (**Appendix H**). The insects included representatives from eleven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Lepidoptera (moths and butterflies), Mecoptera (scorpionflies), Megaloptera (dobsonflies), Neuroptera (Lacewings), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Cyclopidae (copepods), Parastacidae (freshwater crayfish/yabbies), Phreatoicidae (isopods), Oligochaeta (freshwater worms) and Gordioidea (hair worms).

The number of taxa collected per event varied from 9 to 22, with the fewest being collected during Autumn 2010 and most in Spring 2012 (**Table 5.7**). Six families (Tipulidae, Leptophlebiidae, Synthemistidae, Gripopterygidae, Hydropsychidae and Leptoceridae) were found during every survey, but eleven were sampled only once (**Appendix H**).

The average SIGNAL2 scores varied from 5.2 to 6.0 and were thus indicative of mild degradation (**Table 5.7**). Thirteen taxa had SIGNAL2 scores ≤ 4, indicating they were tolerant to a variety of environmental conditions, including pollution (**Appendix H**). Nine taxa were considered to be sensitive to pollution.

Table 5-7 Number of macroinvertebrate taxa recorded at Site CC3 downstream of Gang Gang Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date					
	9/06/2010	8/11/2010	25/05/2011	15/11/2011	22/05/2012	28/11/2012
Number of taxa	9	18	18	16	16	22
SIGNAL2 score	6.00	5.39	5.17	5.19	5.19	5.19

5.2.3.5 Fish and Frogs

No fish or amphibians were observed or caught during the baseline aquatic ecology monitoring events.

5.2.4 Barrier Swamp - Site CC4

Barrier Swamp is a permanently wet, groundwater fed system dominated by *Gleichenia dicarpa*, *Leptospermum grandifolium*, *Lepidosperma limicola*, *Gymnoschoenus sphaerocephalus* and *Xyris gracilis* ssp. *gracilis* (Centennial 2012b). Site CC4 is situated downstream of Barrier Swamp just above a confluence with a small tributary entering from the east. Barrier Swamp is located approximately 800 m to the east of the proposed workings and is therefore not expected to experience any measurable subsidence movements or be adversely impacted by the proposed mining (James Barbato, MSEC, pers. comm.).

5.2.4.1 Aquatic and Riparian Habitat

There was a pine plantation close to the upstream limits of the swamp. The swamp channel meandered through the surrounding dense overgrowth of riparian shrubs, sedges and trees. The channel form was similar to that of Sites CC1-CC3, with cascades over bedrock, pools with exposed bedrock and accumulations of sandy and muddy sediments. The aquatic habitats associated with the pool edge were also similar, comprising trailing bank vegetation and detritus.

The RCE score (49) indicated the stream channel and adjacent features were minimally disturbed.

5.2.4.2 Water Quality

The baseline surface water quality measurements for CC4 presented in **Table 5.8** show that:

> Electrical conductivity levels were very low, ranging from 20-25 µS/sec, which is below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during four surveys, but within the guidelines during the others;

> pH levels in all surveys were below the lower DTV (6.5 units);

> Turbidity levels were generally within the DTV range, except in Spring 2012 when exceeded the upper DTV (25 NTU) slightly.

Table 5-8 Surface water quality measurements recorded during baseline surveys undertaken at Site CC4 downstream of Barrier Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
10/06/2010	14:44	7.68	22	77.3	5.98	17.1
09/11/2010	16:15	14.33	22	75.9	5.24	ND
26/05/2011	12:11	8.41	20	81.1	5.27	12.7
15/11/2011	12:26	15.41	20	97.7	4.44	17.9
22/05/2012	15:34	7.74	25	94.0	4.36	9.9
29/11/2012	8:01	13.43	ND	85.0	4.64	26.6

5.2.4.3 Aquatic Plants and Algae

Two macrophytes were reported: Bulbous Rush in Autumn 2012 and Swamp Clubrush in Spring 2012. Small amounts of filamentous green algae were found in Autumn and Spring 2011, but none were observed during the other surveys. No charophytes were reported.

5.2.4.4 Aquatic Macroinvertebrates

A total of 33 macroinvertebrate taxa were collected during the baseline monitoring events, 29 of which were insect families (**Appendix I**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Parastacidae (freshwater crayfish/yabbies), Oligochaeta (freshwater worms) and Gordioidea (hair worms).

The number of taxa collected per event varied from 13 to 22, with samples collected in spring yielding substantially more taxa (19-22) than those in autumn (13-15) (**Table 5.9**). Seven taxa (Gyrinidae, Chironominae, Tanypodinae, Leptophlebiidae, Synthemistidae, Gripopterygidae and Leptoceridae) were found every survey, but 10 taxa were recorded only once (**Appendix I**).

The average SIGNAL2 scores varied from 5.3 to 6.1 and were thus indicative of mild to no degradation (**Table 5.9)**. Eleven taxa had SIGNAL2 scores, indicative of tolerance to a variety of environmental conditions, including pollution (**Appendix I**). Twelve taxa were sensitive to pollution (i.e. had SIGNAL2 scores ≥ 7).

Table 5-9 Number of macroinvertebrate taxa recorded at Site CC4 downstream of Barrier Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date					
	10/06/2010	9/11/2010	26/05/2011	15/11/2011	22/05/2012	10/06/2010
Number of taxa	13	19	15	20	15	22
SIGNAL2 score	5.54	5.26	5.77	5.68	6.07	5.86

5.2.4.5 Fish and Frogs

No fish were observed or caught during the baseline aquatic ecology monitoring events. Unidentified tadpoles were observed in November 2011.

5.3 Swamps in or near the Southern Part of the Proposed Workings

5.3.1 Marrangaroo Creek Swamp - Site MC1

Site MC1 is situated just below the Marrangaroo Creek Main Swamp near the western border of EL 1588 and above the proposed LW432.

5.3.1.1 Aquatic and Riparian Habitat

The valley floor beyond the limits of Site MC1 supported dense swampy meadows including button grass (*Gymnoschoenus* sp.), coral ferns (*Gleichenia* sp.), sword grass (*Gahnia* sp.) and heath species. The drainage channel was fairly distinct and had several shallow cascades and was thus similar to that at the Carne Creek swamp monitoring sites. The channel had an average and maximum width of 1.0 m and 2.5 m, respectively, a maximum depth of 0.6 m, but the average depth was <10cm. The edge habitats included trailing bank vegetation, detritus, undercut banks and logs and were thus similar to those of the Carne Creek swamp sites. The substratum was composed of bedrock with some boulders and cobbles and sand accumulations and silt were found in some pool sections. Site MC1 returned an RCE score of 49, indicating the stream channel and adjacent features were minimally disturbed.

5.3.1.2 Water Quality

The baseline surface water quality measurements for MC1 presented in **Table 5.10** show that:

> Electrical conductivity levels were very low, ranging from 17-25 µS/sec, which is below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during three surveys, but within the guidelines during the others;

> pH levels during all surveys were below the lower DTV (6.5 units);

> Turbidity levels were within the default trigger value range (2-25 NTU) on two occasions, but exceeded the upper DTV in Spring 2011 and 2012.

5.3.1.3 Aquatic Plants and Algae

In Spring 2010, small amounts of an unidentified sedge and charophytes were observed around the edge of larger pools. Bulbous Rush and filamentous green algae were recorded in Autumn and Spring 2011, but charophytes were only seen in autumn that year. In Autumn 2012, bulbous rush and moderate amounts of filamentous algae were reported. In Spring 2012, Swamp Clubrush, charophyte beds, low to moderate amounts of filamentous green algae and algal mats were present.

Table 5-10 Surface water quality measurements recorded during baseline surveys undertaken at Site MC1 downstream of Marrangaroo Creek Swamp. (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
10/11/2010	15:43	12.95	17	78.9	5.11	ND
26/05/2011	15:29	7.99	18	77.0	5.34	23.5
15/11/2011	08:58	11.22	18	91.8	4.61	42.2
07/06/2012	11:29	7.54	25	91.0	5.41	4.6
29/11/2012	15:35	14.79	ND	84.7	5.42	27.6

5.3.1.4 Aquatic Macroinvertebrates

A total of 27 macroinvertebrate taxa were collected during the baseline monitoring events, 23 of which were insect families (**Appendix J**). The insects included representatives from six orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Talitridae (side swimmers), Parastacidae (freshwater crayfish/yabbies) and Oligochaeta (freshwater worms).

The number of taxa collected per event varied from 13 to 18 (**Table 5.11**). The samples collected in spring yielded slightly more taxa than those in autumn. Eight taxa (Gyrinidae, Chironominae, Tanypodinae, Leptophlebiidae, Synthemistidae, Telephlebiidae, Ecnomidae and Leptoceridae) were found each survey, but a further eight were recorded once only (**Appendix J**).

The average SIGNAL2 scores varied from 5.3 to 5.7 and were thus indicative of mild degradation (**Table 5.11**). Nine taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix J**). Ten taxa had SIGNAL2 scores ≥ 7, indicating they were sensitive to pollution.

Table 5-11 Number of macroinvertebrate taxa recorded at Site MC1 downstream of Marrangaroo Creek Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date					
	10/11/2010	26/05/2011	15/11/2011	7/06/2012	29/11/2012	10/11/2010
Number of taxa	15	13	18	15	17	15
SIGNAL2 score	5.33	5.62	5.53	5.40	5.65	5.33

5.3.1.5 Fish and Frogs

A native fish species, Mountain Galaxias (*Galaxias olidus*) was recorded during each spring survey but not in autumn. Larval fish were also observed in Spring 2011 and 2012. These were most likely Mountain Galaxias. No amphibians were observed or caught.

5.3.2 Paddys Creek Swamp - Site PC1

Site PC1 is situated below a road crossing midway along Paddys Creek, a tributary of Bungleboori Creek, located approximately 2.3 km from the top of the catchment. The site is located at the confluence of two upper sub-catchment branches that support an approximately 800 m long Shrub Swamp (Paddys Creek Swamp) and an unnamed 300 m long Hanging Swamp, respectively. The catchment above the site supports native vegetation and there are several access roads along the ridge lines bounding the sub-catchments.

5.3.2.1 Aquatic and Riparian Habitat

The channel upstream of the road crossing was obscured by the dense vegetation on and around the valley floor. The channel within the study site had shallow incisions, but some areas were steep and had undercut banks, indicative of erosion. The maximum stream width reached 10 m, but the average width in main channel was around 1 m. The maximum depth was 0.8 m and average 0.3 m.

In Autumn 2012, some suspended particulate matter was evident in the runoff, probably due to the high flow rates. The edge habitats sampled consisted of detritus, bulbous rush, logs jams and trailing bank vegetation. The substratum was composed mostly of mobile sandy sediments with sandstone pebbles and cobbles present within the main incised drainage channel. The RCE score (43) indicated the stream channel and adjacent features were subject to small levels of disturbance.

5.3.2.2 Water Quality

The baseline surface water quality measurements for PC1 presented in **Table 5.12** show that:

> Electrical conductivity level in Autumn 2012 was less than the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were slightly below the lower DTV (90% saturation) during both surveys;

> pH levels were below the lower DTV (6.5 units);

> Turbidity levels exceeded the upper DTV (25 NTU) during both surveys.

Table 5-12 Surface water quality measurements recorded during baseline surveys undertaken at Site PC1 at the downstream end of Paddys Creek Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
6/06/2012	15:34	8.17	24	87.8	4.42	44.8
29/11/12	13:12	14.16	ND	85.2	4.61	37.3

5.3.2.3 Aquatic Plants and Algae

Bulbous rush was recorded during both surveys. No filamentous green algae were observed.

5.3.2.4 Aquatic Macroinvertebrates

A total of 22 macroinvertebrate taxa were collected during the two baseline monitoring events, 20 of which were insect families (**Appendix K**). The insects included representatives from nine orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Mecoptera (scorpionflies), Megaloptera (dobsonflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Parastacidae (freshwater crayfish/yabbies) and Oligochaeta (freshwater worms).

More taxa were collected in the Spring (20) than Autumn (17) 2012 survey (**Table 5.13**), with 15 of these being represented during both surveys (**Appendix K**).

The average SIGNAL2 scores for the two surveys are indicative of mild degradation (**Table 5.13**). Ten taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix K**). Six taxa had SIGNAL2 scores ≥ 7, indicating they were sensitive to pollution.

Table 5-13 Number of macroinvertebrate taxa recorded each survey at Site PC1 downstream of Paddys Creek Swamp and their average SIGNAL2 score.

Indicator	Survey Date	
	6/06/2012	29/11/2012
Number of taxa	17	20
SIGNAL2 score	5.41	5.25

5.3.2.5 Fish and Frogs

Unidentified larval fish, probably Mountain Galaxias, were observed in Spring 2012. No amphibians were observed or caught.

5.3.3 Pine Swamp - Site BC1

Site BC1 is situated between Pine Swamp Upper and Pine Swamp in the headwaters of Bungleboori Creek and above the junction of the proposed LW424-LW425. The catchment area above the site consists of pine plantation on the north side of the drainage line and native bushland on the southern side. The shrub swamp at the upstream end of the BC1 drainage channel extends approximately 450 m downstream and feeds an incised creek channel that extends approximately 500 m downstream. The shrub swamp downstream of this creek section extends for 1.7 km to the confluence of a northern upper sub-catchment confluence at Waratah Ridge.

5.3.3.1 Aquatic and Riparian Habitat

The channel area upstream of BC1 was very shallow (<10 cm depth). The aquatic habitat upstream was poor and consisted of a broad sheet flow with sections of boggy ephemeral-looking grass soaks with no distinct channel areas. The creek channel at BC1 was incised into the surrounding valley floodplain to a depth of 1.3 m, had steep sides and overhanging and trailing bank vegetation was prevalent along the bank edges. The immediate riparian zone had a mixed pine tree and eucalypt canopy and a dense understorey of ferns. In Spring 2010, submerged edge grasses and ferns were observed, suggesting that the water level at that time may have been higher than normal. The site was generally shallow (<10 cm deep), although there were occasional pools with a depth of 1.0 m. The channel was mostly narrow with maximum and average widths of 2.5 m and 1.0 m, respectively. The edge habitats included trailing bank vegetation, detritus in the form of eucalypt and pine needles and logs. The substratum consisted of firm sand with abundant but localised deposits of finer clay-like sediments.

The RCE score (34) indicated the stream channel and adjacent features were subject to moderate disturbance and reflected the poor condition of the stream channel and substratum.

5.3.3.2 Water Quality

The baseline surface water quality measurements for BC1 presented in **Table 5.14** show that:

- Electrical conductivity levels were low, ranging from 29-31 µS/cm, and thus either marginally below or above the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);
- Dissolved oxygen (% saturation) levels were well below the lower DTV (90% saturation) during all surveys;
- pH levels during all surveys were below the lower DTV (6.5 units);
- Turbidity levels were generally within the default trigger value range (2-25 NTU), except for Spring 2012 when it was marginally higher than the upper DTV (25 NTU).

Table 5-14 Surface water quality measurements recorded during baseline surveys undertaken at Site BC1 downstream of Pine Swamp (BC1) (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
11/11/2010	8:18	12.08	29	54.5	4.93	ND
26/05/2011	13:57	7.87	29	57.2	5.20	10.4
15/11/2011	10:50	13.21	31	38.7	4.95	10.0
21/05/2012	16:03	9.45	31	40.1	4.48	2.3
29/11/2012	11:50	12.05	ND	19.4	4.83	25.9

5.3.3.3 Aquatic Plants and Algae

No macrophytes or filamentous algae were observed in Spring 2010 or Spring 2011. In Autumn 2011 and Autumn 2012, small amounts of filamentous green algae were reported. In Spring 2012, moderate amounts of filamentous green algae, one Swamp Clubrush plant and algal mats were recorded.

5.3.3.4 Aquatic Macroinvertebrates

A total of 17 macroinvertebrate taxa were collected during the six baseline monitoring events, 13 of which were insect families (**Appendix L**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Mecoptera (scorpionflies), Odonata (dragonflies) and Trichoptera (caddis flies). The other taxa were Hydracarina (freshwater mites), Ostracoda (seed shrimps), Oligochaeta (freshwater worms) and Dugesiidae (flatworms).

The number of taxa collected per event varied from 5 to 10 (**Table 5.15**). Ten taxa were sampled once only while Dytiscidae, Chironominae and Tanypodinae were the only ones found every survey (**Appendix L**).

The average SIGNAL2 scores varied from 2.6 to 4.1 and were thus indicative of severe to moderate degradation (**Table 5.15)**. Nine taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix L**). Only three taxa had SIGNAL2 scores (≥ 7) indicative of sensitivity to pollution.

Table 5-15 Number of macroinvertebrate taxa recorded each survey at Site BC1 downstream of Pine Swamp and their average SIGNAL2 score.

Indicator	Survey Date					
	11/11/2010	26/05/2011	15/11/2011	21/05/2012	29/11/2012	11/11/2010
Number of taxa	8	5	5	10	7	8
SIGNAL2 score	2.63	3.40	2.80	4.00	4.14	2.63

5.3.3.5 Fish and Frogs

No fish were observed or caught. Unidentified tadpoles were observed during each spring survey.

5.3.4 Nine Mile Swamp - Site BCN2

Site BCN2 is located on the unnamed northern tributary of Bungleboori Creek, upstream of its confluence with the main upper tributary draining site BC1 and is approximately 3 km downstream of the headwaters of the upper catchment. BCN2 is situated on Nine Mile Swamp. This shrub swamp extends approximately 1100 m further upstream of BCN2 and further downstream until it merges with Pine Swamp. The catchment area above the site is covered in a pine plantation. Native bushland is present on the northern side of the catchment and in a thin strip adjacent to Nine Mile Swamp. BCN2 is situated outside the proposed workings.

5.3.4.1 Aquatic and Riparian Habitat

The channel was relatively indistinct and completely overgrown with swamp vegetation in some areas. In Autumn 2012, the water body consisted of a broad soak with multiple flow paths. The width of the soak varied from 10 m to over 15 m. The water was shallower in Spring (maximum and average depths of 1.0 m and 0.3 m, respectively) than in Autumn 2012 (maximum and average depths of 0.6 m and 0.2 m, respectively). Multiple flow paths were evident through the soak. There was a round open pool downstream of the road culvert with multiple flow paths evident again further downstream. In Autumn 2012, the substratum was described as mostly sandy, but with soft, muddy sediments in vegetated areas, however, in Spring 2012 it was mostly sandy with some pebble and cobble sized sandstone fragments. The edge habitats included trailing bank (swamp) vegetation (mostly coral fern *Gleichenia* sp), bulbous rush and undercut banks. In Spring 2012, most of the substratum was covered by silt and iron precipitation was evident along edges in some sections of the site.

The RCE score (38) indicated the stream channel and adjacent features were subject to moderate disturbance and reflected the lack of in stream structures such as logs and boulders, riffle/ pool sequencing, channel form and stream substratum.

5.3.4.2 Water Quality

The baseline surface water quality measurements for BCN2 presented in **Table 5.16** show that:

> Electrical conductivity level in Autumn 2012 was equivalent to the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were below the lower DTV (90% saturation) during both surveys;

> pH levels during both surveys were below the lower DTV (6.5 units);

> Turbidity levels were slightly in excess of the upper DTV (25 NTU) during both surveys.

Table 5-16 Surface water quality measurements recorded during baseline surveys undertaken at Site BCN2 at the downstream end of Nine Mile Swamp (BCN2) (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
6/06/2012	13:22	6.93	30	85.5	4.68	29.1
29/11/2012	10:13	14.23	ND	74.9	4.48	27.4

5.3.4.3 Aquatic Plants and Algae

No filamentous green algae were observed. Bulbous rush was recorded during both surveys.

5.3.4.4 Aquatic Macroinvertebrates

A total of 18 macroinvertebrate taxa were collected during the two baseline monitoring events, 15 of which were insect families (**Appendix M**). The insects included representatives from eight orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Mecoptera (scorpionflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Phreatoicidae (isopods), Oligochaeta (freshwater worms) and Dugesiidae (flatworms).

Similar numbers of taxa were collected during the two surveys (**Table 5.17**). Eleven taxa were common to both surveys (**Appendix M)**.

The average SIGNAL2 scores for the surveys were indicative of mild degradation (**Table 5.17**). Eight taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix M)**. Five taxa had SIGNAL2 scores ≥ 7, indicating they were sensitive to pollution.

Table 5-17 Number of macroinvertebrate taxa recorded each survey at Site BCN2 downstream of Nine Mile Swamp and their average SIGNAL2 score.

Indicator	Survey Date	
	6/06/2012	29/11/2012
Number of taxa	14	15
SIGNAL2 score	5.14	5.38

5.3.4.5 Fish and Frogs

No fish or amphibians were observed or caught during the two monitoring events.

5.4 Swamp adjacent to LW502-LW503

Site SSWdn is situated approximately 2.4 km downstream of the headwaters of the Sawyer Swamp catchment area. Both sides of the valley at SSWdn are bordered by steep sided escarpment. The valley floor supports an unnamed Shrub Swamp which extends approximately 200 m upstream and downstream of the site. Monitoring of the aquatic ecological attributes of SSWdn commenced in Autumn 2012.

5.4.1.1 Aquatic and Riparian Habitat

The water at the upstream end of the site emerged from below the ground and continued downstream for at least 100 m. In Autumn 2012, no surface water was observed within the channel upstream of or in the adjacent swamp. The channel was situated adjacent to an access road. The drainage upstream of the site was deeply incised with steep banks and was eroding. The stream had average and maximum widths of 1.0 m and 2.5 m and average and maximum depths of 0.3 m and 0.7 m, respectively. The edge habitats consisted of detritus and trailing bank vegetation. The substratum consisted mostly of sand, but with some isolated boulder outcrops and sandstone rock fragments. The submerged surfaces throughout the site were covered with iron precipitation. The RCE score (43), indicated the stream channel and adjacent features were subject to small amounts of disturbance.

5.4.1.2 Water Quality

The baseline surface water quality measurements for SSWdn presented in **Table 5.18** show that:

> Electrical conductivity level in Autumn 2012 was within the guidelines (30 -350 µS/sec) for slightly disturbed upland rivers in south-east Australia (ANZECC/ARMCANZ 2000);

> Dissolved oxygen (% saturation) levels were well below the lower DTV (90% saturation) during both surveys;

> pH levels during both surveys were below the lower DTV (6.5 units);

> Turbidity levels were within the guidelines (2-25 NTU) during both surveys.

Table 5-18 Surface water quality measurements recorded during baseline surveys undertaken at Site SSWdn downstream of the unnamed swamp adjacent to LW502-503 (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia, ND indicates no data recorded).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
7/06/2012	8:28	11.87	64	26.8	4.38	0.5
30/11/2012	8:06	13.89	ND	47.7	4.68	20.9

5.4.1.3 Aquatic Plants and Algae

Filamentous green algae were present in small amounts in Autumn 2012, but in moderate to abundant amounts in Spring 2012. No macrophytes or charophytes were observed during either survey.

5.4.1.4 Aquatic Macroinvertebrates

A total of 15 macroinvertebrate taxa were collected during the two surveys, 11 of which were insect families (**Appendix N**). The insects included representatives from seven orders: Coleoptera (beetles), Diptera (true flies), Hemiptera (true bugs), Mecoptera (scorpionflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Oligochaeta (freshwater worms) and Dugesiidae (flatworms).

Similar numbers of taxa were collected during the two surveys (**Table 5.19**), with eight being common to both surveys (**Appendix N)**.

The average SIGNAL2 scores for both surveys were indicative of mild degradation (**Table 5.19**). Nine taxa had SIGNAL2 scores ≤ 4, indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix N**). Only three taxa had SIGNAL2 scores (≥ 7) indicative of sensitivity to pollution.

Table 5-19 Number of macroinvertebrate taxa recorded each survey at Site SSWdn downstream of the unnamed swamp adjacent to LW502-503.

Indicator	Survey Date	
	6/06/2012	29/11/2012
Number of taxa	9	14
SIGNAL2 score	4.78	4.23

5.4.1.5 Fish and Frogs

No fish or amphibians were observed or caught during the two monitoring events.

5.5 Summary

5.5.1 Aquatic Habitat

The drainage channels at Sites CC1-CC4 in the northern part of the proposed workings were narrow, shallow and overgrown with dense vegetation. The channel form at these sites was similar, consisting of cascades over bedrock, pools with exposed bedrock and accumulations of sandy and muddy sediment. Fallen logs and moss were common at Site CC1 downstream of Sunnyside East Swamp. The drainage channel at Site MC1 below Marrangaroo Creek Swamp also had several shallow cascades and a substratum consisting of bedrock with some boulders and cobbles and sand accumulations and silt in some pools. The riparian habitat and drainage channels at MC1 and at Sites CC1-CC4 in the northern part of the proposed workings were minimally disturbed.

The drainage channels at the other sites (PC1, BC1, BCN2) in the southern part of the proposed workings were in a poorer condition, with that at PC1 downstream of Paddys Creek Swamp being the most disturbed. The morphology of their drainage channels also differed. Site PC1 had shallow incisions, but with some steep areas with undercut banks, and a substratum consisting mainly of mobile sand with some pebbles and cobbles. The drainage channel at Site BC1 downstream of Pine Swamp was incised into the surrounding valley floodplain and had steep sides and a substratum consisting of firm sand with localised deposits of clay-like sediments. The drainage channel at BCN2 downstream of Nine Mile Swamp consisted of a broad soak with multiple flow paths and had a mostly sandy substratum that was covered in silt in Spring 2012, with some iron precipitation also evident.

The substratum at Site SSWdn on the Sawyers Swamps Creek drainage consisted mostly of sand, but with some boulder outcrops and sandstone rock fragments. The submerged surfaces were covered with iron precipitation. The site was subject to small to moderate amounts of disturbance.

5.5.2 Water Quality

The electrical conductivity and pH levels of the water at the monitoring sites downstream of the swamps were generally below and dissolved oxygen levels mostly below the ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in south-east Australia. The turbidity levels, in contrast were either within or above the upper DTV.

5.5.3 Aquatic Plants and Algae

Aquatic macrophytes have been recorded at all the sites except BC1. The identity of the macrophytes is unclear, because the name recorded at Sites CC1-4 and at MC1 has changed over time from an unidentified member of the Cyperaceae to Bulbous Rush to Swamp Clubrush. The latest survey indicated Bulbous Rush was present downstream of Paddys Creek Swamp and Nine Mile Swamp.

Small amounts of filamentous green algae have been found at all of the sites except PC1 and BCN2. Charophytes, however, have only been recorded at Sites CC1 and MC1. Algal mats have been observed at Sites MC1 and BC1..

5.5.4 Aquatic Macroinvertebrates

The aquatic macroinvertebrate fauna was relatively diverse, with a total of 53 taxa recorded across all sites and surveys. The fauna consisted mostly of insects (44 families), but also included five crustacean taxa (amphipods, copepods, ostracods, isopods and freshwater crayfish/yabbies), three different types of worms (oligochaetes, flatworms and hairworms) and freshwater mites (Hydracarina). The number of macroinvertebrate taxa recorded per site varied from 15 to 32. The fauna at the sites downstream of Sunnyside East Swamp (CC1), Gang Gang Swamp (CC3) and Barrier Swamp (CC4) were the most diverse, while those downstream of Pine Swamp (BC1) and Nine Mile Swamp (BCN2) and the unnamed swamp on Sawyer Swamp Creek (SSWdn) were the least diverse. Only a small proportion (19-25%) of the taxa found at Sites CC1-4 in the northern part of the proposed mining area were recorded during all six surveys. At MC1 and BC1, the sites in the southern part of the area that were surveyed five times, 29% and 59% of the taxa respectively were recorded every survey. At the sites in this area that were sampled twice (PC1, BCN2 and SSWdn), the proportion of taxa recorded every survey varied from 53-68%.

The macroinvertebrate assemblages at Sites BC1, BCN2 and SSWdn were distinct from each other and from those at the other six sites (**Figure 5.2**. The macroinvertebrate fauna at the two other southern sites (PC1 and MC1) was similar to that at the northern sites (CC1-4). The MDS plot also shows the fauna at BC1 was the most variable over time.

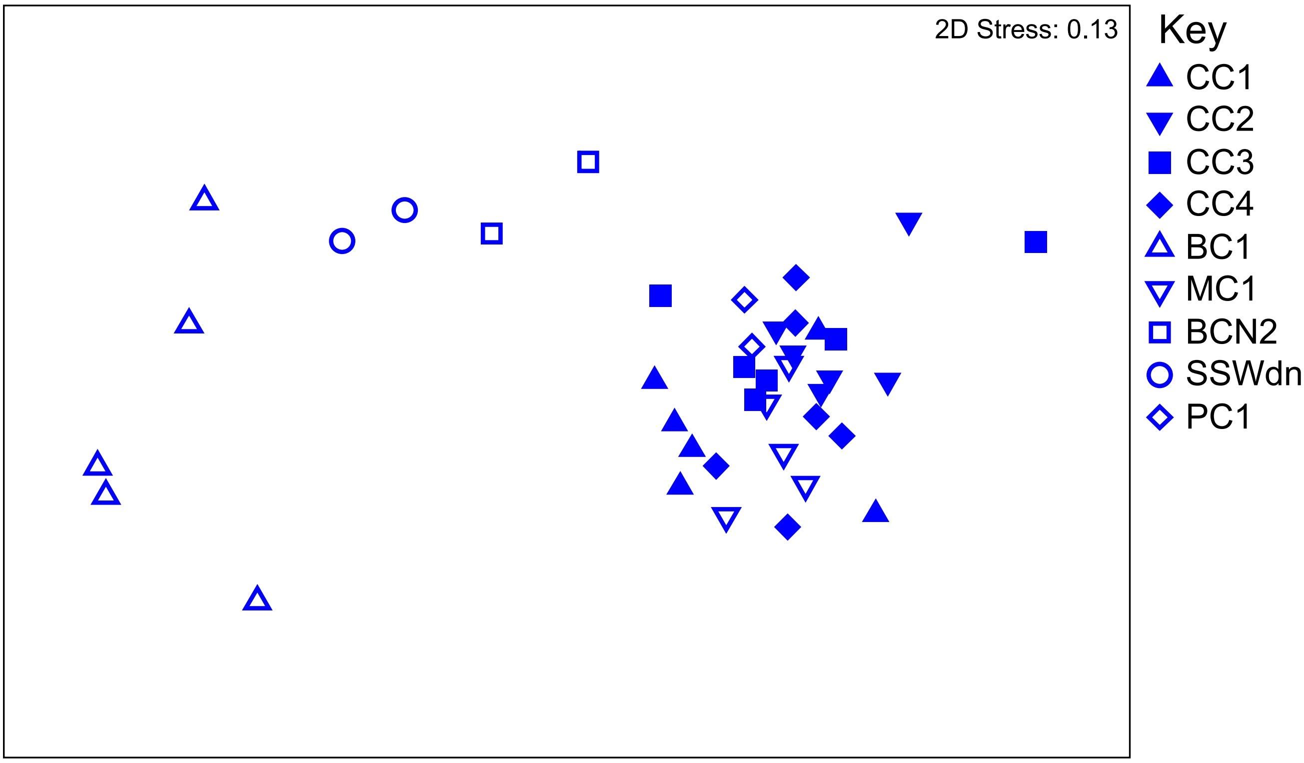

Figure 5-2 MDS plot comparing the multivariate structure of the aquatic macroinvertebrate fauna at Sites WRup, Wrmd and WRdn on the Wolgan River and Site CCXdn on Carne Creek.

The average SIGNAL2 scores indicated that the sites in the northern part of the Project Area varied over time from mildly to not degraded. The scores for the sites in the southern part of the Mine Extension Area indicated that MC1, PC1 and BCN2 were mildly degraded, SSWdn was moderately degraded and BC1 varied from severely to moderately degraded. Between 33% and 60% of the taxa found per site had SIGNAL2 scores indicative of tolerance to a variety of environmental conditions, while 18-42% had scores indicating they were sensitive to pollution.

5.5.5 Fish and Frogs

No frogs were observed or caught during the baseline monitoring. Tadpoles were recorded each spring, but only at Site BC1 downstream of Pine Swamp. One native fish species, the Mountain Galaxias (*Galaxias olidus*), was recorded each spring, but this was found only at Site MC1 downstream of Marrangaroo Creek. Larval fish were also observed at MC1 in spring and at Site PC1 downstream of Paddys Creek.

5.5.6 Conclusions

The biannual baseline monitoring undertaken at Sites CC1-4, BC1 and MC1 spans a period varying from 2.5 to 3 years and thus provides information on the variation within and between years in condition of aquatic habitats, quality of surface water, occurrence and diversity of aquatic plants, algae, macroinvertebrates and fish and health of the macroinvertebrate fauna. The information collected at Sites BCN2, PC1 and SSWdn is less comprehensive, because baseline monitoring at these sites commenced more recently in Autumn 2012. It is recommended that the adequacy of the data from the latter sites be improved by undertaking further baseline monitoring whilst the longwalls in the northern part of the workings are being extracted.

6 Existing Environment - Subterranean Aquatic Ecosystems

Subterranean aquatic systems often support a diverse group of animals, including crustaceans, worms, snails, insects, other invertebrate groups and fish, referred to collectively as stygofauna (Humphreys 2006a). Whilst most stygofauna species spend their entire lives in groundwater, three groups with different degrees of dependence on groundwater are recognised:

> Stygobites - animals that complete their entire life in subterranean aquatic environments;

> Stygophiles - animals that spend their entire life in subterranean aquatic habitats but are also capable of living in epigean habitats;

> Stygoxenes - animals that use subterranean environments but require access to surface environments to complete part of their lifecycle (Humphreys 2006b).

Stygofauna contribute to the biodiversity of Australia and may also be functionally important, contributing to the maintenance of voids, alteration of reduction-oxidation gradients, enhancing the release of organic carbon and cycling of nutrients, movement and transfer of energy and materials through the sediments and maintenance of community structure (Humphreys 2006b).

Information on the distribution of stygofauna within NSW aquifers is sparse and scattered (Serov *et al.* 2012). Preliminary research indicates stygofaunal diversity could be high and that some species may be locally endemic (i.e. restricted to certain areas or sections thereof) (Eberhard and Spate 1995, Hancock and Boulton 2008). The highly localised occurrence of some species combined with their high degree of adaptation to life in subterranean aquatic systems suggests that they may be highly sensitive to changes in the characteristics of the groundwater they inhabit and that disturbance of their habitat could pose a threat to their survival (Boulton *et al.* 2003).

In this section, the results of a pilot survey of stygofauna undertaken in May 2012 at boreholes that target the shallow groundwater below individual swamps and boreholes on the ridge between swamps that target the near-surface unconfined aquifer in the Banks Wall Sandstone are described (See Sections 6.2 and 6.3, respectively). The location of the boreholes sampled is shown in **Figure 6-1** and the GPS co-ordinates, number of bailer samples and volume of water collected from each borehole are presented in **Table 6-1.** Information is presented on the animals found, including the likelihood of them being stygofauna rather than terrestrial species, and the quality of the bore water at the time of sampling. Sampling was undertaken by MPR using a hand-hauled weighted bailer and animals were identified by Dr Grant Hose of Macquarie University. It is important to note that the invertebrates were identified to coarse taxonomic levels varying from sub-family (e.g. Chironominae and Tanypodinae) up to sub-class (e.g. Acarina and Collembola) and that some may have been borehole-colonisers (referred to hereafter as possible stygofauna) rather than groundwater inhabitants (likely stygofauna) while others may have been terrestrial, surface water or surface saturated soil fauna. The information presented is derived from a report on the survey prepared by MPR (2012c). The latter report also contains information on the pilot stygofauna survey undertaken in boreholes below the Angus Place Project Application Area and the results from this are discussed in Section 6.4.

A brief description of the aquifers and groundwater systems in the vicinity of the proposed workings based on the reports prepared by the CSIRO and RPS in consultation with Springvale and Angus Place Collieries (Adhikary and Wilkins 2013; RPS 2013b) is presented in Section 6.1. The results of the groundwater monitoring program in the swamps undertaken by Springvale Coal are outlined in Section 6.2. This information provides a context for the pilot stygofauna study and for the impact assessment in Section 8.

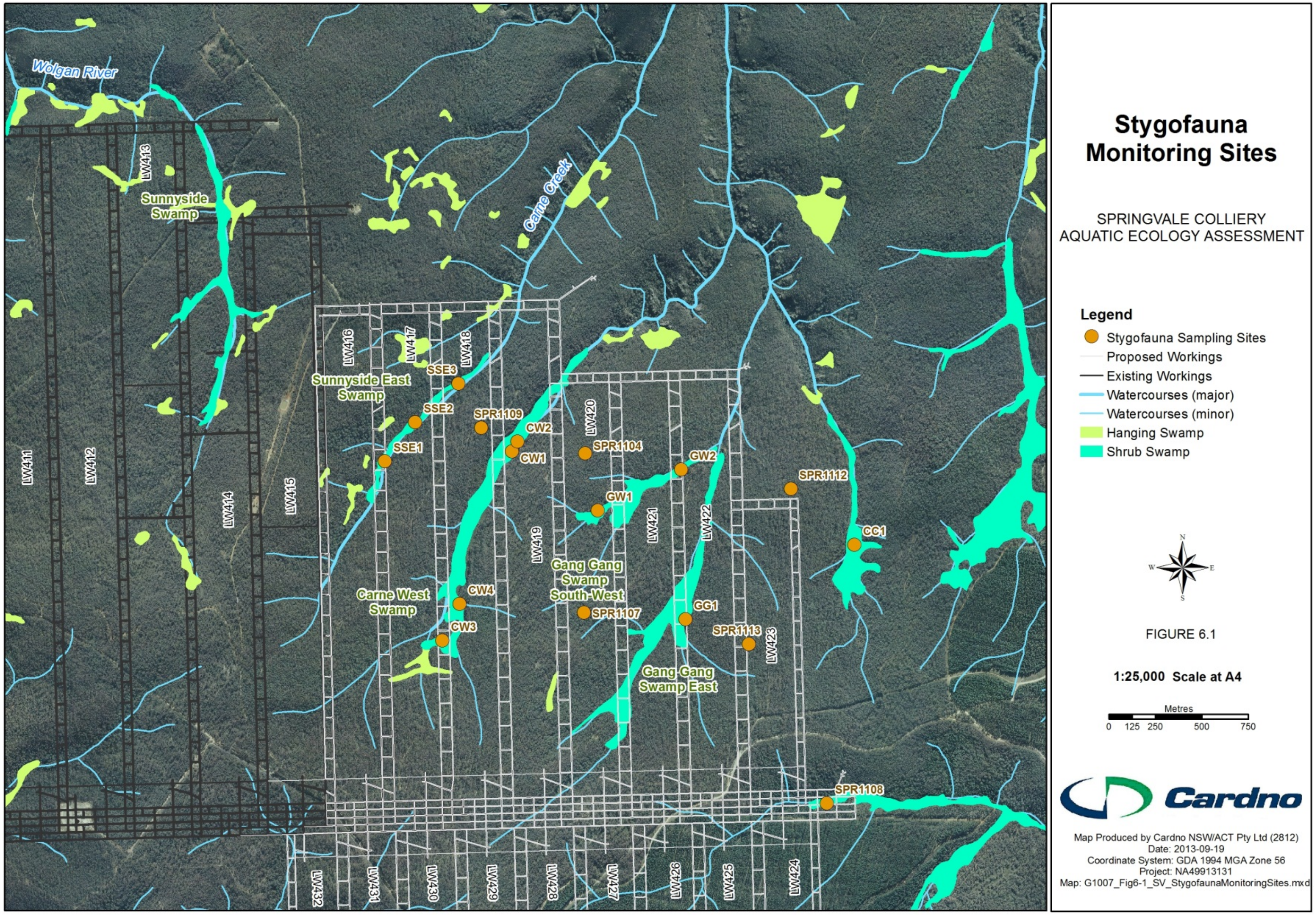

Figure 6-1 Map showing the location of the boreholes used in the stygofauna pilot survey relative to the proposed longwalls in the northern part of the proposed workings.

Table 6-1 GPS co-ordinates, number of bailer samples and volume of water collected from each borehole used in the pilot stygofauna study

Borehole ID	Location	Easting	Northing	Number of bails	Sample volume (litres)
CW1	Carne West Swamp	239352	6303196	7	2.3
CW2	Carne West Swamp	239382	6303247	7	2.1
CW3	Carne West Swamp	238977	6302179	94	10
CW4	Carne West Swamp	239070	6302377	38	10
GG1	Gang Gang Swamp	240285	6302294	6	1.5
GW1	Gang Gang West Swamp	239814	6302877	7	2
GW2	Gang Gang West Swamp	240263	6303097	5	2.2
CC1	Carne Central Swamp	241193	6302693	4	1.5
SSE1	Sunnyside East Swamp	238668	6303143	18	15
SSE2	Sunnyside East Swamp	238831	6303352	16	15
SSE3	Sunnyside East Swamp	239064	6303558	14	4.5
SPR1113	Banks Wall Sandstone Aquifer	240625	6302160	16	15
SPR1107	Banks Wall Sandstone Aquifer	239739	6302330	19	15
SPR1109	Banks Wall Sandstone Aquifer	239188	6303322	24	15.5
SPR1108	Banks Wall Sandstone Aquifer	241045	6301305	16	16
SPR1104	Banks Wall Sandstone Aquifer	239746	6303184	20	15
SPR1112	Banks Wall Sandstone Aquifer	240852	6302995	16	15

6.1 Groundwater Systems Relevant to the Project

The aquifers and aquitards that occur below the Project Application Area form three basic groundwater systems – a perched, surficial hydrogeological system, a shallow regional groundwater system, ranging from non-confined to semi-confined, and a deep confined groundwater system (RPS 2013b).

The perched groundwater system is discontinuous and generally situated close (within metres) to the ground surface. It is derived from excess rainfall that is unable to infiltrate into the deeper groundwater systems due to the presence of less permeable underlying rock layers. The perched groundwater system is recharged by direct rainfall infiltration and by interflows through surficial, weathered geological deposits. It is hydraulically independent of the underlying regional groundwater system and deep confined groundwater system. A brief overview of the information available about groundwater levels in these swamps is presented in Section 5.2.

The shallow regional groundwater system extends from approximately 286 m above the Lithgow Seam to 100 m below the ground surface. It is located primarily in the Banks Wall sandstone layer of the Narrabeen Group. Three main aquifer zones (AQ4, AQ5 and AQ6) have been identified in the Banks Wall Sandstone. The flow of groundwater within this system is generally horizontal and occurs along bedding planes and in a north-easterly direction. However, in the uppermost aquifer zone (AQ6), flow may be influenced by local topography. The infiltration of rainfall into this zone may also result in some vertical flow.

The shallow groundwater system is separated from the deep groundwater system by a sequence of interbedded claystone and sandstones of low permeability that comprise the Mount York Claystone. The deep groundwater system includes the Illawarra coal measures, which generally have low permeability, and three fractured rock aquifer units (AQ1, AQ2 and AQ3). In these aquifers, groundwater flows sub horizontally towards the northeast along fracture-plain conduits. Groundwater from this system drains into the goaf formed by longwall mining and results in most of the mine water inflows.

6.2 Perched Surficial Groundwater System

6.2.1 Groundwater Monitoring

Three stygofauna survey sites, SSE1 on Sunnyside East Swamp and CW3 and CW4 in the upper section of Carne West Swamp, were located in periodically waterlogged areas (See **Figure 6.1**). Water levels at these sites generally fluctuated by about 0.75 m, but levels increased rapidly by more than 2 m after significant rainfall events (RPS 2013b). In periodically waterlogged swamps, aquifer recharge did not contribute significantly to baseflow. The other stygofauna survey sites (i.e. SSE2-3 in Sunnyside East Swamp, CW1 and CW2 in the lower section of Carne West Swamp, GG1 in Gang Gang Swamp and GW1-2 in Gang Gang West Swamp) were situated in permanently waterlogged areas, where groundwater level depends primarily on aquifer recharge, with rainfall inflows making a minor contribution (RPS 2013b). The water level in these systems increased slightly over time.

Groundwater samples collected each month from sites on Carne West, Carne Central and Sunnyside East Swamps were subjected to a variety of chemical analyses. Five of these (i.e. CW1, CW2, CC1, SSE2 and SSE3) are sites where stygofauna has also been sampled. The minimum, maximum and mean pH, electrical conductivity (EC) and dissolved oxygen (DO) levels at these sites are presented in RPS (2013b). The data show that pH levels are generally below the ANZECC/ARMCANZ (2000) lower DTV and that the water in Carne West Swamp (CW1 and CW2)) is more acidic than at the other sites. The electrical conductivity levels at CW and CW2 are also generally below the lower DTV and their mean EC levels are considerably lower than those of the other sites. The DO levels at all of the sites except CC1 were highly variable, with mean levels being lowest at the sites in Sunnyside East Swamp (SSE2 and SSE3) and highest in Carne Central Swamp (CC1).

6.2.2 Pilot Stygofauna Survey

Stygofauna samples were collected using a hand-hauled weighted bailer, with the volume of water sampled varying from 1.5 litres (GG1) to 15 litres (SSE1-2) (MPR 2012c). The swamp bores that yielded small quantities of water had a low rates of recharge, with the water taking 1-2 days to return to background levels after purging. Groundwater quality was measured before samples of stygofauna were collected from the swamp boreholes. The measurements were made on samples collected from just below the water surface. The underlying assumption underpinning the methodology employed is that the taxa found in bore sampling are representative of those in the surrounding aquifer.

The GPS co-ordinates, survey date, number of bailer samples and volume of water collected from each borehole are presented in **Appendix O**.

6.2.3 Groundwater Quality

The water in the permanently waterlogged section of Carne West Swamp (Sites CW1-2) was more acidic, but slightly better oxygenated and much less turbid than that in the periodically waterlogged area of the swamp (Sites CW3-4) (**Table 6.2)**. The water at the sites in the permanently waterlogged area of Sunnyside East Swamp (SSE2 and SSE3) had lower EC, DO and Oxidation-Reduction Potential (ORP) levels, but higher pH and turbidity levels than that in the periodically waterlogged area (SSE1). The EC levels at all the sites were within the ANZECC/ARMCANZ (2000) guidelines. The DO (% saturation) level at this site was within the guidelines at this site but not at the other sites. The pH of the groundwater at all the sites was acidic, but more so at SSE1, CW2 and GG1. All the pH measurements were below the lower DTV. The turbidity levels exceeded the upper DTV at all the sites except GW2a and were considerably higher at CW3, CW4 and GW1 than at the other sites.

Table 6-2 Quality of the groundwater in boreholes located in Carne West(CW1-4); Gang Gang (GG1), Gang Gang West (GW1-2) and Sunnyside East (SSE1-3) Swamps, as measured during the stygofauna survey.

Site	Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen		pH	ORP	Turbidity
			°C	µS/cm	%saturation	mg/L	Units	mV/	NTU
CW1	7/05/2012	13:38	11.97	66	83.3	7.9	5.19	410	31.1
CW2	7/05/2012	14:11	11.41	57	83.1	8.0	4.66	449	165.5
CW3	8/05/2012	14:13	15.88	126	80.6	7.0	6.11	408	421.2
CW4	8/05/2012	14:58	12.52	65	78.7	7.4	5.88	434	363.7
GG1	9/05/2012	15:30	11.67	38	59.2	5.7	4.79	509	65.7
GW1	7/05/2012	16:15	10.13	99	65.6	6.5	6.14	459	421.2
GW2	9/05/2012	11:36	12.98	73	63.7	5.9	5.39	475	65.1
SSE1	8/05/2012	09:26	12.41	61	64.0	6.0	4.21	480	42.5
SSE2	8/05/2012	10:16	09.02	44	36.4	3.7	5.00	462	69.7
SSE2	8/05/2012	10:17	09.02	44	36.4	3.7	5.00	462	69.0
SSE3	8/05/2012	11:01	12.30	50	42.3	4.0	5.03	471	160.4

6.2.4 Stygofauna

A total of 411 invertebrates, representing 16 taxa were recorded across the other 10 boreholes sampled (**Table 6.2**). Four likely and six possible stygofauna taxa were found. The likely stygofauna taxa were cyclopoid copepods, harpacticoid copepods, copepod nauplii and the syncarid Bathynellidae, all of which are crustaceans. The possible stygofauna were Acarina (mites), Phreatoicidea (isopods), Nematoda (round worms), Oligochaeta (segmented worms), Rotifera (wheel animals) and Tardigrada (water bears). The other six taxa were from either terrestrial, surface water or surface saturated soil habitats.

The sample from borehole SSE2 yielded the largest number of animals (249) and representatives of all 14 taxa. Three of the taxa recorded from this borehole were considered likely stygofauna with a further six being possible stygofauna. The sample collected from borehole SSE1 in Sunnyside East Swamp yielded the second largest number of invertebrates (79) and taxa (10), with four taxa considered likely stygofauna and another four possible stygofauna. Borehole SSE3 yielded 15 animals representing seven taxa, two of which were likely stygofauna while four were possible stygofauna. The low number of animals retrieved from Borehole SSE3 probably reflects the smaller volume of water sampled (4.5 litres) relative to SSE1 and SSE2 (15 litres).

No animals were recorded at GW2. The other boreholes sampled contained possible stygofauna taxa, but only CW2-4 contained a likely stygofauna taxon. It is important to note that less than <2.5 L of water were sampled at most of these boreholes, except for CW3 and CW4 where 10 L of water were collected (**Appendix O**).

Table 6-3 Invertebrates recorded during stygofauna sampling undertaken at open piezometers installed in Carne West, Gang Gang, Gang Gang West, Carne Central and Sunnyside East Shrub Swamps

	Carne West				Gang Gang	Gang Gang West	Carne Central	Sunnyside East		
Taxon	CW1	CW2	CW3	CW4	GG1	GW1	CC1	SSE1	SSE2	SSE3
Acarina	4	4	1			2		6	16	3
Collembola	2	1						13	2	1
Cyclopoid Copepoda				2				5	94	1
Harpacticoid Copepoda		1						7	39	6
Copepoda Nauplii			1					9	18	
Tipulidae									51	
Chironominae									6	
Tanypodinae									3	
Phreatoicidea									1	
Nematoda						4		4	1	1
Oligochaeta				1				10	4	2
Rotifera		1			3	2			1	1
Bathynellidae (Syncarida)								1		
Tardigrada			33	2				23	7	
Terrestrial	2			1				1	6	
Unidentified							1			
Number of Likely Stygofauna		1	1	1				4	3	2
Number of Possible Stygofauna	1	2	2	2	1	3	1	4	6	4
Unlikely Stygofauna	2	1		1				2	5	1
Number of taxa	2	4	3	4	1	3	1	10	14	7

6.3 Unconfined Aquifer in the Banks Wall Sandstone

Stygofauna samples were collected from six ridge boreholes used to monitor groundwater levels in the near-surface unconfined aquifer in the Banks Wall Sandstone. The depth of the shallow ridge (aquifer) bores ranged from 30 m to 60 m (MPR 2012c).

Samples were collected using a hand-hauled weighted bailer, with 15 L of water sampled from four of the ridge boreholes and 15.5 and 16 L collected respectively from Boreholes SPR1109 and SPR087 (MPR 2012c). Stygofauna were collected by lowering the bailer to the bottom of the bore and agitating the sediments and water column, but the depth at which samples were taken and bore volume were not documented. Water quality measurements were taken prior to stygofauna sampling and are based on samples collected from 1-2 m below the bore water surface.

The GPS co-ordinates, survey date, number of bailer samples and volume of water sampled from each borehole are presented in **Appendix O**.

6.3.1 Groundwater Quality

The water temperature and electrical conductivity levels at SPR1109 were elevated relative to the other sites (**Table 6.3)**. The dissolved oxygen level at SPR1109 was considerably lower (33.9% saturation) than at the other study sites (70.7-83.6%), reflecting its higher salt content. The pH of the water at all sites was acidic, ranging from 3.76 to 5.77 units, but with the value for SPR1109 again differing substantially from that at the other sites. The ORP values were generally high, ranging from 460-530 mV, which is indicative of reducing conditions. The ORP at SPR1109, however, was much lower (278 mV). The turbidity measurements indicate the water at most sites contained small amounts (< 30 NTU) of suspended solids, relative to that at SP1104 and SPR1109, where readings exceeded 100 and 400 NTU, respectively.

Table 6-4 Quality of the groundwater at the stygofauna sampling sites

Site	Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen		pH	ORP	Turbidity
			°C	µS/cm	%saturation	mg/L	pH Units	mV	NTU
SPR1112	9/05/2012	12:24	14.50	30	72.0	6.5	4.20	530	22.9
SPR1113	9/05/2012	14:39	13.78	27	70.7	6.5	4.57	494	28.6
SPR1109	8/05/2012	12:25	15.98	155	33.9	3.0	5.77	278	421.2
SPR1108	9/05/2012	16:41	12.96	28	73.6	6.8	3.76	530	29.9
SPR1107	8/05/2012	16:01	13.11	42	79.5	7.4	4.31	483	12.2
SPR1104	7/05/2012	15:02	12.65	57	79.6	7.4	5.03	460	118.0
SPR1104	7/05/2012	15:31	12.53	43	83.6	7.9	4.63	485	17.7

6.3.2 Stygofauna

No animals were sampled at borehole SPR1112. The samples collected from the five other ridge boreholes yielded a total of 16 invertebrates, representing five taxa (**Table 6.4**). The samples from borehole SPR1109 contained the most animals however, only one of these (Acarina) was considered possible stygofauna. Possible stygofauna, in the form of Acarina and Rotifera, were found in boreholes SPR1113 and SPR1104. Only the sample from SPR1107 contained likely stygofauna, this being a cyclopoid copepod.

Table 6-5 Invertebrates recorded during stygofauna sampling undertaken at boreholes targeting the near-surface unconfined aquifer in the Banks Wall Sandstone

Taxon	SPR1112	SPR1113	SPR1109	SPR1108	SPR1107	SPR1104
Acarina		1	2			1
Collembola			5	1		
Cyclopoid Copepoda					1	
Rotifera		1				
Terrestrial		2				2
Number of Likely Stygofauna					1	
Number of Possible Stygofauna		2	1			1
Unlikely Stygofauna		1	1	1		1
Number of taxa		2	2	1	1	2

6.4 Conclusions and Study Limitations

The pilot survey has shown that the occurrence of invertebrates was patchy, with samples from most boreholes yielding only a few animals. Samples collected at the three boreholes below Sunnyside East Swamp and borehole CW3 below Carne West Swamp, however, yielded larger numbers (> 15) of invertebrates, with four taxa being considered likely stygofauna and a further six possible stygofauna taxa. The samples collected from boreholes targeting the unconfined aquifer in the Banks Wall Sandstone yielded one likely stygofauna taxon and two possible stygofauna taxa. The sampling undertaken at the boreholes within the Angus Place Project Application Area also yielded small number of invertebrates, with one likely and four possible stygofauna taxa being found in the boreholes targeting the aquifer below Tri Star Swamp and one likely and two possible stygofauna taxa found in the boreholes targeting the unconfined aquifer in the Banks Wall Sandstone.

It is recommended that Centennial commission a more extensive sampling program incorporating finer-scale taxonomic identification prior to the commencement of mining. This would require multiple bores per aquifer to be sampled on multiple occasions, with several sampling events per season if seasonal changes are expected to occur (Hancock and Bolton 2009). Greater replication is needed, because of the limited number of potential sampling sites (i.e. boreholes or wells), the heterogeneous and often highly localised distribution of stygofauna within a specific aquifer, the small sample volume relative to the size of the aquifer and the difficulty of determining the representativeness of the sample collected. The bores that are used to target the various aquifers/groundwater systems should also be representative of the entire Project Application Area. **Figure 6-1** shows that the bores used in the stygofauna survey were all situated in the northern part of the Springvale Project Application Area.

Further studies are needed to establish whether the invertebrates identified as likely and possible stygofauna are indeed stygofauna species, and if so, whether they are locally endemic or widespread. The latter is particularly important because mining is likely to have a significant impact on species that are locally endemic but minimal impact on those that are widespread. Regional scale surveys would be required to establish their distribution patterns and likely conservation significance. It is therefore suggested that a literature review be undertaken of all other stygofauna surveys undertaken in the local area and Western Coalfield of New South Wales. The proposed studies would also help determine whether monitoring during and after mining is necessary.

The survey also suffers from some methodological limitations. MPR (2012c) indicated the results may have been compromised by the monthly purging of the boreholes that occurs prior to the monitoring of groundwater quality. Stygofauna samples should be collected from boreholes prior to any purging (i.e. removal of all the standing water), because purging removes animals and it may take weeks or months for them to re-establish, in some cases this may be longer than the frequency of water quality sampling (Hose and Lategan 2012). The lack of suitable bores has been recognised as a major constraint on accurate assessment of groundwater invertebrate fauna. Hancock and Boulton (2009) suggest that this problem could be overcome by installing bores that are suitable for multiple-parameter surveys (i.e. fauna, geochemistry, water quality and hydrology). Sampling of stygofauna in boreholes using a hand-held bailer is a relatively inefficient process, because each sample unit is small, only a relatively small part of the aquifer (i.e. the water volume inside the bore cavity) is sampled and stygofauna usually occur in low densities. At the ridge boreholes it may be possible to increase sampling efficiency by using a pump to draw animals into the bore cavity from parts of the aquifer further afield (Hancock and Boulton 2008). The use of pumps, however, may be limited by bore construction characteristics, water table depth and time constraints. The low yields from most of the swamps suggest that pumping would not be an appropriate sampling method. As discontinuous perched aquifers could potentially contain highly localised endemic stygofauna, an alternative sampling method is required.

A desk-top review of existing information on geology and hydrology should be undertaken to assess the suitability of the other aquifers within the Project Application Area as potential habitat for stygofauna. If other aquifers appear to provide suitable habitat boreholes that target these layers should be surveyed. Information on the likely occurrence, diversity and abundance of any stygofauna occurring in the aquifer associated with the Lithgow Seam, for example, could potentially be obtained by sampling the water pumped out of the dewatering boreholes, providing that the pump does not have a mechanism (e.g. impellors) that would damage or destroy animals.

7 Potential Impacts on Aquatic Ecology and Avoidance, Mitigation Management Measures -

In this section, the potential direct, indirect and cumulative impacts on aquatic habitats, quality of surface water, aquatic biota in general and threatened aquatic species that may arise during the construction, operation, decommissioning and rehabilitation phases of the Project are described. The assessment of potential impacts on aquatic ecology arising from the Project is based on:

> The description of the Project presented Section 1.2;

> The description of the existing biophysical environment of the streams and drainages located downstream of swamps presented in Sections 4 and 5, respectively;

> Maximum predicted subsidence parameters for the reaches of the Wolgan River, Carne Creek, swamps and their drainage lines within and adjacent to the proposed workings and their predicted impacts on the physico-chemical characteristics of the waterways (MSEC 2013);

> Assessment of potential impacts on the terrestrial components of the swamps (RPS 2013a), groundwater quantity and quality (RPS 2013b; Adhikary and Wilkins 2013) and surface water quality (RPS 2013c);

The potential impacts associated with the construction, operation, decommissioning and rehabilitation phases and measures that could be used to avoid, minimise and manage such impacts are described in Sections 7.1-7.4, respectively. The potential impacts on the Adam's Emerald Dragonfly, the only threatened aquatic species that may occur in the Project Application Area are addressed in Section 7.5. The potential for cumulative impacts on aquatic ecology is discussed in Section 7.6. The potential impacts of the Project on stygofauna and measures to minimise such impacts are described in Section 8.

7.1 Construction

The Project will involve construction of the following:

> Underground access headings and roadways from the current mining area;

> Two additional dewatering bore facilities (Bores 9 and 10) installed within secure compounds would be excavated on Newnes Plateau using a drill rig, lined and then fitted with appropriate bore casing and a pump;

> Associated power and pipeline infrastructure, and upgrade of existing and construction of two new sections of access tracks to the Bore 9 and 10 facilities;

> A downcast ventilation borehole at the Bore 10 facility location;

> A services borehole area;

> New sections of trenched pipelines so that the water delivery capacity of the SDWTS can be increased from the existing 30 ML/day to up to 50 ML/day.

7.1.1 Potential Impacts

7.1.1.1 General Construction Activities

General construction activities that take place in the vicinity of watercourses and swamps could potentially have the following impacts:

> Runoff from areas that have been cleared of vegetation and where soils and sediments have been disturbed or stockpiled during construction of the dewatering borehole facilities, downcast ventilation borehole and pipeline infrastructure could temporarily increase the sediment load in streams, swamps and their drainage lines;

> The upgrade and extension of the existing access tracks to the dewatering boreholes also has the potential to increase soil erosion/sedimentation.

- The increase in sediment load could, in turn, alter the nature of the benthic substratum, smother some aquatic habitats and increase turbidity levels within watercourses, with the latter potentially decreasing the amount of light available for photosynthesis by aquatic plants, clogging the gills and feeding apparatus of aquatic fauna and reducing the visual acuity of some predators;
- Runoff from cleared areas and stockpiles of soil could also transfer sequestered nutrients, organic matter and contaminants into the watercourses and swamps;
- The clearing of riparian vegetation at sites where the dewatering borehole facilities, downcast ventilation borehole and pipeline infrastructure will be installed could have indirect impacts on abundance, distribution and health of aquatic biota that use the vegetation as a habitat, refuge or source of food.
- Accidental release of lubricating oils, hydraulic fluids and fuel from construction equipment could result in the input of toxic hydrocarbons into the streams, swamps and their drainage lines;
- Interfere with the shallow perched aquifers that support the swamps and impact on surface waters that flow through the swamps into the drainage lines;
- The construction of access tracks over watercourses could also lead to changes in the pattern of water flow, disturbance and erosion of stream banks and bed, removal of instream and riparian vegetation and, if flow is obstructed, could either impede or prevent passage of fish and other aquatic organisms.

The likelihood of construction impacts occurring depends on the proximity of the streams, swamps and their associated drainage lines to the works. Construction activities are unlikely to have a direct impact on the upper reaches of Coxs River and the Wolgan River as these are situated to the west of the proposed longwalls. There is, however, a possibility of impacts occurring on the headwater sub-catchment of Carne Creek below the proposed dewatering facility (**Figure 1-1**).

Should sediment plumes form they would be dispersed downstream, with rate of dispersion depending on the prevailing flow. The aquatic flora and fauna that occur in the watercourses within and adjacent to the Project Area would be fairly tolerant of increases in sediment load as these occur during periodic rainfall events. Temporary, localised increases in sediment load that may arise during general construction works are unlikely to have any significant effects on aquatic habitats or associated biota.

7.1.1.2 Construction of Dewatering Boreholes and Associated Pipeline Infrastructure

The construction of dewatering boreholes and installation of pipelines in the vicinity of streams, swamps and their drainages could potentially lead to:

- Discharge of groundwater to the surface if drilling intercepts a confined aquifer where groundwater is under pressure which could, in turn, result in changes to the quantity and quality of surface water and flooding of swamps;
- Contamination of surface water, swamps and shallow perched aquifers with drilling muds/fluids, drilling additives, oils and lubricants which may be toxic to aquatic fauna and flora and stygofauna;
- Erosion of creek bed and banks and increased suspended sediment loads at and downstream of points where pipelines cross watercourses.

The clearing of vegetation around borehole sites could result in erosion and exposure the swamps to increased sedimentation.

The groundwater that is discharged at the surface will be captured initially in a sump and then disposed of appropriately. Surface water run-off from the disturbed areas of the drill pad site will be diverted using clean/dirty diversion banks to a sediment bank for treatment prior to discharge off site. Negligible impacts are expected as the quality of the receiving waters will not be compromised.

7.1.2 Avoidance, Mitigation and Management Measures

7.1.2.1 General Construction Works

Impacts associated with general construction works in the vicinity of watercourses could be minimised by:

- Limiting the area of riparian zone and aquatic habitat disturbed, particularly in the vicinity of proposed dewatering borehole in the headwater catchment of Carne Creek;

> Developing and implementing a Sediment and Erosion Control Plan to protect swamps and aquatic habitats and biota immediately downstream of the construction area;

> Establishing a bunded area for storage of fuels, oils, refuelling and appropriate maintenance of vehicles and mechanical plant;

> Minimising direct access to streams, swamps and their drainages by construction vehicles and mechanical plant;

> Prohibiting re-fuelling, washing and maintenance of vehicles and plant within 30 m of streams, swamps and their drainage lines;

> Reporting spillages to the appropriate officer and immediately deploying spill containment kits to restrict their spread into or within drainage lines.

The Erosion and Sediment Control Plan should be prepared in accordance with Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008) and should include a description of the erosion sediment control structures that are to be used to minimise soil erosion and the potential for the transport of sediment to downstream waters. Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any construction works.

Construction works in the vicinity of watercourses should also be done in accordance with the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (See Section 3.2.4.2) (NSW DPI 2013). These indicate that:

> Riparian buffer zones should be established and maintained in or adjacent to Type 1 or 2 Habitat (i.e. those freshwater fish habitats considered to be highly or moderately sensitive) or Class 1-3 waterways (i.e. those containing major, moderate or minimal fish habitat);

> Riparian buffer zones should be designed to maintain lateral connectivity between aquatic and riparian habitat;

> The width of the riparian buffer zone should be based on the habitat type and waterway class, with buffer zones of 100 m, 50 m and 10-50 m being applicable respectively to highly sensitive freshwater fish habitats or waterways major fish habitat, moderately sensitive freshwater fish habitats or waterways containing moderate fish habitat, and minimally sensitive fish habitats or waterways containing minimal fish habitat.

> Existing riparian vegetation should be retained in an undamaged state where possible and that disturbed areas should be revegetated with local native species and monitored to ensure revegetation is successful;

> If rehabilitation is required this should include native instream vegetation and snags, where appropriate.

If pipeline or access track crossings need to be constructed over watercourses this should be done in accordance with the requirements outlined in Chapter 4 of the NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI 2013).

7.1.2.2 Construction of Dewatering Boreholes and Associated Pipeline Infrastructure

The potential for direct impacts associated with the construction of dewatering boreholes and pipelines would be avoided by not installing them above longwalls overlain by the headwaters of Carne Creek.

It is understood the dewatering bores would be installed in the same manner as the existing bores using blind boring drilling methods and that they would then be cased and grouted along their entire lengths. Grouting would prevent drainage of shallow aquifers and subsequent impacts on discharge and baseflows. The use of biodegradable drilling muds would reduce the risk of any contamination. The potential for indirect impacts through runoff could be avoided by avoiding drilling during wet weather and containing and then removing any water discharged during drilling and bore development. The initial mine water rising to the surface would be captured in a sump located downslope from the boreholes. Sediment basins would be installed to capture dirty water for treatment.

Should pipelines be required to cross watercourses, the angle of crossing should be as close to perpendicular as possible to the drainage line or watercourse to avoid potential for creek and bed erosion.

7.2 Mining Operations

Springvale Coal proposes to use the retreat longwall mining method to extract coal from the Lithgow Seam. Seventeen new longwall panels (LW416 to LW432) would be extracted to the east and the southeast, while three (LW501-LW503) would be extracted to the southwest of the existing workings at Springvale. Operations would be staged such that the panels to the east would be extracted before those to the south-west of the existing longwalls.

During mining operations, the water that accumulates in the underground workings (mine water make) needs to be removed to maintain operational safety. The increase in mine water make will be managed by transferring it to the SDWTS via Bore 9 or Bore 10 in addition to the Ventilation Shaft Borehole and the Pit Top Collection system borehole and by discharge into the Coxs River via LDP009. Inflows of mine water make from LW420-423 will be managed through Bore 9, while inflows from LW424-432 and LW501-503 will be managed by Bore 10. Mine water make from both the Springvale and Angus Place Mines is currently transferred via the SDWTS to Delta Electricity's Wallerawang Power Station for use in their cooling towers. This transfer results in a significant reduction in the quantity of mine water make that is discharged into the Coxs River. At present, the volume of mine water make produced by both mines is below the capacity of the SDWTS, so discharges to the river via LDP009 occur only when the transfer cannot take place for operational reasons.

The combined volume of mine water make from both mines is currently 18.5 ML/d. The extension projects will increase the volume to 25 ML/d in 2015 and to a peak of about 45 ML/d in 2024/25. The volume will then decline to 26 ML/d in 2032 following completion of mining of proposed works at Springvale in 2025 (RPS 2013c). Mining of proposed works and dewatering at Angus Place would cease in 2032. The SDWTS currently has a capacity of 30 ML/d, but this may be upgraded to 50 ML/d at a later stage in the project to accommodate the increased inflows into the SDWTS from the adjacent project at Angus Place Mine. If the upgrade does not take place discharge to the Coxs River via LDP009 would be increased. Springvale EPL 3607 permits up to 30, 000 KL/d (30 ML/d) of mine water make to be discharged into the river via LDP009. The water balance modelling based on existing infrastructure indicates an average of 29.9 ML/d from Springvale Mine and Angus Place Mine combined would be transferred to the SDWTS and that no mine water make would need to be discharged from LDP009 in 2023 (the year in which groundwater inflows will be maximal). If the SDWTS is upgraded but the capacity of the power station remains at 30ML/d, excess mine water make would be discharged into Coxs River via LDP009. In this case, there would be a marked increase in the volume of discharge at LDP009 between 2019 and 2025, followed by a sudden decline in discharge. In 2023, the average volume of discharge via LDP009 would be 14.4 ML/d.

7.2.1 Potential Impacts

7.2.1.1 Ground Movements

The extraction of coal from the proposed longwalls will result in vertical and horizontal movements of the rock and soil mass above the extracted coal seam. At the surface, the following movements may occur:

> Vertical (downward) and horizontal displacements of the surface which are referred to as vertical subsidence and horizontal subsidence, respectively;

> Changes in surface slope, which is referred to as tilt;

> Changes in the horizontal distance between two points on the surface which is referred to as tensile strain if the distance between the two points increases and compressive strain if the distance between the two points decreases.

In incised valleys and gorges, subsidence can give rise to un-conventional effects, including:

> Upsidence is the reduced downward subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley;

> Valley Closure is the reduction in the horizontal distance between the valley sides;

> Compressive Valley Strains which occur within the bases of valleys as the result of valley closure and upsidence movements;

> Tensile Valley Strains which occur at the tops of the valleys as the result of valley closure movements.

These ground movements may cause fracturing of the stream bed and banks, movements of joint and bedding plains in the stream bed, uplift and buckling of strata in the stream bed (NSW DoP 2008). These physical impacts, in turn, may result in diversions of surface and sub-surface flows, drainage of pools and increases in groundwater inflows. Tilting of stream beds may result in erosion of the stream bed and banks and increased instream sediment load, changes in flow rates and migration of stream channels. These physical impacts can have adverse effects on aquatic flora and fauna through loss of aquatic habitat, desiccation of fringing vegetation, reductions in longitudinal connectivity, deterioration of water quality and changes in the diversity of riparian and aquatic plants, aquatic macroinvertebrates and fish. Ground movements may also result in drainage of and changes in baseflow to swamps. These changes in water level, in turn, could result in desiccation of swamps, loss of standing pools, increased vulnerability to damage during fires, changes in species distribution and composition of vegetation and changes in water quality, including elevated iron and manganese levels and proliferation of iron bacterial mats. Subsidence could potentially also lead to changes in the slope of swamps which could induce or increase the rate of scouring.

The proposed longwalls will be situated to the east of the upper reaches of the Wolgan River, but an approximately 0.9 km reach of the river would be situated within 600 m of the proposed longwalls, with the closest longwall (LW416) being 460 m away from the river (MSEC 2013). The proposed longwalls in the northern part of the proposed workings area would be located directly below approximately 2.0 km of Carne Creek and its associated drainage lines.

MSEC (2013) has provided subsidence predictions for the proposed longwalls and assessed the impact of the ground movements on the physical attributes of the Wolgan River, Carne Creek and the drainage lines. The maximum predicted ground movements in the reaches of the Wolgan River and Carne Creek occurring within 600 m of the proposed longwalls are presented in **Table 7.1**.

Table 7-1 Maximum predicted ground movements in Wolgan River and Carne Creek resulting from extraction of Longwalls 416-432 (MSEC 2013).

Type of Ground Movement	Wolgan River	Carne Creek
Subsidence	<20 mm	1375 mm
Upsidence	65 mm	725 mm
Valley closure	75 mm	875 mm
Tilt	No measurable change	25 mm/m
Compressive strains	0.5-1.0 mm/m	5.0-15.0 mm/m

The predicted impacts of these movements on the physical stream attributes and the consequences for the aquatic ecology of these watercourses are summarised below.

The key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of the approximately 3 km stretch of the Wolgan River situated within 600 m of the proposed longwalls are:

> This reach of the river is not expected to experience any measurable conventional tilts, curvatures or ground strains because the maximum predicted subsidence resulting from extraction of the longwalls is small (< 20 mm) but it may experience low levels of subsidence;

> The compressive strains due to the valley closure movements are unlikely to cause fracturing of the river bed, but if any does occur, it would be isolated, shallow, discontinuous and minor in nature and is not expected to divert surface water flows into subterranean flows;

> As ground movements resulting from extraction of the existing longwalls at Angus Place and Springvale Collieries has not caused significant fracturing or surface water flow diversions, the extraction of LW416-LW432 is unlikely to cause significant fracturing or surface water flow diversions.

Given the above, there are unlikely to be any significant physical subsidence impacts on this reach of the Wolgan River.

If minor, superficial, isolated, discontinuous fracturing of the riverbed does occur, it could lead to drainage of overlying pools and loss of aquatic habitat and associated biota in localised areas. During dry weather there could potentially be loss of connectivity between pool habitats. The presence of large amounts of sediment in the river bed (See Section 4.2.1), suggests that any shallow cracks that do form are likely to be infilled by sediment. As the base surface water flows are small and derived from shrub swamps and perched aquifers such infilling would most likely occur during high flow events. Impacts on pool habitats and biota are consequently expected to be localised and temporary persisting until the cracks are infilled and overtopping of flows is resumed. The weathering of freshly exposed minor fractures in the sandstone rocks could result in localised, transient increases in salinity and concentrations of iron, manganese, aluminium, zinc and nickel, and decreases in dissolved oxygen levels. Increases in iron staining could result in smothering of the substratum and sessile biota, but this would only extend a short distance downstream from where the water re-emerges. The resulting consequences for aquatic ecology of any physical subsidence impacts that do occur in this reach of the Wolgan River are thus expected to be localised and transient and would not therefore have a significant impact.

The key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of the reach of Carne Creek confined within Sunnyside East Swamp are:

> The post mining grade is expected to be similar to the natural grade of the swamp, so mine-induced subsidence is unlikely to cause any adverse changes in ponding or scouring and mining-induced tilt or vertical subsidence is unlikely to cause significant changes in the distribution of the stored surface waters within the swamp;

> The compressive strains are expected to cause minor, isolated fracturing of the topmost bedrock beneath the swamp, but the cracks are expected to be infilled with sediment during subsequent flow events;

> Fracturing of bedrock may result in some diversion of surface water flows into the dilated strata beneath them, but these are expected to re-emerge further downstream, so there is unlikely to be a net loss of water from the catchment.

Given the above, there are also unlikely to be any significant physical subsidence impacts on this reach of Carne Creek. The consequences for aquatic habitats and biota of changes in ponding and scouring and fracturing of bedrock are expected to be similar to those in the drainage lines and are discussed later in this section.

The key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of the drainage lines, including the sections of Carne Creek located outside the extent of the Shrub Swamps, are:

> The drainage lines directly above the proposed longwalls are expected to experience the full range of subsidence movements and compressive strains due to valley related movements of between 5 mm/m and 15 mm/m, while those away from the proposed longwalls are likely to experience low subsidence and compressive strains of less than 2 mm/m;

> The predicted changes in grade are not expected to cause any adverse changes in ponding or scouring, but may result in minor increases in the levels of ponding in areas where the natural gradient is low;

> Fracturing of bedrock is expected to occur in some sections of the drainage lines, but the cracks are expected to be infilled with sediment during subsequent flow events;

> Fracturing of bedrock may result in some diversion of surface water flows into the dilated strata beneath them, but these are expected to re-emerge further downstream, so there is unlikely to be a net loss of water from the catchment.

Given the above, there are also unlikely to be any significant physical subsidence impacts on these drainage lines.

The minor localised increases in levels of ponding in areas of low grade could lead to a small increase in the availability of aquatic habitat. In drainage lines with surface soils, fracturing of bedrock could lead to temporary loss of aquatic habitat and connectivity, stranding of aquatic biota and exposure to aerial conditions. In areas where diversion of surface water into sub-surface layers occurs, there could be some drainage of pooled water and loss of aquatic habitat and connectivity. These losses are expected to be localised and temporary and would persist until the cracks are infilled with sediments during subsequent flow events. These losses would be less important in ephemeral drainage lines, as aquatic habitat is present only during flow events and for a short time thereafter. It may also be difficult to detect changes in habitat availability and connectivity, because of the large variability in natural flows within the ephemeral systems. In the drainage lines situated downstream of swamps, the small base surface water flows are likely to result in more rapid infilling of cracks. The diversion of surface water into sub-surface layers could affect the quality of the water in the drainage lines at and immediately downstream of the point where surface flows re-emerge. This is because the weathering of freshly exposed fractures in sandstone rocks can cause increases in salinity and concentrations of iron and other metals and reductions in dissolved oxygen levels. Increases in iron staining could also smother aquatic habitats and sessile biota. The resulting consequences for aquatic ecology of any physical subsidence impacts that do occur in the drainages are thus expected to be localised and transient and would not therefore have a significant impact.

The maximum predicted ground movements for the Shrub Swamps presented in MSEC (2013) indicate that the Shrub Swamps in the northern part of the proposed workings area would experience greater ground movements than all of those in the southern part, except Marrangaroo Creek Swamp which would experience the greatest maximum predicted conventional subsidence (1650 mm), tilt (13 mm/m), hogging curvature (0.2 km^{-1}) and sagging curvature (0.35 km^{-1}). Sunnyside Swamp and Nine Mile Swamp situated just outside and on the periphery of the Project Area respectively are expected to experience minimal ground movements.

MSEC (2013) indicated that non-conventional ground movements may also occur and presented maximum predicted total upsidence and closure estimates for each swamp. Sunnyside East Swamp is expected to experience considerably greater maximum total upsidence (750 mm) and closure (1000 mm) than the other swamps (75-450 mm upsidence and 100-600 mm closure), with Nine Mile Swamp experiencing the smallest changes. The predicted upsidence and closure would be greater for parts of the swamps above the centrelines of the longwalls and less for parts above the chain pillars. The Shrub Swamps directly above the proposed longwalls are expected to experience compressive strains due to valley closure of between 5 mm/m and 15 mm/m, which is similar to those for the drainage lines.

The Hanging Swamps are predicted to experience subsidence up to 1500 mm, tilts up to 13 mm/m, and curvatures up to 0.20 km^{-1} hogging and 0.35 km^{-1} sagging, with those in the Marrangaroo Creek, Sunnyside East and Carne West catchments experiencing greater maximum predicted conventional subsidence, tilt, hogging and sagging than those in the Gang Gang, Pine, Paddys Creek catchments and that above longwalls 502-503 (MSEC 2013). The Hanging Swamps in the Paddys Creek catchment would experience substantially smaller ground movements than those in the other catchments. The Hanging Swamps are not expected to experience significant valley related upsidence movements or compressive strains due to closure movements because they are situated on the sides rather than base of valleys

The key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of Shrub Swamps and Hanging Swamps are:

> The post mining grade is expected to be similar to the natural grade of the swamp, so mine-induced subsidence is unlikely to cause any adverse changes in ponding or scouring and mining-induced tilt or vertical subsidence is unlikely to cause significant changes in the distribution of the stored surface waters within the swamp;

> The compressive strains are expected to cause minor, isolated fracturing of the topmost bedrock beneath the swamp, but the cracks are expected to be infilled with sediment during subsequent flow events;

> Fracturing of bedrock may result in some diversion of surface water flows into the dilated strata beneath them, but these are expected to re-emerge further downstream, so there is unlikely to be a net loss of water from the catchment.

Given the above, there are also unlikely to be any significant physical subsidence impacts on Shrub Swamps and Hanging Swamps. The consequences for aquatic habitats and biota within the drainage lines downstream of the swamps will therefore also not be significant.

7.2.1.2 Discharge and Recharge

Extraction of the longwall panels has the potential to affect groundwater discharge to and recharge from streams and Shrub Swamps, which in turn, will affect their baseflows. Groundwater flow to swamps and creeks and thus baseflows would be increased by bed separation effects and enhanced horizontal permeability. The predicted impacts on baseflows vary from positive (increased baseflow, or reduced net leakage) to negative (decreased baseflow, or increased leakage) (RPS 2013b). The Hanging Swamps within the Application Area are associated with the perched aquifer system and depend primarily on rainfall recharge. Hanging swamps and their drainages will therefore not be affected by changes in groundwater table levels and baseflow.

The hydrogeological modelling indicates the discharge to Carne Creek would decline from 6.6 ML/day in 2012 to 6.3 ML/day in 2022 and 6.06 ML/day in 2032 but when mining is completed it would increase to 6.37 ML/day by 2064 (Adhikary and Wilkins 2013). Discharge to the Wolgan River would be reduced from 1.35 ML/day in 2012 to 1.25 ML/day, 1.09 ML/day and 0.96 ML/day in 2022, 2032 and 2064 respectively. The predicted reductions in groundwater discharge during mining are smaller than the simulated seasonal variation in baseflow (0.96 ML/day in Carne Creek and 0.55 ML/day in Wolgan River). In the Wolgan River, the predicted average change in groundwater levels after 2012 would increase from 1.4 cm in 2022 to 3.6 cm in 2032 and 6.0 cm in 2064. In Carne Creek, the predicted average change in groundwater levels after 2012 would increase from 2.2 cm in 2022 to 4.2 cm in 2032 but reduce to 1.6 cm in 2064.

The impacts of longwall extraction on the shallow groundwater and baseflow are therefore expected to be minor. RPS (2013b) has suggested that the magnitude of the changes are likely to be smaller than that predicted by the hydrogeological modelling, because this has not taken into account the infilling of fractures within the creeks by sediments, a factor that would reduce impacts on baseflows. They also indicated that the monitoring of surface water flows undertaken at gauging stations has not demonstrated any detectable effects of previous longwall extraction on surface flows. The impacts on swamps will be smaller than those that occur naturally as a result of seasonal variation (Adhikary and Wilkins 2013). It is expected that mining will change the water head in most swamps by a few centimetres on average and by a maximum of 15 cm in Gang Gang Swamp South East. Given the above, it is highly unlikely that there would be any measurable effects on the aquatic ecology of streams or drainages downstream of swamps.

Shallow fracturing of the bedrock overlying the longwalls is expected to enhance shallow permeability and facilitate infiltration of runoff and surface water to the ground and recharge of shallow aquifers and reduce runoff during rain events (RPS 2013b). The increase in permeability is likely to be short lived, because the cracks would be infilled with sediment during subsequent flow events. The water that infiltrates is expected to re-emerge as surface flow further downstream and would thus contribute to baseflow within the watercourse. Loss of groundwater to deeper aquifers is not expected to occur as the perched aquifer that supports the swamps is hydraulically independent of the underlying groundwater systems.

It should be noted that shallow subsidence caused by previous mining operations has not reduced surface flows in the swamps or shallow groundwater levels. There is consequently unlikely to be any detectable effects on aquatic ecological attributes in the watercourse immediately downstream of the swamps.

7.2.1.3 Discharge of Mine Water Make

The transfer of mine water make to the SDWTS results in a significant reduction in the potential impact of any discharges into the Coxs River. The volume of discharge from LDP009 to the river is, however, predicted to increase during the Project. The increase in the volume of the discharge is likely to affect the flow regime, geomorphology, water quality, aquatic habitat and aquatic biota of the river, with impacts depending on the level of river flow.

The long-term data from the NSW Office of Water Gauging Station (212054) on the Coxs River immediately upstream of the Lake Wallace indicates the flow rate varies from 0.3 to 5.321 ML/d with a median value of 12.2 ML/d. The discharges that are likely to be released from LDP009 between 2019 and 2025 are expected to have moderate to significant effects on low flows (i.e. within the 80th to 95th flow percentile), small to moderate effects on low to moderate flows (i.e. within the 50th to 80th percentiles) and minimal to small effects on high flows (i.e. within the 0 to 50th percentiles). The magnitude of the impacts will also increase as the discharge volume increases between 2019 and 2025. The average discharge of 14.4 ML/d that would occur when groundwater inflows are maximal, for example, would result in ratios of discharge flow to river flow of 5:1 to 2:1 during low flows, 2:1 to 1.2 during moderate flows and less than 1.2 during high flows. As there are no records of flows from LDP009 it is difficult to put the likely changes before 2019 into context. Changes in flows over this period are expected to be small, so the impacts on the natural flow within the river would be minimal, as will be those that occur after 2025.

The marked increase in flow within the river between 2019 and 2025 could increase erosion of stream banks and channels, turbidity levels and downstream transport of sediment, nutrients and aquatic biota if it coincides with periods of low to moderate flows. Increases in the discharge rate during such periods could exacerbate the existing erosion of the stream bank and channel that is evident along the river (See Section 4.2) and could lead to further downstream transport of sediment and a potential increase in turbidity. Increases in turbidity and sediment load can impact on instream biota by decreasing light levels and thus photosynthesis, clogging feeding and respiratory appendages in fish and reducing the visual acuity of predators (NSW Fisheries 1999). Such impacts are likely to be short-lived (i.e. will occur for a few days when discharge rates are increased) and would be negligible relative to those that occur naturally during high flow events. The increase in dilution resulting from the greater flow is likely to counteract any increase in turbidity and flow-on effects on aquatic biota.

The increases in flow within the river between 2019 and 2025 could increase the area and top width of flow and depth of water, which would, in turn, increase the availability of instream habitat and improve its connectivity along the river and connection with adjoining riparian habitats. The impact on habitat availability and connectivity would be small to moderate during low and medium flows and negligible during high flows The increased connectivity would enable mobile species such as fish and yabbies to move through the stream network more freely than at present and could potentially allow them to access additional foraging and/or spawning areas. Increases in depth of water during low flows could increase the extent to which the edge habitat along the river bank is wetted, which could, in turn, result in an increase in abundance of macroinvertebrates. It could also drown out riffle habitat and result in a loss of macroinvertebrates associated with that habitat. Increases in water level during such periods could also increase inundation of riparian vegetation, prevent their die-back and improve their reproductive success. Releases during low flow periods may result in more stable aquatic habitats and conditions that are more conducive to the establishment and growth of aquatic macrophytes. These are unlikely to persist, as they would be flushed away during subsequent natural high flow events. An increase in the stability of the edge habitat due to continuous discharges during low and moderate flow periods could lead to a shift in the composition of macroinvertebrate assemblages.

Sudden increases in flow rate during low flow conditions could also flush away potential instream habitats such as woody debris, leaf litter, pebbles and benthic sediment. The impact on such habitats, however, would be negligible relative to that which occurs naturally during high flow events.

Changes in the flow regime could potentially result in a decrease in the diversity and abundance of macroinvertebrates, with the magnitude of change depending on the volume of and variability in the discharge and sensitivity of the taxa to flows. Exotic fish species that prefer slow-moving streams could be disadvantaged by the increase in flows.

The release of large volumes of mine water make would change the quality of the water in the river at and downstream of the discharge point. The general increase in flows and water levels could lead to improvements in some water quality parameters, by facilitating exchange of oxygen with the atmosphere and thus increasing dissolved oxygen levels, and diluting contaminants and nutrients in runoff from the adjoining land and those released through licenced discharge points situated between the mine and Lake Wallace. The magnitude of change will depend on the background level of the various constituents in the receiving waters and the capacity of the river for dilution, which is in turn dependent on river flow, inflows from tributaries and other discharge points and the distance to Lake Wallace.

Data on the current quality of the discharge at LDP009 is limited. They show that pH, turbidity, boron and manganese levels are consistent with the ANZECC/ARMCANZ (2000) criteria, but EC, total dissolved solids (TDS) and aluminium levels exceed their respective DTVs (RPS 2013). The potential for an increase in salinity in the river is of particular concern, as the long-term data from the NSW Office of Water Gauging Station No. 212054 indicate median EC in the Coxs River above Lake Wallace (~600 µS/cm) is well below that of the discharge from LDP009 (1,055 µS/cm). The records from the gauging station show considerable variation in salinity, with an overall trend of increasing salinity from 1992 until 2007, when the salinity rose to

1,100 - 1,200 μS/cm, followed by a marked decline in 2010-2011 with levels rarely exceeding 700 μS/cm. The data also show that marked increases in salinity are relatively gradual but declines in salinity are abrupt.

A salt mass balance model has been used to predict the EC levels in the Coxs River at a point immediately upstream of Lake Wallace as a result of the discharge under normal (median flow of 12.23 ML/d) and dry conditions (95th percentile flow of 2.9 ML/d) and depending on whether or not the SDWTS is upgraded (RPS 2013c). If the capacity of the SDWTS remains at 30 ML/d and normal conditions prevail, EC levels would increase from 600 μS/cm in 2012 to 818 μS/cm in 2015, then decline to 725 μS/cm in 2019, gradually increase again reaching a peak of 814 μS/cm in 2024 and then decline gradually to 690 μS/cm in 2032. If drought conditions prevailed, the EC levels would increase from 600 μS/cm in 2012 to 891 μS/cm in 2015, then decline to 831 μS/cm) in 2019 and then gradually increase again reaching a peak of 910 μS/cm in 2024 and then decline gradually to 800 μS/cm in 2032.

If the capacity of the SDWTS is increased to 50 ML/d and normal conditions prevail, the EC levels would increase from 600 μS/cm in 2012 to 785 μS/cm in 2013-2014, then decline to 647 μS/cm) in 2017-2018 and then gradually increase again reaching a peak of 841 μS/cm in 2024 and then decline gradually to 626 μS/cm in 2032. If drought conditions prevailed, the EC levels would increase from 600 μS/cm in 2012 to 898 μS/cm in 2013-2014, then decline to 725 μS/cm) in 2017, increase sharply to 900 μS/cm in 2020 and remain above this level until 2025 before dropping to 679 μS/cm in 2032.

It should be noted that the contribution of mine water make from the Springvale Mine to the changes in salinity would be small and well within the range of natural background variability. If the SDWTS is not upgraded, the contribution would vary from 0 μS/cm to 11 μS/cm under normal conditions and from -1 μS/cm to 8 μS/cm under dry conditions. If the system is upgraded it would vary from 0 to 51 μS/cm under normal conditions and from 0 μS/cm to 141 μS/cm under dry conditions (RPS 2013c).

The greatest changes in salinity and hence potential for impact on aquatic biota would occur at the beginning and during the middle of the Project. The potential for impact on aquatic biota would also be greater if the SDWTS is upgraded. The extent of the mixing zone is unknown, but it is obvious that this will extend further downstream during low and moderate flows than high flows. It is also important to note that the increases in salinity will occur over a much shorter timeframe than the natural increases in salinity and will be sustained for longer periods than in the past. The decrease in salinity will be as sharp as some of the natural declines that have occurred, but low salinities will be sustained for longer. Aquatic biota will thus be exposed to salinity conditions they have not previously experienced.

The changes in the salinity regime of the river adjacent to and downstream of LDP009 resulting from the discharge of mine water make could potentially have direct toxic effects on some organisms and indirect effects on others through modification of species composition of the ecosystem and effects on species that provide food or refuge (ANZECC/ARMCANZ 2000). The scientific literature indicates many species of aquatic plants, riparian plants and macroinvertebrates in Australian freshwater systems are salt sensitive and that direct adverse biological effects become apparent when the salinity rises above 1500 μs/cm. (Hart *et al*. 1991). Although this suggests that the aquatic biota in the river is unlikely to be impacted by the salinities resulting from the discharge, it should be noted that toxic effects on early life-history stages and more subtle sub-lethal and indirect effects are likely to occur at lower salinities (Hart *et al*. 1991, Nielsen *et al*. 2003). The extent to which such impacts may occur is largely unknown, with sub-lethal effects only becoming apparent after several generations (Rutherford and Kefford 2005).

The increase in salinity during the peak discharge of mine water make is also likely to be too rapid for the aquatic biota in the Coxs River to acclimate or adapt. Aquatic organisms that are unable to cope with the increase will either perish or disperse to areas with more favourable conditions, while tolerant forms will survive with little or no reproduction and recruitment or as dormant propagules (Nielsen *et al*. 2003). In the mixing zone, this will lead to a decrease in biodiversity and the remnant assemblages being dominated by salt-tolerant species (Williams 2001). The impact will be greatest during low flow periods when dilution is poorest.

7.2.1.4 Other Activities

The maintenance of bushfire clearance areas could potentially have the following impacts on watercourses:

> Loss of riparian vegetation and associated habitat and food resources;

> Input of fallen and/or burnt vegetation;
> Deposition of ash and runoff containing sediment resulting from erosion of burnt areas during rainfall events;
> Reduced water quality.

7.2.2 Avoidance, Mitigation and Management Measures

7.2.2.1 Ground Movements

Springvale Coal proposes to minimise further physical impacts arising from mine-induced subsidence by setting the proposed longwalls back at least 460 m from the Wolgan River. The potential for impacts on swamps and their drainages would be minimised by narrowing the overall void widths of LW416 to LW432 and LW501 to LW503 to 261 m, or less and increasing the chain pillar widths to 58 m (MSEC 2013).

During the extraction of the proposed longwalls, the watercourses, swamps and drainage lines within and immediately outside the proposed workings area should be periodically inspected by suitably qualified personnel for evidence of subsidence-induced impacts. The levels and quality of the groundwater and surface water associated with the swamps should also be monitored. A Trigger Action Response Plan for surface water and groundwater should be developed in consultation with the NSW Office of Water. If the changes in quality and quantity of groundwater and surface water that occur during or after extraction of the longwalls are greater than expected, their effects on downstream aquatic ecology should be investigated immediately. Trigger values (i.e. thresholds that would need to be exceeded) that would result in the initiation of such studies would need to be identified. The assessment and management of potential subsidence impacts would also be conducted in accordance with the Newnes Plateau Shrub Swamp Management Plan.

Although significant impacts on aquatic ecology are unlikely, it is recommended that the condition of aquatic habitats, quality of water and diversity of aquatic biota at potential impact sites on the Wolgan River, Carne Creek and in the drainages be monitored periodically during and after the extraction of LW416-LW432 and LW501-LW503. Simultaneous monitoring should also be undertaken at appropriate reference sites on nearby watercourses that will not be affected by mining. This would enable impacts associated with mining to be distinguished from natural variability. The existing upstream monitoring site (WRup) on Wolgan River could serve as a potential reference site as it has not been impacted by previous mining and is not expected to be affected by the proposed mining. The existing monitoring sites downstream of the Sunnyside East (CC1), Carne West (CC2) and Gang Gang (CC3) swamps would serve as potential impact sites in the northern part of the proposed workings area, while that downstream of Barrier Swamp (CC4) would serve as a reference site. It is recommended that an additional reference site be established downstream of another nearby Shrub Swamp in the headwaters of Carne Creek that will not be affected by the mining.

Before mining commences, it is recommended that further biannual monitoring of aquatic habitats and biota be undertaken at Site CCXdn and at the sites downstream of Paddys Creek (PC1) and Nine Mile (BNC2) and at appropriate reference sites in order to establish an adequate baseline. Further baseline monitoring of the sites downstream of the Marrangaroo Creek (MC1) and Pine Swamps (BC1) may also be necessary before mining commences to ensure that before and after mining contrasts are not confounded by changes in climatic conditions.

The use of SIGNAL2 scores, an indicator of pollution, should be reviewed as mining may result in other forms of disturbance to which this index may not be sensitive. It is also suggested that a less selective method be used to sample fish (e.g. backpack electrofishing) and that this be done in a quantitative way and that the percentage cover of instream aquatic flora be estimated using transects and/or quadrats. Sampling methods that would enable the abundance of aquatic macroinvertebrates to be assessed should also be considered. At present, only the RCE scores, numbers of macroinvertebrate taxa and SIGNAL2 scores would be suitable for before, during and after mining comparisons.

If the impacts of the extraction of the longwalls on aquatic habitats and biota are greater than predicted the following contingent measures should be implemented:

> Stream remediation measures, such as backfilling or grouting, should be used in areas where fracturing of controlling rock bars and/or stream bed leads to protracted diversion of stream flow and drainage of pools;

> Appropriate control measures should be implemented to limit the potential for deposition of eroded sediment into watercourses (e.g. installation of sediment fences down slope of areas where subsidence has led to erosion, and use of rocks, brush matting or vegetation to stabilise areas prone to erosion and soil slumping);

> Soft engineering techniques, such as coir logs, jute matting, hay bales, water dissipaters constructed from timber logs and rocks and revegetation using tube stock or direct seeding, could be used to minimise erosion, slumping and / or scouring of swamps and sediment inputs to their drainages.

If stream remediation is required, an aquatic ecology monitoring programme should be developed to monitor its effectiveness and the response of the aquatic ecosystem.

If these management strategies prove ineffectual, appropriate offset and compensatory measures would need to be implemented.

7.2.2.2 Discharge and Recharge of Streams

No avoidance, mitigation or management measures are required, because impacts on discharge and recharge of streams are expected to be minor and smaller than natural seasonal changes.

7.2.2.3 Discharge of Mine Water Make

The transfer of mine water make to the SDWTS significantly reduces the quantity of water that would otherwise be discharged via surface licenced discharge points.

The impact of the discharge of mine water make on instream ecology would be minimised by ensuring it meets the conditions specified in the Springvale's Environment Protection Licence 3607. At present, there is a limit on the volume of the discharge from SP_LDP009 of 30,000 kL/d and 100 percentile concentration limits on oil and grease (10 mg/L), conductivity (1200 µS/cm), pH (6.5-9.0 units), total suspended solids (50 mg/L), turbidity (50) and concentration of various metals.

In addition, it is recommended that:

> Appropriate measures be used to minimise the potential for erosion and sedimentation at the licenced discharge point and on the Coxs River downstream thereof and that extent of erosion should be monitored regularly;

> Effects of changes in the quality of the constituents and temperature of the receiving water should be taken into consideration, particularly those constituents of mine water make that could have ecotoxic effects on aquatic biota.

As the aquatic biota in the river has not previously been exposed to the type of salinity regime that will prevail when discharge is at a peak it is suggested that a literature review be undertaken to determine the likely impacts of abrupt and sustained changes in salinity and that an aquatic ecology monitoring programme be implemented to determine their actual impact on aquatic flora and fauna.

7.2.2.4 Other Activities

Impacts on watercourses associated with the maintenance of bushfire clearance areas would be minimised by the implementation of appropriate measures specified in the Bushfire Management Plan.

7.3 Decommissioning and Rehabilitation Phases

The decommissioning phase of the Project would involve permanent sealing of underground access points, dismantling and removal of surface infrastructure and services and rehabilitation of the underlying land to ensure that it is appropriate for the proposed final land use. The existing water management structures at the Springvale pit top would be retained for management of surface water run-off from rehabilitated areas. Natural drainage patterns will be restored in the long term.

Facilities such as dewatering boreholes, ventilation shafts and access roads on Newnes Plateau would be decommissioned as soon as practicable after they are no longer required (Golder Associates 2013) and fully rehabilitated to return them to an end land use of forestry, commensurate with the surrounding areas.

The areas that have been disturbed during the life of the mine will need to be returned to a stable, productive and/or self-sustaining condition similar to those that existed before mining. Rehabilitation would be an ongoing process that takes place progressively as soon as each disturbed area is no longer required. Rehabilitation works typically involve clearing and grading of land, spreading of topsoil, seeding and/or revegetation, application of fertilisers and control of weeds. Land contamination issues would need to be addressed and managed prior to rehabilitation. Once rehabilitation has been completed, monitoring is required to ensure erosion is not occurring and that seeding and/or revegetation is successful. The above works would be undertaken in accordance with the Rehabilitation Management Plan.

7.3.1 Potential Impacts

During the decommissioning phase of the Project impacts on instream ecology could occur if erosion of denuded areas results in soil being blown into streams, swamps and their drainage lines or runoff containing sediments and contaminants such as fertilisers and herbicides enters these areas during rainfall events. Excess sediment and fertilisers and small amounts of herbicides could potentially have adverse effects on aquatic flora and fauna. The potential for such effects would depend on the residence time of the sediment and contaminants within particular areas of the watercourses.

7.3.2 Avoidance, Mitigation and Management Measures

The ingress of sediments into streams, swamps and their drainages and potential for impacts on aquatic ecology resulting from decommissioning and rehabilitation works would be minimised by implementing appropriate measures specified in the Erosion and Sediment Control Plan prepared in accordance with Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries (DECC 2008). The measures would include temporary erosion and sediment controls such as sediment fences, sandbag weirs, temporary drains and temporary silt traps. Runoff from rehabilitated areas may also be directed to sediment control retention ponds for treatment prior to discharge.

The decommissioning of boreholes would be undertaken in accordance with the Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee 2011).

7.4 Impacts on Threatened Species and Key Threatening Processes

7.4.1 Threatened Species

7.4.1.1 Introduction

An assessment of the significance of impacts on Adams Emerald Dragonfly has been prepared in accordance with the Threatened Species Assessment Guideline – The Assessment of Significance (DECC NSW 2007). These guidelines specify the important factors that must be taken into considered when assessing potential impacts on threatened species, populations or ecological communities listed under Schedules 4, 4A and 5 of the *FM Act*. The factors are:

1. Whether the proposed action is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction;
2. The extent to which the species habitat is likely to be removed or modified as a result of the action proposed, whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and whether the habitat to be removed, modified, fragmented or isolated is important to the long-term survival of the species in the locality;
3. Whether the proposed action is likely to have an adverse effect on critical habitat (either directly or indirectly;
4. Whether the proposed action is consistent with the objectives or actions of a recovery plan or threat abatement plan;

5. Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

7.4.1.2 Assessment of Significance for Adam's Emerald Dragonfly

(a) Is the proposed mine extension likely to have an adverse effect on the life cycle of Adam's Emerald Dragonfly that would result in a risk of extinction of a viable local population of the species?

The Adam's Emerald Dragonfly has a predominantly aquatic life cycle, with larvae living for approximately seven years before metamorphosing into adults, which fly away from water to mature (NSW DPI 2012b). Larval Adam's Emerald Dragonfly have been found in small creeks with gravel or sandy bottoms and narrow shaded riffle zones with moss and extensive riparian vegetation. The adults return to water to breed, with males congregating at breeding sites and guarding a territory and females laying their eggs into the water. The adults are believed to live for only a few months. This species appears to have a low natural rate of recruitment and limited dispersal abilities.

The life cycle of Adams Emerald Dragonfly would be adversely affected if the construction, operation, decommissioning and/or rehabilitation phases of the Project resulted in loss or modification of its habitat or reduced the quality of the water. If fracturing of stream beds does occur during extraction of the proposed longwalls it could lead to drainage of overlying pools and loss of aquatic habitat and changes in concentrations of iron, manganese, aluminium, zinc and nickel and levels of iron staining. These impacts are expected to be minor, localised and temporary in nature, persisting until the cracks are infilled and overtopping of flows is resumed. Given the above, it is highly unlikely that the lifecycle of this dragonfly would be affected to such an extent that it would place a viable local population of this species, if one exists within the Project Area, at risk of extinction.

(b) Is the habitat of Adam's Emerald Dragonfly likely to be (i) removed or modified, (ii) become fragmented or isolated from other areas of habitats by the proposed mine extension and (iii), if so how important is the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species?

Larval Adam's Emerald Dragonfly are aquatic and inhabit small creeks with gravel or sandy bottoms and narrow shaded riffle zones with moss and extensive riparian vegetation (NSW DPI 2012b). The adults are terrestrial, but return to water to breed. Potential habitat for the larvae of this species occurs in the reaches of Wolgan River and Carne Creek within the Project Area. Potential habitat for the larval stage could be lost or become isolated, if fracturing of the stream bed results in drainage of pools. These impacts are expected to be minor, localised and temporary in nature, persisting until the cracks are infilled and overtopping of flows is resumed. Given the above, it is highly unlikely that changes in the availability of habitat due to mining would affect the long-term survival of this species, if it exists in these watercourses.

(c) Is the proposed mine extension likely to have an adverse direct or indirect effect on critical habitat?

Critical habitat for this species has not been declared under the FM Act.

(d) Is the proposed mine extension consistent with the objectives or actions of a recovery plan or threat abatement plan?

There is no recovery plan or threat abatement plan for this species at present.

(e) Does the proposed mine extension constitute or is it part of a key threatening process or is it likely to result in the operation of, or increase the impact of, a key threatening process?

Longwall mining is not classed as a Key Threatening Process under the *FM Act* under which Adam's Emerald Dragonfly is listed as a threatened species.

7.4.1.3 Conclusion

If a viable population of Adam's Emerald Dragonfly is present in the reaches of Wolgan River and Carne Creek or drainages within the Project Application Area, it is highly unlikely that the proposed mining operations would have any significant impact on the species, because it would only be subject to temporary, localised, minor impacts.

7.4.2 Key Threatening Processes

7.4.2.1 Degradation of native riparian vegetation along New South Wales water courses

A number of processes can result in degradation of riparian vegetation, including clearing of vegetation, gravel extraction, cropping, livestock grazing, trampling and introduction of, or invasion by, non-native species. Riparian vegetation can also be degraded by erosion, drowning, bank slumping and altered flooding regimes. Degradation of riparian vegetation can impact upon threatened species by:

> Altering the timing and quality of organic debris;
> Facilitating erosion and changes to channel structure;
> Increasing nutrient and sediment runoff;
> Reducing the availability of food and potential habitat for aquatic fauna.

The native riparian vegetation growing along the reaches of the Wolgan River and Carne Creek and their drainage lines above and adjacent to the proposed workings could potentially be degraded by clearing of vegetation during construction works and by fracturing of stream banks and beds, changes in ponding, flooding or scouring of river banks during the operational phase. As most of the proposed construction works will take place on the ridge lines and mid-slopes, the potential for degradation of native riparian vegetation due to clearing is limited. The subsidence predictions for the Wolgan River indicate that minor, isolated fracturing may occur, but changes in the levels of ponding, flooding or scouring of the river banks would not be significant (MSEC 2013). The surface fractures would be infilled with sediment during subsequent rainfall or major flow events, so any impacts on riparian vegetation are likely to be localised, temporary and minor. Subsidence is not expected to have any adverse impacts on Carne Creek (MSEC 2013), so its riparian vegetation should not be degraded.

The native riparian vegetation growing the upper reach of Coxs River could be affected by the change in flow regime resulting from increased discharges via LDP009 between 2019 and 2025. The effects are likely to include greater wetting of the vegetation during low flows, greater dispersion of propagules, an increase in dislodgement of plants due to greater erosion and bank slumping when the discharge rate is increased and greater invasion of exotic plants as a result of more stable flows. Such impacts would be of minor significance relative to those that occur naturally during major flow events.

7.4.2.2 Instream structures and other mechanisms that alter natural flows

The installation and operation of instream structures that alter the natural flow regime can impact on threatened aquatic flora and fauna by:

> Disrupting natural environmental cues for reproductive cycles;
> Creating physical barriers to native fish movement and migration;
> Altering the natural processes of sediment erosion, transport and deposition, leading to loss of fish habitat;
> Changing the total amount of water available for riverine ecosystems;
> Creating environments that are more suited to exotic species.

The Project does not involve installation or operation of instream structures that would alter natural flow regimes of rivers and streams. Other mechanisms that may alter natural flows are discussed in Section 7.4.2.4.

7.4.2.3 Removal of large woody debris from New South Wales rivers and streams

The removal of large woody debris can result in loss of habitat, refugia, resting places and spawning sites for threatened aquatic biota and expose them to changes in sediment load and turbidity as a result of destabilisation of stream banks and stream beds.

As construction works would be undertaken primarily on ridge lines and mid-slopes above the proposed workings, the removal of large woody debris from rivers and streams is unlikely to be necessary. If the removal of trees, trunks, branches, tree heads or root masses is required, impacts on aquatic species that are dependent on this resource could be minimised by placing the woody debris upstream or downstream of the construction site.

7.4.2.4 Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands

The release of mine water make via LDP009 will increase surface flows, change the frequency, duration, magnitude and variability of low to moderate flow events, alter surface water levels and affect the rate of rise or fall of water levels in a reach of the upper Coxs River. The effects of these changes on aquatic and riparian habitats and biota are described in Section 7.2.1.3. Threatened aquatic species, populations and communities would not be affected by the change in the flow regime, as none are present in these watercourses. Impacts on other aquatic species, populations and communities could potentially be mitigated by ensuring discharges mimic natural flows.

7.4.2.5 Alteration of habitat following subsidence due to longwall mining

Mine-induced subsidence may cause fracturing of the stream bed and banks, movements of joint and bedding plains in the stream bed, uplift and buckling of strata in the stream bed, which may in turn result in loss of surface flows, drainage of pools, increases in groundwater inflows and reduction in water quality (NSW DoP 2008). Ground movements may also result in drainage of and changes in baseflow to swamps. The subsidence predictions for the Wolgan River indicate that minor, isolated fracturing of the stream bed may occur, but the fractures would be infilled with sediment during subsequent rainfall or major flow events (MSEC 2013). Changes in the availability and quality of aquatic habitat would consequently be localised, temporary and minor. Subsidence is not expected to have significant impact on the levels of ponding, flooding or scouring of the banks of the Wolgan River (MSEC 2013), so changes in these attributes are unlikely to result in significant changes in aquatic habitat. Subsidence is not expected to have any adverse impacts on Carne Creek (MSEC 2013), so its aquatic habitat should not be altered.

7.5 Cumulative Impacts

7.5.1 Definition and Area Limitations

The term cumulative impacts refers to the total impact on the environment in a defined area that results from incremental direct and indirect impacts of the Project combined with past, present, and reasonably foreseeable future actions. This section consequently addresses the possibility of cumulative impacts on instream ecology arising due to multiple types of disturbances associated with the Project, expansion of existing longwall blocks and activities of others in the catchment.

In the western part of the Project Application Area, and adjoining the proposed longwalls (LW416-LW423) are the already extracted longwalls LW1 and LW401-LW415. The proposed workings area is located just to the south of the proposed Angus Place East Mine Extension Project for which Golder Associates are currently preparing an EIS. The southern part of the Project Application Area boundary, south of the proposed longwalls LW424-LW432 adjoins the New State Mine and Lithgow State Mine to the east and Clarence Colliery situated to the south-east. Angus Place Pit Top, Springvale Pit Top, Wallerawang Power Station, Castlereagh Highway, Lidsdale Rail Siding, pastoral farming and residential areas are situated to the west of the proposed workings. The pattern of land use around the Project Application Area is shown in **Figure 7-1.**

As the headwaters of the Wolgan River and sub-catchments of Carne Creek and its associated drainage lines originate above Springvale on the Newnes Plateau, it is the activities that take place within this mine and within the adjoining Angus Place Colliery that would have cumulative effects on these watercourses.

7.5.2 Subsidence

The headwaters of the Wolgan River have been undermined by the existing Springvale longwalls, but are located to the west of the proposed longwalls within the Project Application Area. The previous longwalls at Angus Place Colliery were extracted up to 150 m from the centreline of the river (MSEC 2013). The proposed longwalls in the Angus Place East Area would not undermine the river, but would undermine its drainage lines. MSEC (2013) has estimated that the river has already experienced valley related movements up to 270 mm upsidence and 330 mm closure due to the extraction of the existing longwalls at

Angus Place and Springvale Collieries and predicted that it would experience a further 65 mm upsidence and 75 mm closure due to the extraction of the proposed longwalls. As the existing mining has not caused any significant fracturing or surface water flow diversions along the Wolgan River, MSEC (2013) has concluded that the extraction of the proposed longwalls at Springvale and Angus Place Collieries will also not do so. The drainage lines in the western part of the proposed Angus Place East Area that drain into the Wolgan River could experience the full range of predicted subsidence movements when the longwalls in that area are extracted. The impact of these movements on the drainage lines, however, is not expected to be significant (MSEC 2013).

The headwaters of Carne Creek have not been disturbed by past or recent mining activities, but would be undermined by some of the proposed longwalls in the northern part of the Springvale proposed workings area. The headwaters of Carne Creek are also likely to experience valley related movements during the extraction of the proposed Angus Place East longwalls and could be sensitive to these movements (MSEC (2013). The drainage lines located to the east of the Angus Place East Area and the northern part of the Springvale proposed workings area that flow into Carne Creek could also experience the full range of predicted subsidence movements. The impact assessment undertaken by MSEC (2013), however, indicates these movements are unlikely to have a significant impact on the physical attributes of the creek or its drainages. As previous mining of the drainage lines does not appear to have resulted in any loss of surface water flows or adverse impacts, these are unlikely to occur when the proposed longwalls are extracted.

The existing workings at Springvale and Angus Place Collieries are overlain by 13 Shrub Swamps and 26 Hanging Swamps and their associated drainages (MSEC 2013). Surface impacts have been detected at four of the swamps (Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp) that were directly undermined. Goldney *et al.* (2010) investigated these impacts and concluded that those at Narrow Swamp North and South were mostly the result of mine water discharge, but mine subsidence ground movements may have had some lesser impacts. The impacts at the other two swamps were attributed to a combination of mine-induced subsidence, mine water discharge and erosion from nearby roads, although the relative importance of these could not be assessed. Changes in flows were reported along Kangaroo Creek after the extraction of Angus Place LW940, but no loss of surface water flows or adverse impacts on the other drainage lines were reported during previous mining (MSEC 2013). Past practices, such as discharge of large quantities of mine water and construction of various roads and access paths, have also resulted in impacts to some swamps and their drainages. Centennial has acknowledged this and developed management plans and a mine layout that would reduce the risk of future mining-related impacts. The measures outlined in Section 7.2.2.1 would minimise impacts on swamps and drainage lines overlying the Springvale and Angus Place Mine Extension Areas, none of which have been undermined previously. As previous mining of the drainage lines does not appear to have resulted in any loss of surface water flows or adverse impacts, the aquatic ecology of the drainages downstream of swamps is unlikely to be impacted significantly when the proposed longwalls are extracted.

7.5.3 Discharges

Three licenced discharge points (LDPs), two of which are associated with Springvale and the third with Angus Place Colliery (MPR 2010) can discharge mine water into Wolgan River in accordance with the EPLs of the two collieries, when there are operational issues with the SDWTS. The proposed mining at the two collieries is unlikely to have a significant effect on the instream ecology of the Wolgan River. The impacts of past and present mining are unknown. Mine water has not been discharged into Carne Creek. No mine water has been discharged into Wolgan River by Springvale since April 2010.

The Upper Coxs River catchment has already been degraded by the clearing of land for agriculture and grazing, mining operations, urban and industrial development and construction of impoundments. The reach of the river immediately above Lake Wallace receives inflows from two tributaries that have been impacted by mining, with Neubeck Creek receiving acidic mine drainage from exposed coal deposits and water pumped from a nearby underground mine site (Battaglia *et al.* 2005) and Sawyers Swamp Creek receiving inputs of various metals and acid due to seepage from the old open cut mine "Lidsdale Cut" and the base of the Sawyers Swamp Creek ash dam. The sewage treatment plant on Pipers Flat Creek, a relatively large tributary that flows into Coxs River just above the Wallerawang Power Station, is believed to be a source of high conductivity and phosphorus levels (Jones *et al.* 1989; Harris and Hillman 1991). The reach of Coxs River immediately below the confluences with these tributaries receives periodic inputs from five LDPs associated with Wallerawang Power Station. Lidsdale Siding, Pine Dale Coal Mine and Western Coal Services also have LDPs that discharge directly into the Coxs River (GHD 2013). The discharge of mine water make into the Coxs River could therefore potentially result in further degradation of the reach of the river between Springvale's LDP009 and Lake Wallace.

If the capacity of the SDWTS is not upgraded the discharge into the Coxs River catchment from all assessed mining operations is predicted to be between 4,500 ML/yr and 9,800 ML/yr until 2031 and between 500 ML/yr and 1,000 ML/yr thereafter (GHD 2013). If the capacity of the SDWTS is increased to 50 ML/d, the discharge into the Coxs River catchment is expected to be up to 9,800 ML/yr in 2015, to decline to 850 ML/yr in 2030 and be between 500 ML/yr and 1,500 ML/yr thereafter. The decline in discharges after 2015 is due to the decrease in the number of active mining operations. The licensed discharge from each source is predicted to peak at different times. As the predicted peak outflow from the Springvale Mine would occur after completion of other mining projects in the Coxs River catchment, the potential for cumulative impact is small.

7.5.4 Other Activities

Other activities taking place in Newnes State Forest, including tree logging, track construction, undergrowth clearing and burning, and recreational activities such as four-wheel driving and motor biking could potentially impact on the Wolgan River, Carne Creek, swamps and their drainage lines (Springvale Coal 2012b). These activities lead to the development of informal tracks which are susceptible to erosion. Runoff from such tracks could carry loose sediment into the watercourses and reduce the quality of the water. The magnitude and geographic extent of impacts arising from forestry and recreational activities is unknown and cannot therefore be assessed relative to that potentially due to mining activities.

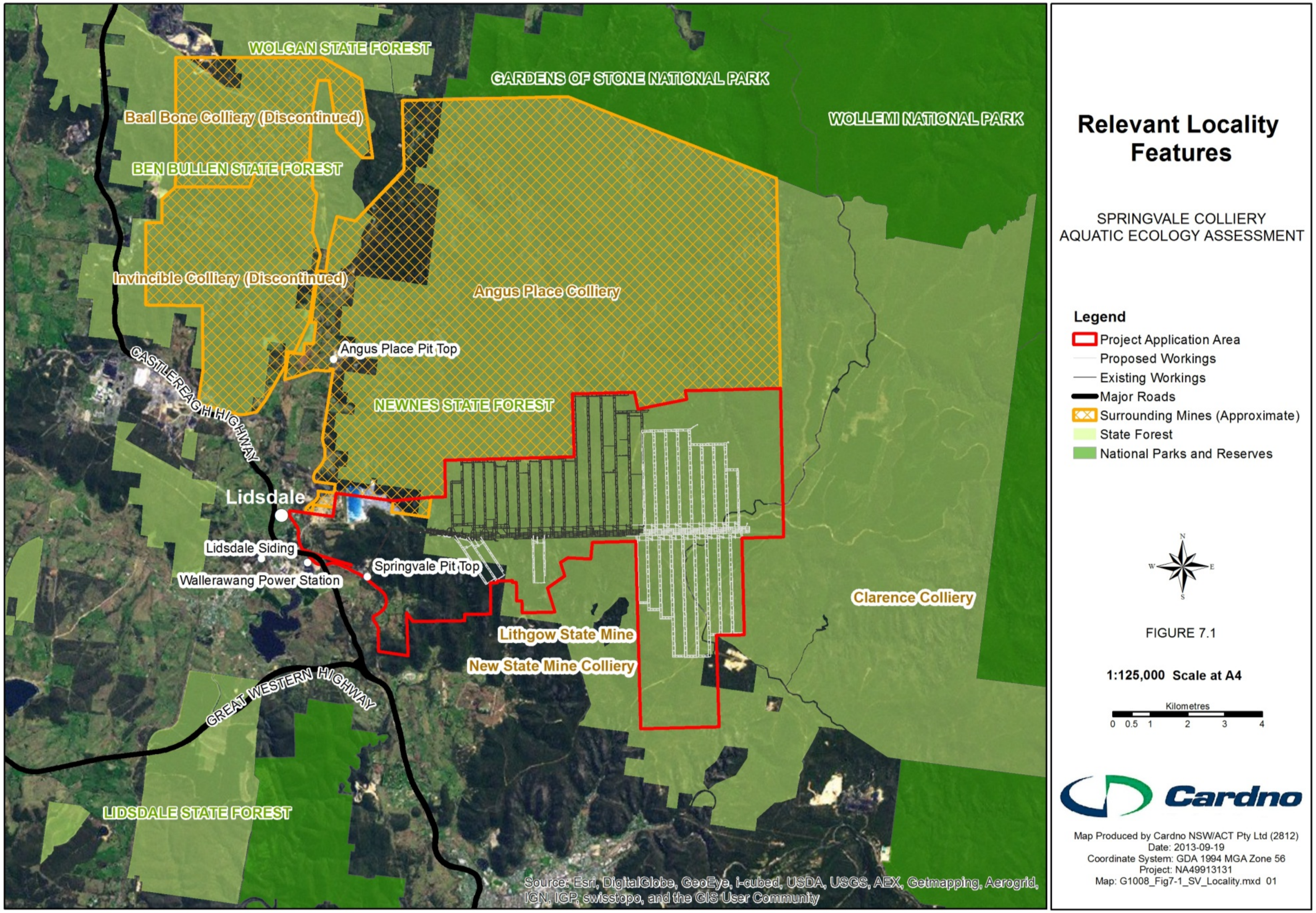

Figure 7-1 Project Application Area relative to other developments and national parks

8 Potential Impacts on Stygofauna and Management Measures

Stygofauna are threatened by activities that change the quality or quantity of groundwater, disrupt the connectivity between different aquifers and between aquifers and surface systems or remove soil pores. If stygofauna species with a limited geographic distribution occur in the Project Application Area, the disturbance of aquifers by mining operations could potentially result in local population extinctions, loss of genetic diversity and even species extinctions. In this section, the potential impacts of the various phases of the Project on the stygofauna associated with the aquifers that comprise the three groundwater systems that exist below the Project Application Area are described. The assessment of potential impacts on stygofauna arising from the Project is based on:

> The description of the works associated with the construction, operation, decommissioning and rehabilitation phases presented in Sections 7.1-7.4;

> The description of the stygofauna presented in Section 6 and MPR (2012c);

> Assessment of potential impacts on groundwater quantity and quality (RPS 2013b; Adhikary and Wilkins 2013).

As the information on likely occurrence of stygofauna in the Project Application Area is based on a pilot survey of only two of the six aquifers present and information on the distribution of stygofauna within NSW aquifers generally is sparse, the precautionary principle has been adopted. It has therefore been assumed that stygofauna are likely to occur in all the aquifers below the Project Application Area. The precautionary approach is considered to be justified as stygofauna have been recorded in fractured rock aquifers and are known to occur down to depths of at least 600 m (Serov *et al.* 2012). It is also in line with the philosophy of the Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities (DEC 2004). It is important to bear in mind that the assessment of potential impacts is hindered by our general lack of knowledge about stygofauna and natural changes in groundwater characteristics that occurred prior to mining.

The possibility of cumulative impacts on these assets arising due to multiple types of disturbances associated with the Project, extension of existing longwall operations and activities of others in the catchment is also addressed. There are no practical measures that could be used to avoid, minimise or manage such impacts.

8.1 Construction

8.1.1 Potential Impacts

Construction activities that take place in the vicinity of Shrub or Hanging Swamps could potentially interfere with the shallow perched aquifers that support the swamps. The stygofauna that inhabit the perched groundwater system could be impacted through:

> Discharge of groundwater to the surface and associated flooding of swamps and changes in the quality of surface water, including increased sediment load;

> Contamination resulting from inadvertent discharges of drilling muds/fluids, drilling additives, oils and lubricants into surface water within the swamps or their seepage into the aquifers;

> Greater sediment loads in infiltrated water as a result of erosion of areas around the borehole sites and along access roads where vegetation has been cleared.

The construction of dewatering boreholes and underground roadways are the activities most likely to impact on any stygofauna associated with the fractured rock aquifers within the deep groundwater system. The construction of dewatering bores could potentially expose stygofauna to changes in groundwater quality as a result of cross contamination of water within aquifers during or after drilling and contamination of aquifers by drilling muds/fluids or inputs of contaminants from the surface. The potential for cross contamination depends on the permeability of the strata and quantity of groundwater that may enter the borehole during drilling. The machinery used to construct underground roadways is likely to compact sediment, which could in turn reduce the size of interstitial spaces and voids in the underlying strata where stygofauna live. The vibrations emanating from machinery could also affect groundwater quality by mobilising fine sediment and disturb stygofauna.

8.1.2 Avoidance, Mitigation and Management Measures

Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any construction works in the vicinity of the swamps to prevent the input of sediment into the perched aquifer system during rainfall events.

The dewatering bores would be installed in the same manner as the existing bores using blind boring and mud rotary drilling methods and that they would then be cased and grouted along their entire lengths (RPS 2013b). These measures would prevent shallow aquifers from draining into deeper aquifers or underground, cross contamination of aquifers differing in water quality and minimise inflows to the bores during drilling. The installation of dewatering bores is consequently unlikely to have any significant impacts on groundwater resources or any associated stygofauna.

8.2 Mining Operations

8.2.1 Potential Impacts

8.2.1.1 Ground Movements

The extraction of coal from the proposed longwalls will result in vertical and horizontal movements of the rock and soil mass above the extracted coal seam, which may, in turn, affect groundwater systems. Physical impacts, such as fracturing of rock bars, drainage of rock pools, diversion of creek flows, tensile cracking and tensile/shear movement of near-surface strata, bending of strata and horizontal separation of bedding planes, could lead to:

> Redirection of sub-surface flows to the surface;

> Mixing of aquifers or groundwater with surface water;

> Changes in the characteristics of aquifer storages;

> Depressurisation of strata overlying extracted coal seams.

These, in turn, could lead to cross-aquifer contamination, mine water inflows and loss of groundwater resources. The chemical interaction between freshly broken rock faces and percolating groundwater could also change groundwater quality, through elevated iron and manganese levels. Sub-surface fractures resulting from subsidence can result in breaching of deep aquifers within the fractured zone and drainage of groundwater into mine workings, and changes in their storage capacity.

Changes in groundwater quantity (i.e. levels, pressures and fluxes) and quality, the physical disruption of aquifers, clogging of pore spaces by compaction and mobilisation of fine sediment activated by vibrations produced by mining equipment could potentially affect the distribution and composition of stygofauna.

Hydrogeological modelling has been used to predict the magnitude and spatial extent of depressurisation at the top of AQ6, AQ4 and the top of the Lithgow Seam, 2, 7 and 13 years after extraction of the proposed Springvale walls (RPS 2013b). The likely depressurisation has been expressed in terms of drawdown, that is, the drop in water level from its current position to the levels anticipated at the end of mining. The isolated drawdown at the base of AQ6 is expected to reach 5 m two years after extraction commences and increase to 10 m after 7 years and remain at that level until recovery commences. The drawdown at this level would be contained within the project boundary. The isolated drawdown at the top of AQ4 is expected to remain at 0.5 m until mining ceases in year 13. The water levels in the AQ6 and AQ4 units are not expected to recover to pre-mining levels. The largest decline will occur at the top of the Lithgow Seam, with isolated drawdown predicted to increase from 50 m two years after mining commences to 150 m after 7 years and remain at this level until mining ceases. The magnitude of the drawdown would, however, be considerably smaller at the eastern and northern boundary of the Project Application Area, particularly two years after mining commences. Recovery of this aquifer unit is expected to commence as soon as mining ceases with the water level exceeding that of pre-mining level after 120 years.

The hydrological modelling undertaken by Adhikary and Wilkins (2013) indicates mining would have the following effects:

> The aquifer containing the Lithgow seam (AQ1) would become unsaturated above the longwall panels, but once mining ceases would be refilled within about 50 years;

> A 15-70 m thick unsaturated region would develop in the aquifer (AQ3) below the Mt York claystone layer, this would refill partially when mining ceases, but would take 350 years to reach steady state;

> There would be a slight (3%) desaturation of the aquifers (AQ5 and AQ6) above the Mt York claystone, which would persist after mining ceases;

> The saturation of the aquifer that contains sandstone with laminated siltstone and Middle River Coal (AQ2) and that located in the Banks Wall Sandstone (AQ4) is not expected to change, but pore pressure will change.

This implies that stygofauna associated with different aquifers will be subject to different forms of disturbance, with impacts being greater on those associated with deep aquifers, assuming they support such animals. Loss of groundwater to deeper aquifers is not expected to occur as the perched aquifer that supports the swamps is hydraulically independent of the underlying groundwater systems.

8.2.1.2 Dewatering of Boreholes

Mining will increase the rate of mine water inflow from the current 300 l/s to around 400 l/s to 500 l/s between 2020 and 2032 (Adhikary and Wilkins 2013). The conductivity of the inflows is expected to remain similar to that at present (i.e. 700 to 1000 µS/cm) (RPS 2013b). This water will need to be removed via dewatering boreholes. The pumping of groundwater from the underground workings to the surface via dewatering boreholes causes significant and rapid reductions in the level of the water table (Serov *et al.* 2012). Dewatering would consequently result in direct loss of any stygofauna inhabiting the borehole; reduce the volume of saturated sediments and thus the amount of potential habitat available to any remaining stygofauna. Dewatering could also affect the quality of the water within inter-connected aquifers and the permeability of the rock mass.

8.2.2 Avoidance, Mitigation and Management Measures

During the extraction of the longwalls the level and quality of the groundwater associated with the aquifers likely to be impacted by subsidence should be monitored by suitably qualified personnel.

A Trigger Action Response Plan for groundwater should be developed in consultation with the NSW Office of Water. If the changes in quality and quantity of groundwater and surface water that occur during or after extraction of the longwalls are greater than expected, an independent hydrogeologist should be asked to review the monitoring data and determine whether a response action needs to be implemented.

8.3 Decommissioning and Rehabilitation Phases

8.3.1 Potential Impacts

The dewatering boreholes on Newnes Plateau will be decommissioned as soon as practicable after they are no longer required (Golder Associates 2013). The decommissioning of dewatering boreholes is unlikely to have any impact on stygofauna as they would be permanently sealed by full grouting from the top to the bottom of the bore, in accordance with the Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee 2011).

Rehabilitation works such as clearing and grading of land, spreading of topsoil, seeding and/or revegetation, application of fertilisers and control of weeds are unlikely to impact on any stygofauna that may exist in the shallow regional groundwater or deep confined groundwater system, but could affect those associated with the shallow perched aquifer system. During rainfall events, there is a possibility of stygofauna associated with the perched groundwater system being impacted by runoff laden with sediment and contaminants such as fertilisers and herbicides. This is because this groundwater system is situated within metres of the land surface and is derived from excess rainfall that is unable to infiltrate into the deeper groundwater systems due to the presence of less permeable underlying rock layers (RPS 2013b).

When mining ceases the impacts on the deeper aquifers and any stygofauna inhabiting them will persist for some time. The hydrogeological modelling undertaken by Adhikary and Wilkins (2013) indicates:

> The unsaturated region in the aquifer containing the Lithgow seam would be refilled within about 50 years.

> The aquifer below the Mt York claystone layer would refill partially, but take 350 years to reach a steady state;

> The loss of water from the aquifers above the Mt York claystone would persist after mining ceases.

8.3.2 Avoidance, Mitigation and Management Measures

No practical mitigation measures can be recommended for impacts that may arise during the decommissioning phase.

Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any rehabilitation construction works in the vicinity of the swamps to prevent the input of sediment into the perched aquifer system during rainfall events.

8.4 Cumulative Impacts

The NSW Office of Water database of registered bores and wells in NSW indicates there are two registered bores within 5 km and 112 registered bores within 10 km of the centre-point of the Project (RPS 2013b). One of the nearby bores targets the AQ1 aquifer, but no information is available on the depth of the second bore. The bores located within 10 km of the Project Area target the AQ1, AQ2, AQ3 and AQ4 aquifers and intervening semi-permeable layer. A large proportion of these are monitoring bores that target AQ4 in the Banks Wall Sandstone. Six bores target the Lithgow Seam, one of which extracts water for power generation. This suggests there is possibility of cumulative impacts on some aquifers occurring as a result of drawdown from multiple bores. Information on the extent of drawdown relative to the volume of the aquifer and occurrence of stygofauna is required to determine whether the impact would be significant.

Hydrogeological modelling has also been used to predict the cumulative magnitude and spatial extent of drawdown due to all the neighbouring mines and the likely rate of recovery of aquifer units (RPS 2013b). The cumulative drawdown at the base of AQ6 is expected to reach 5 m two years after extraction commences and increase to 10 m after 7 years. The drawdown at this level would be contained within the Project Application Area boundary. The cumulative drawdown at the top of AQ4 is expected to remain at 0.5 m until mining ceases in year 13, when it would increase to 5 m, to the east of the Project. The water levels in the AQ6 and AQ4 units are not expected to recover to pre-mining levels. The largest decline will occur at the top of the Lithgow Seam, with cumulative drawdown predicted to increase from 50 m two years after mining of the proposed workings commences to 150 m after 7 years and remain at this level until mining of the proposed workings ceases. The magnitude of the drawdown would, however, be considerably smaller at the eastern and northern boundaries of the Project Area, particularly two years after mining commences. Recovery of this aquifer unit is expected to commence as soon as mining ceases with the water level exceeding that of pre-mining level after 120 years. This means the change in groundwater levels and effects on stygofauna due to all the neighbouring mines would be the same as that due solely to the Springvale Mine Extension.

Stygofauna associated with the perched surficial groundwater system could have been impacted by past mining-related activities, including discharge of mine water and construction of roads and access paths. They could also have been impacted by other activities that take place in Newnes State Forest, including tree logging, track construction, undergrowth clearing and burning, and recreational activities such as four-wheel driving and motor biking. All of these activities can increase the potential for erosion and sediment-laden runoff entering the shallow aquifer during rainfall events. Because there is insufficient information available on stygofauna distribution and abundance in general it is not possible to determine the likelihood or magnitude of any impacts on them.

9 Conclusions

The information available on instream ecology and the aquatic ecology of the drainages downstream of the swamps and proposed works indicates the Project would not have any significant impacts on aquatic habitats, aquatic flora or aquatic fauna, provided that the appropriate measures to avoid, minimise and manage impacts associated with the construction, operation, rehabilitation and decommissioning phases are implemented. The discharge of mine water make will result in more rapid and sustained changes in salinity than occur naturally. Although the salinity level in the Coxs River would be below that likely to have adverse effects on aquatic biota, the rapidity and sustained nature of the changes may be problematic. The assessment of potential impacts on stygofauna is limited by the lack of information on their occurrence in the aquifers within the Project area, their response to environmental perturbations and likely conservation significance.

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APPENDIX A

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CR1 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			28/10/2010	9/06/2011	2/11/2011	31/05/2012	21/11/12	
Coleoptera	Dytiscidae	Diving Beetles	X	X	X	X	X	2
	Gyrinidae	Whirligig Beetles		X		X	X	4
	Hydraenidae	Scavenger Water Beetles					X	3
	Hydrochidae	Minute Rove Beetles					X	4
	Hydrophilidae	Scavenger Water Beetles	X		X	X	X	2
	Scirtidae	Marsh Beetles	X			X		6
Diptera	Ceratopogonidae	Biting Midges			X		X	4
	Chironominae	Bloodworms	X	X	X		X	3
	Orthocladiinae	Bloodworms	X	X		X	X	4
	Tanypodinae	Bloodworms		X	X	X	X	4
	Culicidae	Mosquitoes	X				X	1
	Dixidae	Mensicus Midges		X	X	X	X	7
	Simuliidae	Black Flies	X	X		X	X	5
	Tipulidae	Crane Flies		X		X	X	5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	5
	Caenidae	Mayflies		X	X			4
	Leptophlebiidae	Mayflies	X	X	X	X	X	8
Hemiptera	Corixidae	Lesser Water Boatmen	X	X	X	X	X	2
	Hydrometridae	Water Measurers					X	3
	Notonectidae	Backswimmers	X	X	X	X	X	1
	Veliidae	Small Water Striders	X		X		X	3
Odonata	Aeshnidae	Dragonflies			X	X	X	4
	Hemicorduliidae	Dragonflies		X	X	X	X	5
	Coenagrionidae	Damselflies		X				2
	Lestidae	Damselflies	X				X	1
	Synlestidae	Damselflies	X		X	X	X	7
Plecoptera	Gripopterygidae	Stoneflies	X	X		X		8
	Notonemouridae	Stoneflies	X	X	X	X	X	6

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			28/10/2010	9/06/2011	2/11/2011	31/05/2012	21/11/12	
Trichoptera	Hydrobiosidae	Caddis Flies	X		X	X	X	8
	Hydroptilidae	Caddis Flies	X	X	X	X	X	4
	Leptoceridae	Caddis Flies	X	X	X	X	X	6
Non-Insects	Hydracarina	Freshwater Mites	X					6
	Cladocera	Water Fleas	X			X	X	1
	Cyclopidae	Copepods			X	X	X	*
	Parastacidae	Freshwater Crayfish/Yabbie	X		X		X	4
	Ostracoda	Seed Shrimps	X		X	X	X	*
	Oligochaeta	Freshwater Worms	X	X	X	X	X	2
	Ancylidae	Freshwater Limpets				X	X	4
	Lymnaeidae	Freshwater Snails		X		X	X	1
	Physidae	Freshwater Snails	X			X		1
	Planorbidae	Freshwater Snails	X	X	X			2
	Dugesiidae	Flatworms					X	2

APPENDIX B

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CR2 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			7/06/2010	27/10/2010	9/06/2011	1/11/2011	29/05/2012	22/11/12	
Coleoptera	Dytiscidae	Diving Beetles	X	X		X	X	X	2
	Elmidae	Riffle Beetles				X			7
	Gyrinidae	Whirligig Beetles		X	X	X	X		4
	Hydraenidae	Scavenger Water Beetles	X					X	3
	Hydrophilidae	Scavenger Water Beetles						X	2
Diptera	Ceratopogonidae	Biting Midges		X		X	X	X	4
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms	X		X	X	X	X	4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Dixidae	Mensicus Midges						X	7
	Simuliidae	Black Flies	X	X	X	X	X	X	5
	Stratiomyidae	Soldier Flies	X	X					2
	Tipulidae	Crane Flies	X	X	X	X	X	X	5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	X	5
	Caenidae	Mayflies	X	X	X	X	X	X	4
	Leptophlebiidae	Mayflies		X	X	X	X	X	8
Hemiptera	Corixidae	Lesser Water Boatmen	X	X	X	X	X	X	2
	Hydrometridae	Water Measurers						X	3
	Notonectidae	Backswimmers	X	X		X	X	X	1
	Veliidae	Small Water Striders	X	X			X		3
Lepidoptera	Pyralidae	Moths	X	X	X				3
Mecoptera	Nannochoristidae	Scorpionflies						X	9
Odonata	Hemicorduliidae	Dragonflies	X						5
	Libellulidae	Dragonflies	X						4
	Telephlebiidae	Dragonflies						X	9
	Coenagrionidae	Damselflies	X	X					2
	Synlestidae	Damselflies				X	X	X	7
Plecoptera	Gripopterygidae	Stoneflies		X		X			8

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			7/06/2010	27/10/2010	9/06/2011	1/11/2011	29/05/2012	22/11/12	
	Notonemouridae	Stoneflies	X	X	X	X	X		6
Trichoptera	Hydrobiosidae	Caddis Flies		X	X	X		X	8
	Hydropsychidae	Caddis Flies		X	X			X	6
	Hydroptilidae	Caddis Flies	X		X		X	X	4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Philorheithridae	Caddis Flies	X	X	X		X	X	8
Non-Insects	Collembola	Springtails	X						
	Cyclopidae	Copepods	X	X			X		*
	Atyidae	Freshwater Shrimp			X		X	X	3
	Parastacidae	Freshwater Crayfish/Yabbies	X	X		X	X	X	4
	Ostracoda	Seed Shrimps	X					X	*
	Oligochaeta	Freshwater Worms	X	X			X	X	2
	Corbiculidae	Basket Shells		X					4
	Sphaeriidae	Pea Shells	X			X		X	5
	Ancylidae	Freshwater Limpets			X	X			4
	Lymnaeidae	Freshwater Snails		X	X	X			1
	Physidae	Freshwater Snails	X	X		X		X	1
	Planorbidae	Freshwater Snails		X		X			2
	Nemertea	Nemerteans	X						

Springvale Mine Extension Project

APPENDIX C

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CR4 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			27/10/2010	8/06/2011	1/11/2011	30/05/2012	20/11/12	
Coleoptera	Dytiscidae	Diving Beetles		X		X	X	2
	Gyrinidae	Whirligig Beetles			X			4
	Hydraenidae	Scavenger Water Beetles					X	3
	Hydrophilidae	Scavenger Water Beetles					X	2
Diptera	Ceratopogonidae	Biting Midges	X				X	4
	Chironominae	Bloodworms	X				X	3
	Orthocladiinae	Bloodworms	X		X	X	X	4
	Tanypodinae	Bloodworms	X		X		X	4
	Simuliidae	Black Flies	X	X	X	X	X	5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	5
	Caenidae	Mayflies	X		X	X	X	4
	Leptophlebiidae	Mayflies	X	X		X	X	8
Hemiptera	Corixidae	Lesser Water Boatmen	X	X		X	X	2
	Notonectidae	Backswimmers		X			X	1
	Veliidae	Small Water Striders			X		X	3
Lepidoptera	Pyralidae	Moths		X	X	X		3
Odonata	Aeshnidae	Dragonflies				X	X	4
	Gomphidae	Dragonflies	X	X	X	X	X	5
	Hemicorduliidae	Dragonflies	X	X	X		X	5
	Telephlebiidae	Dragonflies			X		X	9
	Coenagrionidae	Damselflies	X	X	X		X	2
	Lestidae	Damselflies					X	1
	Megapodagrionidae	Damselflies	X		X		X	5
	Synlestidae	Damselflies	X		X		X	7
Plecoptera	Gripopterygidae	Stoneflies	X		X			8
	Notonemouridae	Stoneflies				X	X	6
Trichoptera	Calamoceratidae	Caddis Flies		X	X			7

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			27/10/2010	8/06/2011	1/11/2011	30/05/2012	20/11/12	
	Ecnomidae	Caddis Flies		X	X	X		4
	Hydrobiosidae	Caddis Flies		X		X		8
	Hydropsychidae	Caddis Flies		X		X		6
	Hydroptilidae	Caddis Flies	X	X		X	X	4
	Leptoceridae	Caddis Flies	X	X	X	X	X	6
Non-Insects	Hydracarina	Freshwater Mites				X		6
	Cladocera	Water Fleas					X	1
	Cyclopidae	Copepods	X			X	X	*
	Atyidae	Freshwater Shrimp	X			X		3
	Parastacidae	Freshwater Crayfish/Yabbie		X	X		X	4
	Ostracoda	Seed Shrimps	X					*
	Oligochaeta	Freshwater Worms		X	X		X	2
	Sphaeriidae	Pea Shells	X	X	X		X	5
	Ancylidae	Freshwater Limpets	X					4
	Lymnaeidae	Freshwater Snails	X				X	1
	Physidae	Freshwater Snails	X	X	X		X	1
	Planorbidae	Freshwater Snails	X	X		X		2
	Temnocephalidae	Temnocephalans					X	
	Dugesiidae	Flatworms	X					2

Springvale Mine Extension Project

APPENDIX D
MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CR5 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			8/06/2010	28/10/2010	7/06/2011	2/11/2011	30/05/2012	19/11/2012	
Coleoptera	Dytiscidae	Diving Beetles			X	X		X	2
	Hydrophilidae	Scavenger Water Beetles		X	X				2
Diptera	Chaoboridae	Phantom Midges			X	X			2
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms	X	X		X	X	X	4
	Tanypodinae	Bloodworms	X	X	X			X	4
	Simuliidae	Black Flies	X		X			X	5
Ephemoptera	Baetidae	Mayflies			X				5
	Caenidae	Mayflies	X	X	X	X	X	X	4
Hemiptera	Corixidae	Lesser Water Boatmen	X	X	X	X	X	X	2
	Notonectidae	Backswimmers				X		X	1
Hemiptera	Veliidae	Small Water Striders	X						3
Odonata	Hemicorduliidae	Dragonflies		X	X	X	X		5
	Coenagrionidae	Damselflies	X	X		X		X	2
Trichoptera	Calamoceratidae	Caddis Flies		X					7
	Ecnomidae	Caddis Flies	X	X			X	X	4
	Hydropsychidae	Caddis Flies	X		X	X	X		6
	Hydroptilidae	Caddis Flies			X		X		4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
Non-Insects	Hydracarina	Freshwater Mites	X	X	X	X		X	6
	Cladocera	Water Fleas			X	X		X	1
	Centropagidae	Copepods			X		X	X	*
	Cyclopidae	Copepods	X	X		X			*
	Atyidae	Freshwater Shrimp	X	X		X	X	X	3
	Parastacidae	Freshwater Crayfish/Yabbie					X		4
	Ostracoda	Seed Shrimps	X	X		X	X	X	*
	Glossiphoniidae	Leeches					X		1

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			8/06/2010	28/10/2010	7/06/2011	2/11/2011	30/05/2012	19/11/2012	
	Oligochaeta	Freshwater Worms	X	X	X	X	X	X	2
	Hyriidae	Hydra	X			X			3
	Sphaeriidae	Pea Shells	X					X	5
	Ancylidae	Freshwater Limpets	X						4
	Lymnaeidae	Freshwater Snails		X			X		1
	Physidae	Freshwater Snails		X	X	X	X	X	1
	Planorbidae	Freshwater Snails			X				2
	Dugesiidae	Flatworms		X		X		X	2

Springvale Mine Extension Project

APPENDIX E

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE WRup AND THEIR SIGNAL2 SCORES

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Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	8/11/2010	25/05/2011	15/11/2011	23/05/2012	27/11/2012	
Coleoptera	Dytiscidae	Diving Beetles	X	X	X	X	X	X	2
	Elmidae	Riffle Beetles						X	7
	Gyrinidae	Whirligig Beetles	X	X	X		X	X	4
	Hydraenidae	Scavenger Water Beetles	X						3
	Hydrophilidae	Scavenger Water Beetles	X						2
	Scirtidae	Marsh Beetles					X		6
Diptera	Ceratopogonidae	Biting Midges	X	X	X	X	X	X	4
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms						X	4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Culicidae	Mosquitoes		X	X	X			1
	Dixidae	Mensicus Midges	X						7
	Simuliidae	Black Flies						X	5
	Tipulidae	Crane Flies					X		5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	X	5
	Leptophlebiidae	Mayflies		X	X	X	X	X	8
Hemiptera	Corixidae	Lesser Water Boatmen	X	X	X	X	X	X	2
	Notonectidae	Backswimmers	X	X	X	X	X	X	1
	Veliidae	Small Water Striders		X		X			3
Odonata	Aeshnidae	Dragonflies	X	X	X				4

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	8/11/2010	25/05/2011	15/11/2011	23/05/2012	27/11/2012	
	Gomphidae	Dragonflies				X			5
	Hemicorduliidae	Dragonflies	X	X	X	X	X	X	5
	Libellulidae	Dragonflies	X	X					4
	Synthemistidae	Dragonflies	X		X		X	X	5
	Telephlebiidae	Dragonflies	X				X	X	9
	Coenagrionidae	Damselflies		X	X	X			2
	Lestidae	Damselflies	X	X	X	X	X	X	1
	Megapodagrionidae	Damselflies				X		X	5
	Synlestidae	Damselflies			X	X	X	X	7
Plecoptera	Gripopterygidae	Stoneflies					X		8
	Notonemouridae	Stoneflies				X		X	6
Trichoptera	Ecnomidae	Caddis Flies		X	X		X	X	4
	Hydropsychidae	Caddis Flies						X	6
Trichoptera	Hydroptilidae	Caddis Flies			X				4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Philorheithridae	Caddis Flies					X		8
	Polycentropodidae	Caddis Flies				X			7
Non-Insects	Hydracarina	Freshwater Mites				X			6
	Cladocera	Water Fleas				X			1
	Cyclopidae	Copepods			X		X		*
	Phreatoicidae	Isopods						X	4

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	8/11/2010	25/05/2011	15/11/2011	23/05/2012	27/11/2012	
	Oligochaeta	Freshwater Worms	X			X		X	2
	Dugesiidae	Flatworms						X	2

Springvale Mine Extension Project

APPENDIX F

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE WRmd AND THEIR SIGNAL2 SCORES

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Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/11/2010	23/05/2011	16/11/2011	21/05/2012	26/11/2012	9/11/2010	
Coleoptera	Dytiscidae	Diving Beetles	X	X	X	X	X	X	2
	Elmidae	Riffle Beetles				X	X		7
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	X	4
	Hydrophilidae	Scavenger Water Beetles		X	X	X	X		2
	Psephenidae	Water Pennies			X				6
	Scirtidae	Marsh Beetles		X		X	X		6
Diptera	Ceratopogonidae	Biting Midges	X	X	X	X	X	X	4
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms		X	X	X			4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Empididae?	Dance Flies	X					X	5
	Simuliidae	Black Flies	X			X	X	X	5
	Tipulidae	Crane Flies	X	X	X			X	5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	X	5
	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
	Oniscigastridae	Mayflies	X		X			X	8
Hemiptera	Notonectidae	Backswimmers				X			1
Odonata	Gomphidae	Dragonflies	X	X				X	5
	Synthemistidae	Dragonflies	X	X	X	X	X	X	5
	Telephlebiidae	Dragonflies	X	X	X	X	X	X	9
	Synlestidae	Damselflies		X	X	X	X		7

Order	Taxon	Common name	Survey Date 9/11/2010	23/05/2011	16/11/2011	21/05/2012	26/11/2012	9/11/2010	SIGNAL2 Score
Plecoptera	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8
Trichoptera	Atriplectididae	Caddis Flies	X					X	7
	Conoesucidae	Caddis Flies			X	X			7
	Helicopsychidae	Caddis Flies				X			8
	Hydrobiosidae	Caddis Flies				X	X		8
	Hydroptilidae	Caddis Flies		X		X			4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Philorheithridae	Caddis Flies	X	X	X	X	X	X	8
	Polycentropodidae	Caddis Flies	X					X	7
Non-Insects	Oligochaeta	Freshwater Worms	X	X		X	X	X	2
	Sphaeriidae	Pea Shells	X	X	X	X		X	5
	Dugesiidae	Flatworms					X		2

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APPENDIX G

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE WRdn AND THEIR SIGNAL2 SCORES

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Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	9/11/2010	26/05/2011	17/11/2011	24/05/2012	27/11/2012	
Coleoptera	Dytiscidae	Diving Beetles	X	X	X	X	X	X	2
	Elmidae	Riffle Beetles		X	X	X		X	7
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	X	4
	Hydrophilidae	Scavenger Water Beetles		X		X			2
	Noteridae	Burrowing Water Beetles			X	X			4
	Scirtidae	Marsh Beetles			X		X		6
Diptera	Athericidae	Flies					X	X	8
	Ceratopogonidae	Biting Midges	X	X	X	X		X	4
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms	X		X	X	X		4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Culicidae	Mosquitoes	X						1
	Simuliidae	Black Flies		X	X		X		5
	Tipulidae	Crane Flies	X	X	X	X	X	X	5
Ephemeroptera	Baetidae	Mayflies	X	X	X	X	X	X	5
	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
	Oniscigastridae	Mayflies	X	X	X				8
Hemiptera	Notonectidae	Backswimmers	X	X		X	X		1
	Veliidae	Small Water Striders		X				X	3
Mecoptera	Nannochoristidae	Scorpionflies						X	9
Megaloptera	Cordyalidae	Dobsonflies			X				7

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	9/11/2010	26/05/2011	17/11/2011	24/05/2012	27/11/2012	
Odonata	Gomphidae	Dragonflies	X						5
	Hemicorduliidae	Dragonflies		X					5
	Synthemistidae	Dragonflies	X	X	X	X	X	X	5
	Megapodagrionidae	Damselflies	X	X					5
	Synlestidae	Damselflies	X	X	X	X	X	X	7
Plecoptera	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8
	Notonemouridae	Stoneflies					X		6
Trichoptera	Atriplectididae	Caddis Flies			X	X		X	7
	Calamoceratidae	Caddis Flies						X	7
	Helicopsychidae	Caddis Flies		X					8
	Hydrobiosidae	Caddis Flies		X	X		X	X	8
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Philorheithridae	Caddis Flies			X			X	8
	Polycentropodidae	Caddis Flies				X		X	7
Non-Insects	Cyclopidae	Copepods	X						*
	Ostracoda	Seed Shrimps	X						*
	Oligochaeta	Freshwater Worms		X	X	X			2
	Sphaeriidae	Pea Shells		X			X		5

Springvale Mine Extension Project

APPENDIX H

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CCXdn AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date		SIGNAL2 Score
			7/06/2012	28/11/2012	
Coleoptera	Dytiscidae	Diving Beetles		X	2
	Elmidae	Riffle Beetles	X	X	7
	Gyrinidae	Whirligig Beetles	X	X	4
	Scirtidae	Marsh Beetles	X	X	6
Diptera	Chironominae	Bloodworms	X	X	3
	Orthocladiinae	Bloodworms		X	4
	Tanypodinae	Bloodworms	X	X	4
	Simuliidae	Black Flies	X	X	5
	Tipulidae	Crane Flies	X		5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	8
	Oniscigastridae	Mayflies		X	8
Odonata	Synthemistidae	Dragonflies	X	X	5
	Telephlebiidae	Dragonflies	X	X	9
Plecoptera	Austroperlidae	Stoneflies	X	X	10
	Gripopterygidae	Stoneflies	X	X	8
	Notonemouridae	Stoneflies		X	6
Trichoptera	Calocidae/Helicophidae	Caddis Flies	X	X	9
	Ecnomidae	Caddis Flies	X	X	4
	Helicopsychidae	Caddis Flies	X		8
	Hydrobiosidae	Caddis Flies	X	X	8
	Hydropsychidae	Caddis Flies		X	6
	Leptoceridae	Caddis Flies	X	X	6
	Philorheithridae	Caddis Flies	X	X	8
Non-Insects	Hydracarina	Freshwater Mites	X	X	6
	Oligochaeta	Freshwater Worms		X	2

Springvale Mine Extension Project

APPENDIX I

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CC1 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012	
Coleoptera	Dytiscidae	Diving Beetles		X	X	X	X		2
	Elmidae	Riffle Beetles						X	7
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	X	4
	Psephenidae	Water Pennies						X	6
	Scirtidae	Marsh Beetles	X					X	**6**
Diptera	Ceratopogonidae	Biting Midges	X	X	X	X	X	X	4
	Chironominae	Bloodworms	X	X	X	X	X		3
	Orthocladiinae	Bloodworms	X			X		X	4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Simuliidae	Black Flies		X			X	X	**2**
	Sciomyzidae?	Marsh Flies			X				**5**
	Tipulidae	Crane Flies	X	X	X	X		X	**5**
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
Mecoptera	Nannochoristidae	Scorpionflies				X	X		5
Odonata	Synthemistidae	Dragonflies	X		X	X	X	X	5
	Telephlebiidae	Dragonflies		X	X	X	X	X	9
Plecoptera	Austroperlidae	Stoneflies	X	X					10
	Eustheniidae	Stoneflies						X	10
	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8
	Notonemouridae	Stoneflies						X	6
Trichoptera	Calocidae/Helicophidae	Caddis Flies		X	X			X	9

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012	
	Ecnomidae	Caddis Flies		X	X	X	X	X	4
	Hydrobiosidae	Caddis Flies		X		X		X	8
	Hydroptilidae	Caddis Flies			X	X			4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Odontoceridae	Caddis Flies				X			7
	Philorheithridae	Caddis Flies	X						8
	Polycentropodidae	Caddis Flies					X		7
Non-Insects	Hydracarina	Freshwater Mites		X		X	X	X	6
	Parastacidae	Freshwater Crayfish/Yabbie						X	4
	Oligochaeta	Freshwater Worms	X	X	X	X	X		2
	Gordioidea	Horsehair Worms		X		X			6

Springvale Mine Extension Project

APPENDIX J

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CC2 AND THEIR SIGNAL2 SCORES

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Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012	
Coleoptera	Elmidae	Riffle Beetles				X	X	X	**7**
	Gyrinidae	Whirligig Beetles			X	X	X	X	4
	Scirtidae	Marsh Beetles	X	X		X		X	**6**
Diptera	Ceratopogonidae	Biting Midges					X	X	**4**
	Chironominae	Bloodworms	X		X	X	X		**3**
	Orthocladiinae	Bloodworms	X			X	X		**4**
	Tanypodinae	Bloodworms	X		X	X	X	X	**4**
	Simuliidae	Black Flies	X		X	X	X	X	**5**
	Tipulidae	Crane Flies	X	X	X	X	X	X	**5**
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
Mecoptera	Nannochoristidae	Scorpionflies						X	9
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	X	2
	Telephlebiidae	Dragonflies	X	X	X	X		X	9
Plecoptera	Austroperlidae	Stoneflies						X	10
	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8
Trichoptera	Calocidae/Helicophidae	Caddis Flies				X			9
	Ecnomidae	Caddis Flies	X		X		X	X	4
	Helicophidae	Caddis Flies						X	10
	Hydrobiosidae	Caddis Flies					X		8
	Hydropsychidae	Caddis Flies		X	X		X	X	6
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			10/06/2010	8/11/2010	25/05/2011	14/11/2011	22/05/2012	28/11/2012	
	Philorheithridae	Caddis Flies	X	X	X	X	X	X	8
Non-Insects	Parastacidae	Freshwater Crayfish/Yabbie					X		4
	Oligochaeta	Freshwater Worms	X	X		X	X		2

Springvale Mine Extension Project

APPENDIX K

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CC3 AND THEIR SIGNAL2 SCORES

Cardno
Shaping the Future

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			9/06/2010	8/11/2010	25/05/2011	15/11/2011	22/05/2012	28/11/2012	
Coleoptera	Dytiscidae	Diving Beetles				X	X	X	2
	Elmidae	Riffle Beetles						X	7
	Gyrinidae	Whirligig Beetles		X	X	X	X	X	4
	Scirtidae	Marsh Beetles		X	X	X			6
Diptera	Ceratopogonidae	Biting Midges		X	X	X	X		4
	Chironominae	Bloodworms		X	X	X	X	X	3
	Orthocladiinae	Bloodworms		X	X	X		X	4
	Tanypodinae	Bloodworms		X	X	X	X	X	4
	Empididae?	Dance Flies			X				5
	Simuliidae	Black Flies	X		X	X	X		5
	Tipulidae	Crane Flies	X	X	X	X	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
Hemiptera	Notonectidae	Backswimmers						X	1
	Veliidae	Small Water Striders		X					3
Lepidoptera	Pyralidae	Moths	X						3
Mecoptera	Nannochoristidae	Scorpionflies						X	9
Megaloptera	Cordyalidae	Dobsonflies		X				X	7
Neuroptera	Neurorthidae	Lacewings		X					9
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	X	5
	Telephlebiidae	Dragonflies		X		X	X	X	9
Plecoptera	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8

Order	Taxon	Common name	Survey Date 9/06/2010	8/11/2010	25/05/2011	15/11/2011	22/05/2012	28/11/2012	SIGNAL2 Score
Trichoptera	Ecnomidae	Caddis Flies		X		X		X	4
	Hydropsychidae	Caddis Flies	X	X	X	X	X	X	6
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Philorheithridae	Caddis Flies	X		X		X		8
	Polycentropodidae	Caddis Flies						X	7
Non-Insects	Cyclopidae	Copepods						X	
	Parastacidae	Freshwater Crayfish/Yabbie			X		X	X	4
	Phreatoicidae	Isopods						X	4
	Oligochaeta	Freshwater Worms		X	X		X	X	2
	Gordioidea	Horsehair Worms			X				6

Springvale Mine Extension Project

APPENDIX L

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CC4 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date						SIGNAL2 Score
			10/06/2010	9/11/2010	26/05/2011	15/11/2011	22/05/2012	29/11/2012	
Coleoptera	Dytiscidae	Diving Beetles		X				X	2
	Elmidae	Riffle Beetles		X					7
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	X	4
	Scirtidae	Marsh Beetles	X			X		X	6
Diptera	Ceratopogonidae	Biting Midges	X	X	X			X	4
	Chironominae	Bloodworms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodworms	X		X	X	X	X	4
	Tanypodinae	Bloodworms	X	X	X	X	X	X	4
	Empididae?	Dance Flies			X				5
	Simuliidae	Black Flies		X	X	X	X	X	5
	Tipulidae	Crane Flies		X		X	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	X	8
Hemiptera	Notonectidae	Backswimmers						X	1
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	X	5
	Telephlebiidae	Dragonflies		X	X	X	X	X	9
	Megapodagrionidae	Damselflies		X	X				5
Plecoptera	Austroperlidae	Stoneflies	X						10
	Gripopterygidae	Stoneflies	X	X	X	X	X	X	8
Trichoptera	Calocidae/Helicophidae	Caddis Flies		X	X	X		X	9
	Conoesucidae	Caddis Flies						X	7
	Ecnomidae	Caddis Flies		X			X		4

Order	Taxon	Common name	Survey Date 10/06/2010	9/11/2010	26/05/2011	15/11/2011	22/05/2012	29/11/2012	SIGNAL2 Score
	Helicophidae	Caddis Flies					X	X	10
	Hydrobiosidae	Caddis Flies					X	X	8
	Hydropsychidae	Caddis Flies				X		X	6
	Hydroptilidae	Caddis Flies				X			4
	Leptoceridae	Caddis Flies	X	X	X	X	X	X	6
	Odontoceridae	Caddis Flies			X			X	7
	Philorheithridae	Caddis Flies	X			X	X	X	8
	Polycentropodidae	Caddis Flies				X			7
Non-Insects	Hydracarina	Freshwater Mites				X			6
	Parastacidae	Freshwater Crayfish/Yabbie		X		X			4
	Oligochaeta	Freshwater Worms	X	X		X			2
	Gordioidea	Horsehair Worms		X					6

Springvale Mine Extension Project

APPENDIX M

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE MC1 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			10/11/2010	26/05/2011	15/11/2011	7/06/2012	29/11/2012	
Coleoptera	Elmidae	Riffle Beetles					X	7
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	4
	Scirtidae	Marsh Beetles		X			X	6
Diptera	Ceratopogonidae	Biting Midges	X	X	X		X	4
	Chironominae	Bloodworms	X	X	X	X	X	3
	Orthocladiinae	Bloodworms	X		X	X		4
	Tanypodinae	Bloodworms	X	X	X	X	X	4
	Simuliidae	Black Flies		X		X		5
	Tipulidae	Crane Flies	X		X	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	8
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	5
	Telephlebiidae	Dragonflies	X	X	X	X	X	9
	Megapodagrionidae	Damselflies			X		X	5
Plecoptera	Gripopterygidae	Stoneflies	X	X	X	X		8
Trichoptera	Calocidae/Helicophidae	Caddis Flies			X			9
	Ecnomidae	Caddis Flies	X	X	X	X	X	4
	Helicophidae	Caddis Flies					X	10
	Helicopsychidae	Caddis Flies	X					8
	Hydrobiosidae	Caddis Flies					X	8
	Hydropsychidae	Caddis Flies	X			X		6
	Leptoceridae	Caddis Flies	X	X	X	X	X	6

Order	Taxon	Common name	Survey Date 10/11/2010	26/05/2011	15/11/2011	7/06/2012	29/11/2012	SIGNAL2 Score
	Odontoceridae	Caddis Flies		X				7
	Philorheithridae	Caddis Flies			X	X		8
Non-Insects	Hydracarina	Freshwater Mites			X		X	6
	Talitridae	Side Swimmers			X			3
	Parastacidae	Freshwater Crayfish/Yabbie			X			4
	Oligochaeta	Freshwater Worms	X			X	X	2

Springvale Mine Extension Project

APPENDIX N

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE PC1 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date		SIGNAL2 Score
			6/06/2012	29/11/2012	
Coleoptera	Gyrinidae	Whirligig Beetles	X	X	4
	Hydraenidae	Scavenger Water Beetles		X	3
	Hydrophilidae	Scavenger Water Beetles		X	2
	Scirtidae	Marsh Beetles		X	6
Diptera	Ceratopogonidae	Biting Midges	X	X	4
	Chironominae	Bloodworms	X	X	3
	Orthocladiinae	Bloodworms	X	X	4
	Tanypodinae	Bloodworms	X	X	4
	Simuliidae	Black Flies	X	X	5
	Tipulidae	Crane Flies	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	8
Hemiptera	Veliidae	Small Water Striders		X	3
Mecoptera	Nannochoristidae	Scorpionflies	X	X	9
Megaloptera	Cordyalidae	Dobsonflies		X	7
Odonata	Synthemistidae	Dragonflies	X	X	5
	Telephlebiidae	Dragonflies	X	X	9
Plecoptera	Gripopterygidae	Stoneflies	X	X	8
Trichoptera	Hydroptilidae	Caddis Flies	X		4
	Leptoceridae	Caddis Flies	X	X	6
	Philorheithridae	Caddis Flies	X	X	8
Non-Insects	Parastacidae	Freshwater Crayfish/Yabbie	X		4
	Oligochaeta	Freshwater Worms	X	X	2

Springvale Mine Extension Project

APPENDIX O

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE BC1 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			10/11/2010	26/05/2011	15/11/2011	7/06/2012	29/11/2012	
Coleoptera	Dytiscidae	Diving Beetles	X	X	X	X	X	2
	Hydrophilidae	Scavenger Water Beetles	X		X			2
Diptera	Chironominae	Bloodworms	X	X	X	X	X	3
	Tanypodinae	Bloodworms	X			X		4
	Culicidae	Mosquitoes	X	X	X	X	X	1
	Tipulidae	Crane Flies	X					5
Ephemeroptera	Leptophlebiidae	Mayflies					X	8
Hemiptera	Corixidae	Lesser Water Boatmen	X					2
	Veliidae	Small Water Striders				X		3
Mecoptera	Nannochoristidae	Scorpionflies				X		9
Odonata	Megapodagrionidae	Damselflies		X				5
Trichoptera	Leptoceridae	Caddis Flies		X	X	X	X	6
	Polycentropodidae	Caddis Flies					X	7
Non-Insects	Hydracarina	Freshwater Mites				X		6
	Ostracoda	Seed Shrimps				X		
	Oligochaeta	Freshwater Worms	X					2
	Dugesiidae	Flatworms				X	X	2

Springvale Mine Extension Project

APPENDIX P

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE BCN2 AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date		SIGNAL2 Score
			6/06/2012	29/11/2012	
Coleoptera	Dytiscidae	Diving Beetles	X		2
	Scirtidae	Marsh Beetles		X	6
Diptera	Chironominae	Bloodworms	X	X	3
	Orthocladiinae	Bloodworms	X		4
	Tanypodinae	Bloodworms	X	X	4
	Simuliidae	Black Flies	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	8
Hemiptera	Veliidae	Small Water Striders		X	3
Mecoptera	Nannochoristidae	Scorpionflies	X	X	9
Odonata	Synthemistidae	Dragonflies		X	5
	Telephlebiidae	Dragonflies	X	X	9
Plecoptera	Notonemouridae	Stoneflies	X		6
Trichoptera	Hydrobiosidae	Caddis Flies	X	X	8
	Leptoceridae	Caddis Flies	X	X	6
	Polycentropodidae	Caddis Flies		X	7
Non-Insects	Phreatoicidae	Isopods	X	X	4
	Oligochaeta	Freshwater Worms	X	X	2
	Dugesiidae	Flatworms	X	X	2

APPENDIX Q

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE SSWdn AND THEIR SIGNAL2 SCORES

Order	Taxon	Common Name	Survey Date		SIGNAL2 Score
			7/06/2012	30/11/2012	
Coleoptera	Dytiscidae	Diving Beetles	X	X	2
	Hydrophilidae	Scavenger Water Beetles		X	2
	Scirtidae	Marsh Beetles	X		6
Diptera	Chironominae	Bloodworms	X	X	3
	Orthocladiinae	Bloodworms		X	4
	Tanypodinae	Bloodworms	X	X	4
	Culicidae	Mosquitoes		X	1
Hemiptera	Veliidae	Small Water Striders		X	3
Mecoptera	Nannochoristidae	Scorpionflies	X	X	9
Odonata	Telephlebiidae	Dragonflies	X	X	9
Plecoptera	Notonemouridae	Stoneflies		X	6
Trichoptera	Leptoceridae	Caddis Flies	X	X	6
	Polycentropodidae	Caddis Flies		X	7
Non-Insects	Oligochaeta	Freshwater Worms	X	X	2
	Dugesiidae	Flatworms	X	X	2