Aquatic Ecology and Stygofauna Assessment

Angus Place Mine Extension Project

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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

This Aquatic Ecology and Stygofauna Impact Assessment has been prepared by Cardno Ecology Lab, on behalf of Centennial Angus Place (Angus Place), to support the Environmental Impact Statement (EIS) for the Angus Place 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;

> Descriptions 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 Application Area;

> 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

Centennial Angus Place is seeking approval to extend its longwall mining operations to the east and north-east of its existing operations within its Mining Lease (ML) 1424 at Angus Place, 15 kilometres northwest of the city of Lithgow. The Project involves:

> Development of underground access headings and roadways from the current mining area to the east to allow access to the proposed mining area;

> Retreat longwall mining of the proposed longwall panels LW1001 to LW1019;

> Use of the existing ancillary surface facilities and infrastructure at Angus Place Pit Top and on Newnes Plateau;

> Processing of coal through the existing crusher and screening plant at the Angus Place pit top and its subsequent transfer to offsite locations using existing road haulage trucks;

> Installation and operation of seven additional dewatering borehole facilities and associated infrastructure on Newnes Plateau;

> Installation and operation of dewatering reinjection boreholes and pipeline infrastructure at the existing Ventilation Facility site;

> Construction and operation of a downcast ventilation shaft;

> Upgrade and extension of the existing access tracks from Sunnyside Ridge Road to the dewatering borehole facilities and proposed downcast ventilation shaft;

> Management of mine inflows by transferring water to Wallerawang Power Station (WPS), via the Springvale Delta Water Transfer Scheme (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;

> Life-of-mine rehabilitation at the Angus Place 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.

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;

> The provisions in the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act*), NSW Threatened Species Conservation Act 1995 (*TSC Act*) and NSW Fisheries Management Act 1994 (*FM Act)* (including Fisheries Management Amendment Act 1997) that relate to the conservation of threatened species, populations and communities;

> The Protection of the Environment Operations Act 1997 (*POEO Act*) which regulates the volume and concentration of key pollutants discharged to the aquatic environment.

The Policy and Guidelines for Fish Habitat Conservation and Management (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 Project Application 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 Adam's Emerald Dragonfly, a threatened invertebrate species listed under the *FM* Act occurs in the vicinity of the Project Application Area. This species has not been recorded in the area, but could potentially 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 water courses;

> Instream structures and other mechanisms that alter natural flows;

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

Two 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 and Biota

Descriptions are provided of the aquatic ecology of the upper reaches of the Coxs River, Kangaroo Creek, Wolgan River, Carne Creek and of the drainages downstream of two Shrub Swamps (Twin Gully and Tri Star) and one Hanging Swamp (Bird Rock) 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 Catchment

Monitoring was undertaken at four sites, CR1, CR2, CR4 and CR5, in the upper reach of the Coxs River above Lake Wallace and at two sites, KCup and KCdn on its tributary, Kangaroo Creek. CR1 and KCup are located upstream of any influence from licenced discharge point LDP001.

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 channel in Kangaroo Creek was also narrow, with that at KCup being incised into the valley floor and having steep sides and that at KCdn being box-shaped with unstable, undercut banks. The river banks were steep, undercut, unstable and actively eroding in some sections. The river banks were covered by grasses with occasional blackberry bushes. Eucalypt and willow trees were also present at CR5. The riparian vegetation at KCup consisted of ferns while that at KCdn was composed of native eucalypts with an understorey of grasses and thick blackberry. The substratum in the river consisted of sandy and/or muddy deposits with some pebbles, cobbles and boulders, while that in the creek was mostly sandy, but with some boulder or bedrock outcrops and a large amount of detritus also present at KCup. The riparian and aquatic environments at CR2 and CR4 were in a poorer condition than those at CR1 and CR5 and that at KCdn was poorer than that at KCup.

The electrical conductivity (EC) levels at CR2, CR4, CR5 and KCdn exceeded the ANZECC/ARMCANZ (2000) guidelines. EC levels at CR1 were always within the guidelines, while those at KCup were often below the lower Default Trigger Value (DTV). The dissolved oxygen levels (DO) at all of the sites, except CR5, were generally below the guidelines. The water at CR2, CR5 and KCdn was more alkaline than the upper DTV, but that at KCup was more acidic than the lower DTV. The pH at CR1 and CR4 was generally within the guidelines. The turbidity levels at all six sites were generally within the guidelines.

More aquatic plant taxa were found at CR1 and CR5 than at CR2 and CR4. Two species of aquatic plants were recorded at KCdn, but none were found at KCup. Filamentous green algae were present at all six sites. Charophytes were recorded at CR1, CR4, CR5 and KCup only.

The aquatic macroinvertebrate fauna of the river 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 in the creek was less diverse, with a total of 24 and 39 taxa recorded at KCup and KCdn, respectively and 45 taxa across both sites. The fauna consisted of insects, crustaceans, worms, molluscs, springtails, freshwater mites and leeches. The fauna in the 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 fauna at KCup was significantly impaired as was that at KCdn in 2011. The fauna at KCdn was severely impaired in 2012. The average SIGNAL2 score, an index of environmental quality based on the sensitivity of macroinvertebrate families to various forms of pollution, indicated KCup was moderately degraded, but KCdn and the Coxs River sites varied from moderately to severely degraded, with Sites CR1 and CR5 being in the poorest condition. The macroinvertebrate assemblages at KCup and KCdn were distinct from each other and from those at the Coxs River sites. The assemblages at CR1 were also distinct 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. Mountain Galaxias was the only species recorded in Kangaroo Creek. Tadpoles were observed at all the sites except KCup, but no frogs were found.

The above indicates that the aquatic habitat and quality of water in the upper Coxs River are both degraded but despite this aquatic biota is relatively diverse. The discharge from LDP001 appears to have adverse effects on the condition of the aquatic habitats and quality of water at KCdn and CR2, but its effect on biological indicators is less clear with only SIGNAL2 and AUSRIVAS scores being poorer on average at KCdn than at KCup, and macrophytes being less diverse at CR2 than CR1.

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 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 more acidic than in the river and also well below the guidelines. The EC and DO levels at CCXdn were 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 were 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, with WRup being in the poorest condition. CCXdn was not degraded. 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 also undertaken at sites in the drainages downstream of two Shrub Swamps in the Wolgan River catchment, Twin Gully Swamp (TGS) and Tri Star Swamp (TRIS), and at that below Bird Rock Swamp (BRS), a Hanging Swamp in the Carne Creek catchment.

The drainage channels below all three swamps were overgrown with dense vegetation. The substratum consisted mainly of bedrock, but with some sand and silt accumulations. Boulders were also present at TGS and BRS. Moss was prevalent along the stream banks downstream of the Shrub Swamps. There was evidence of habitat scouring, deepening of pools and creation of new flow paths during high flows. The riparian habitat and stream channels downstream of the swamps were minimally disturbed.

The EC of the water at TGS and TRIS was lower than that at BRS and below ANZECC/ARMCANZ (2000) guidelines. The DO levels at all sites were frequently below the guidelines, but more so at TGS. The pH levels at all three sites were below the guidelines, with those at TGS and BRS being the most acidic. Turbidity levels at TGS and BRS were within the guidelines, but those at TRIS occasionally exceeded the upper guideline.

Bulbous Rush and/or Swamp Clubrush were present at TRIS, but no aquatic macrophytes were recorded at TGS or BRS. Filamentous green algae were generally present downstream of the Shrub Swamps, but found only once at BRS. Charophytes were observed occasionally at TRIS.

The macroinvertebrate fauna downstream of the Shrub Swamps was more diverse that that at BRS. The fauna consisted primarily of insect families, plus crustaceans, worms, bivalves, freshwater mites, leeches and springtails. Less than a quarter of the taxa were recorded every survey. The sites downstream of the Shrub Swamps were mildly degraded, whereas that at BRS varied from mildly degraded to undisturbed. The macroinvertebrate fauna at BRS was also distinct from that at TGS and TRIS. No fish or amphibians were found.

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 collected from boreholes on Tri Star Swamp yielded two likely (Cyclopoid Copepoda and Ostracoda) and three possible stygofauna taxa (Acarina, Nematoda and Tardigrada). No animals were found in the Twin Gully samples, probably due to the small sample size. Samples from the unconfined aquifer yielded one likely (Bathynellid syncarid) and two possible stygofauna taxa (Acarina and Nematoda). The other taxa recorded were either terrestrial or associated with saturated soils.

Potential Impacts and Management Measures

Construction Phase

Runoff from areas of land that are disturbed and where soil is stockpiled during construction of the dewatering boreholes, ventilation shaft and pipeline infrastructure could potentially deposit sediments in the drainage lines associated with the Wolgan River and headwater sub-catchments of Carne Creek. This sediment could be dispersed downstream into the Wolgan River and Carne Creek as a result of flow during significant rainfall events. The temporary, localised increases in sediment load that may arise during construction works are unlikely to have any significant effects on aquatic flora and fauna, as these are likely to be fairly tolerant of the increases in sediment load that occur naturally during periodic rainfall events. These impacts would be minimised by limiting the land area disturbed and using measures specified in the Erosion and Sediment Control Plan to protect aquatic habitats and biota immediately downstream of the construction area.

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. The potential for such impacts would be minimised by establishing a bunded area for storage of fuels, oils, refuelling and appropriate maintenance of vehicles and mechanical plant.

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. The potential for such impacts 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.

Groundwater inflows during the construction of the underground roadways would be discharged into Kangaroo Creek through LDP001 as part of the normal site mining operations.

The upper reach of the Coxs River and Kangaroo Creek are situated to the west of the proposed longwalls and will not be impacted by the proposed construction activities.

Longwall 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 subsidence predictions and assessment of the physical impacts of the likely ground movements (MSEC 2013) indicates there are unlikely to be any significant changes in levels of ponding, flooding or scouring of banks or alignment of the Wolgan River and no adverse impacts on Carne Creek. Fracturing of the river bed may occur, but this would be minor, shallow and isolated in nature and would not divert surface flows into subterranean flows. Weathering of freshly exposed fractures could result in increases in concentrations of some metals. These impacts are expected to be localised and temporary persisting until the cracks are infilled and overtopping of flows is resumed. Impacts on pool habitats and biota are therefore also expected to be localised and temporary and therefore not significant.

In the drainage lines, there may be minor localised increases in ponding and a small increase in the availability of aquatic habitat in areas with low grade. Longwall extraction is not expected to have any adverse effects on ponding or scouring of swamps. Minor, isolated fracturing of bedrock is expected to occur in swamps and drainage lines and could lead to temporary loss of aquatic habitat and connectivity. The cracks would persist until the cracks are infilled by sediment. 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. The diversion of surface water into sub-surface layers is expected to have localised, transient effects on the quality of the water in section of drainage lines where surface flows re-emerge.

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 and mobilise sediment in the underlying strata where stygofauna live. 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 they support such animals.

The potential for physical impacts has been minimised by setting the proposed longwalls back from the centreline of Wolgan River and Carne Creek and by aligning the longwalls with the general horizontal stress direction. 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, 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 Kangaroo Creek via LDP001. The transfer of water into the SDWTS results in a significant reduction in the potential impact of any discharge to the creek and the reach of the Coxs River below its confluence.

The discharge from LDP001 is predicted to peak between 2019 and 2025 if the capacity of the SDWTS remains at 30 ML/d. The increase in discharges over that period 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 in the two watercourses. Sudden increases in discharge could exacerbate the existing erosion of the stream bank and channel, flush away potential instream habitat and lead to downstream transport of sediment. Such impacts would be short-lived and negligible relative to those that occur naturally during high stream flows. The increase in dilution resulting from the greater flow may counteract the increase in turbidity and its effects on aquatic biota.

The peak discharges would result in 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. Releases during low flow periods may increase the stability of aquatic habitats, which could be more conducive to growth of aquatic macrophytes. The change in the flow regime could lead to loss of flow-sensitive taxa and decreases in the diversity and abundance of aquatic macroinvertebrates.

The discharge of mine water make would also elevate EC, pH, total dissolved solids, barium, calcium, magnesium, potassium, sodium, Total Sulphur and alkalinity levels of the water in the creek and river downstream of LDP001. The greatest changes in these constituents and hence potential for impact on aquatic biota would occur between 2019 and 2025, if the SDWTS remains at its current capacity. The increase in salinity will be more rapid and sustained than the changes that occur naturally. The decreases in salinity will be of similar magnitude to some of the natural declines but more prolonged. If the SDWTS is upgraded to 50 ML/d there would be a reduction in the discharge soon after the Project commenced. The magnitude of change would be greater but the duration of impact would be shorter than if the SDWTS is upgraded. The aquatic biota will thus be exposed to salinity conditions they have not previously experienced and may be subject to direct toxic effects and indirect effects resulting from modification of species composition of the ecosystem. The peak discharge is likely to have a moderate impact on aquatic biota in Kangaroo Creek and a small to moderate impact on that in Coxs River.

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 would be minimised by ensuring it meets the conditions specified in the Angus Place Environment Protection Licence 467. 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 watercourse further downstream and that the 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 also be taken into consideration;

> The likely impacts of abrupt and sustained changes in salinity should be determined and an aquatic ecology monitoring programme should be implemented to determine their actual impacts 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 Angus Place that would be prepared 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 and its associated swamps could potentially have been impacted by past construction activities at the two mines, the extraction of the previous Springvale and Angus Place longwalls and mine-water discharge. The impacts associated with the proposed longwalls would not be significant. The river could in the future be affected by mine decommissioning and rehabilitation. The information that is available indicates past, present and future impacts of mining on the habitats along the Wolgan River are unlikely to be significant.

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 Springvale Project Application Area. The creek could potentially be impacted by some construction activities associated with the Mine Extension Project and could in the future be affected by mine decommissioning and rehabilitation. The information that is available indicates 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 forestry and recreational 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 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 on the occurrence of stygofauna to determine the likelihood or magnitude of such impacts.

Overall Conclusion

This assessment indicates the proposed extraction of coal will 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 will result in more rapid and sustained changes in salinity than occur naturally. Although the salinity levels would be below that likely to have direct 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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Glossary

Term or Acromym	Definition
Angus Place	Angus Place Mine
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
AUSRIVAS	Australian River Assessment System (http://ausrivas.canberra.edu.au)
aquifer	A geological structure or formation that is permeated with water or is capable of being permeated with water.
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)
DTV (Default trigger value)	Guideline trigger value derived from ecosystem data for undisturbed or slightly-modified ecosystems supplied by state agencies.
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	Former division of Industry and Investment NSW
Impaired macroinvertebrate fauna	Faunal assemblages that contain fewer taxa than

Term or Acromym	Definition
	undisturbed reference streams with similar environmental characteristics.
Key Threatening Process (KTP)	A process that either adversely affects threatened species populations or ecological communities or could cause species, populations or ecological communities that are not threatened to become threatened.
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
pH	Negative logarithm of hydrogen ion concentration
Phreatic	Relating to or denoting underground water in the zone of saturation (beneath the water table)
Project	The Angus Place Mine Extension Project
Project Application Area	Area within the red line in Figure1-1 that includes all activities proposed as part of the Angus Place 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 – A pipeline that is used to transfer groundwater inflows from dewatering bores associated with the Angus Place and Springvale Mines to the Wallerawang Power Station.
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,

Term or Acromym	Definition
	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 electrolytic conductivity
WPS	Wallerawang Power Station

1 Introduction

1.1 Purpose of the Report

Centennial Angus Place Pty Ltd proposes to extend its longwall mining operations to the east and north-east of its existing workings within its Mining Lease (ML) 1424 at Angus Place Colliery (Angus Place), located 15 kilometres northwest of the city of Lithgow. The location of the Angus Place Pit Top, Project Application Area, existing and proposed workings are shown in **Figure 1-1**.

The Angus Place 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 that is being prepared by Golder Associates.

1.2 Project Overview

The Project will:

> Continue to extract up to 4 million tonnes per annum (Mtpa) of ROM coal from the Lithgow Seam underlying the Project Application Area;

> Develop underground access headings and roadways from the current mining area to the east to allow access to the proposed mining area;

> Undertake secondary extraction by retreat longwall mining for the proposed longwall panels LW1001 to LW1019;

> Continue to use the existing ancillary surface facilities at the Angus Place pit top;

> Continue to manage the handling of ROM coal through a crusher and screening plant at the Angus Place pit top, and the subsequent loading of the coal onto the existing road haulage trucks 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 Angus Place pit top and on Newnes Plateau;

> Install and operate seven additional dewatering borehole facilities on Newnes Plateau and the associated power and pipeline infrastructure;

> Upgrade and extend the existing access tracks from Sunnyside Ridge Road to the dewatering borehole facilities;

> Install and operate water transfer boreholes and pipeline infrastructure at the existing Ventilation Facility site (APC-VS2);

> Construct and operate a downcast ventilation shaft (APC-VS3) and upgrade the existing access track to the proposed facility from Sunnyside Ridge Road;

> Manage the predicted increase in 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 exploration activities, predominately borehole drilling and core sampling, to refine the existing geological model of the site;

> 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 225 persons and 75 contractors;
> Progressively rehabilitate disturbed areas at infrastructure sites no longer required for mining operations;
> Undertake life-of-mine rehabilitation at the Angus Place 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 up to 25 years.

A more detailed description of the Project is presented in Section 4 of the EIS (Golder Associates 2013).

1.3 Project Location

The Angus Place Colliery (Angus Place) is located within the Lithgow Local Government Area (LGA) and is situated five kilometres north of the village of Lidsdale, eight kilometres northeast of the township of Wallerawang and 15 kilometres northwest of the City of Lithgow (Centennial Angus Place 2012). The mine pit top is located just off Castlereagh Highway and approximately 20km northwest of Lithgow. The underground longwall mine is situated below a sandstone plateau of undulating bushland within the Newnes State Forest. The pit top, administration and surface water management infrastructure are located on the foot slopes of the Newnes Plateau.

Angus Place is bordered by Baal Bone Colliery (Xstrata Coal Pty Ltd) to the north and Invincible Colliery (CET Resources Pty Ltd) to the northwest, Springvale Coal Pty Limited to the south and Wolgan Valley and Newnes State Forest to the north and east, respectively.

1.4 Project Application Area

The Project Application Area covers an area of approximately10,460 hectares and encompasses:

> Angus Place Pit Top located just off the Castlereagh Highway,
> Existing underground workings and supporting infrastructure;
> Surface facilities adjacent to Wolgan Road, five kilometres north of the village of Lidsdale, which support the existing underground operations;
> Proposed underground workings and supporting infrastructure in the area identified as Angus Place East.

The Project Application Area is bordered by Gardens of Stone National Park to the north and north-east, Newnes State Forest and Birds Rock Flora Reserve to the east, the existing Angus Place Colliery longwalls (LWs 19-26) to the west and existing and proposed Springvale Colliery longwalls to the south. The Project Application Area is situated below sections of the Coxs River and Wolgan River Catchments, which in turn are part of the Hawkesbury – Nepean Catchment Area.

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 LW1001 to LW1019 in the Lithgow Seam (MSEC 2013). The area includes the 26.5 degree angle of draw line from the extents of Longwalls 1001 to 1019 and the predicted 20 mm subsidence contour resulting from the extraction of the proposed longwalls.

1.6 Scope of Works

The scope of works for the Aquatic Ecology and Stygofauna Assessment was determined by the requirements of 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 the report where these are addressed are summarised in **Tables 1-1-1.3**.

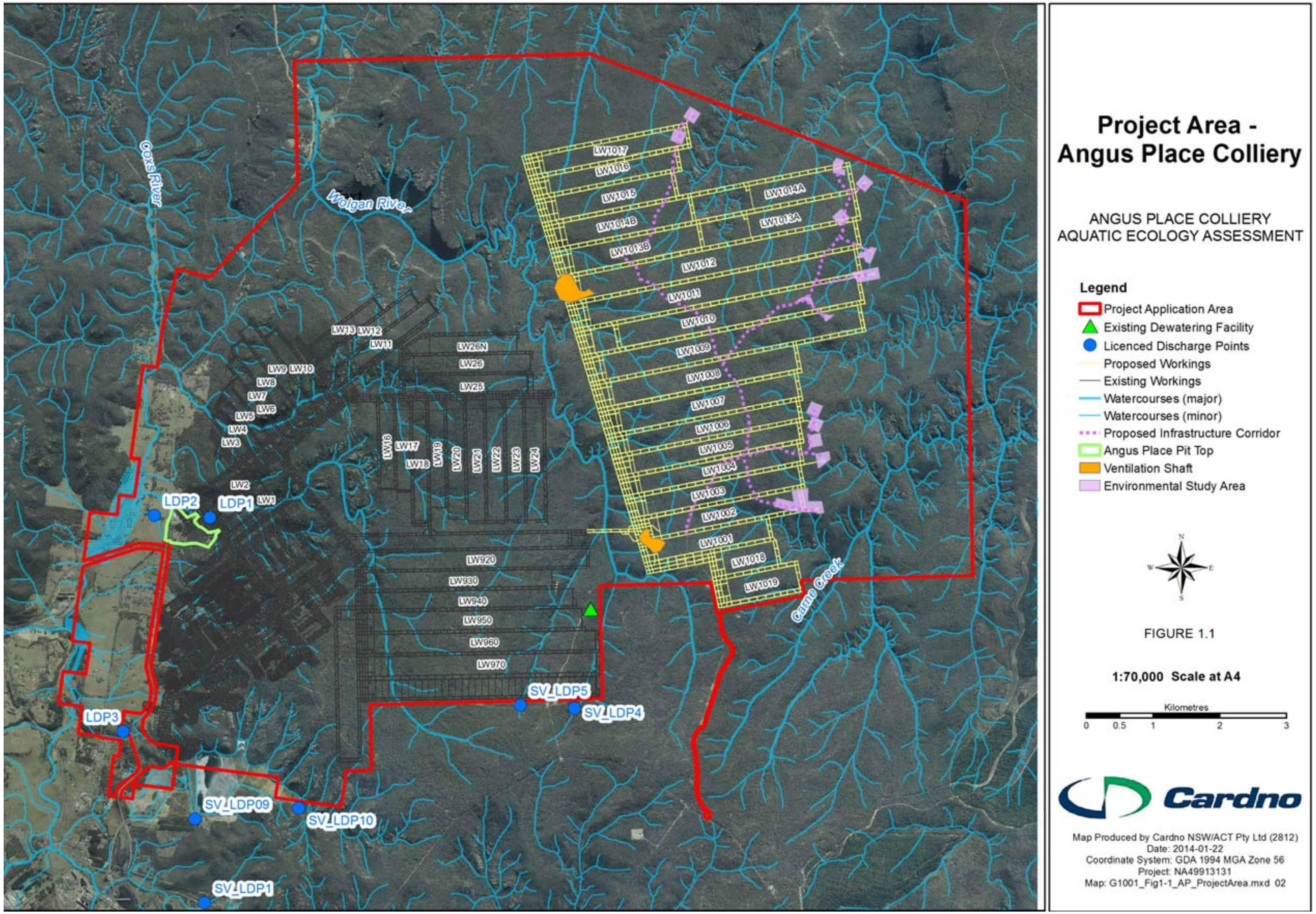

Figure 1-1 Map showing the location of the Project Application Area, Angus Place Pit Top, existing and proposed workings. Note that Environmental Study Areas are places where surface infrastructure such as powerlines, pipelines and dewatering boreholes may be constructed.

Table 1-1 Director General's (DP & I) requirements pertinent to the Aquatic Ecology and Stygofauna Assessment

Assessment Requirements	Relevant Sections of the Report
Description of the existing environment, using sufficient baseline data.	4.2-4.7, 5.1-5.3, 6.1-6.4
Assessment of the potential impacts of all stages of the development, including any cumulative impacts.	7.1-7.5, 8.1-8.5
Assessment of impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including GDEs and environmental flows.	7.1-7.5, 8.1-8.5
Detailed assessment of potential impacts of the development on aquatic threatened species or populations and their habitats, endangered ecological communities and GDEs	7.4, 8.1-8.5
Description of measures that would be implemented to avoid, minimise and, if necessary, offset the potential impacts of the development.	7.1-7.5, 8.1-8.5
Measures that would be taken to avoid, reduce or mitigate impacts on biodiversity, particularly that associated with Temperate Highland Peat Swamps;	7.1-7.5, 8.1-8.5
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 the Aquatic Ecology and Stygofauna Assessment

Assessment Requirements	Relevant Sections of the 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 and 3.2
Description of survey methodology	4.1, 6.2 and 6.3
Likely impacts on biodiversity, native vegetation and habitat	7.1-7.5, 8.1-8.5
Impact of quality, temperature and quantity of discharged water on aquatic biodiversity	7.2.1.3
Impact of changes to groundwater levels	7.2.1, 7.2.2, 8.2.1
Likely impacts on threatened biodiversity	7.4
Measures to avoid, mitigate and manage impacts	7.1-7.5, 8.1-8.5

Table 1-3 NSW Office of Water's (NOW) requirements pertinent to the Aquatic Ecology and Stygofauna Assessment

Assessment Requirements	Relevant Section of the 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	4.2-4.7, 5.1-5.3, 6.1-6.4
Assessment of GDEs for condition and water quality and quantity requirements for aquatic ecosystems (macroinvertebrate, macrophytes, stygofauna)	4.2-4.7, 5.1-5.3, 6.1-6.4
Assessments of impacts on groundwater and surface water dependent ecosystems within and adjacent to mining operation	7.1-7.5, 8.1-8.5
Mitigation measures to address impacts on groundwater and surface water dependent ecosystems during and after mining operations	7.1-7.5, 8.1-8.5
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 – Aquatic Ecology of Streams – 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 Twin Gully, Tri Star and Bird Rock swamps;

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

> Section 7 - Potential Impacts on Aquatic Ecology 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 Mine Extension 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 that is 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 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 (*WM* Act) 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 may be required.

2.1.2 Threatened Species, Populations and Communities

Threatened freshwater species, populations and communities are listed under the Environment 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 (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 NSW.

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, Lambs 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 Angus Place Mine to the aquatic environment via Licenced Discharge Points (LDPs) is regulated through Environment Protection Licence (EPL) No. 467 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 the frequency with which and method 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 29 June 2013 indicates discharges to the aquatic environment may occur through LDP001, LDP002, LDP003 and LDP005. LDP001 is where excess water pumped to the surface fire tanks or from an underground storage area is discharged to a V-notch weir structure into Kangaroo Creek, a tributary of the Coxs River (Centennial Coal 2013). Most of the water passes through two settling ponds and two wetland systems which are separated by a series of rock gabions. Some of the underground water is transferred to the weir directly through a galvanised pipe. LDP002 discharges water from the pit top operations to the Coxs River after it has passed through an oil water separator and settling ponds. LDP003 is situated across the Wallerawang haul road from the decommissioned Kerosene Vale Colliery, which was used as a stockpile site during 2012 and discharges to the Coxs River after prolonged rainfall. LDP005 is where treated sewage effluent from Angus Place is discharged via a spray irrigation network to a designated utilisation area. LDP006 an emergency discharge point on an unnamed tributary of the Wolgan River has been removed from the EPL.

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. The assessment of the Project will require consideration of the NSW Office of Water guidelines.

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

The Fisheries NSW 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 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 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 DPI will consider the 'sensitivity' of any key fish habitats that will be affected by the proposed mine expansion. 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'. 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 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 (4.1.2);

The specific policies and guidelines that may be relevant include those for:

> 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 (GDEs) 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 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 (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. A water licence is required for any activity that interferes with an aquifer and for activities that result in the movement of water from one part of the aquifer to another or to and from a surface water body. 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 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 Application 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 *EPBC Act* may occur or suitable habitat for them may occur within the Lithgow LGA. Two of these species, Murray Cod (*Maccullochella peelii*) and Australian Grayling (*Prototroctes maraena*), 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 and coastal 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 on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria (DPI 2006a). This species inhabits streams and rivers, particularly clear gravely streams with a moderate flow, as well as estuarine areas. The records on the 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 (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. 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 lots of 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, fast-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 range of Murray Cod, Australian Grayling, Macquarie Perch indicates they are highly unlikely to occur in the Project Application Area. The cascades between the Newnes Plateau and Wolgan Valley would 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). Shrub swamps have deep sandy organic sediments that are periodically to permanently 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 limicola*. Pouched Coral Fern (*Gleichenia dicarpai)* and Button Grass (*Gymnoschoenus sphaerocephalus*) sometimes occur 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 Angus Place, 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 2013b).

RPS (2013a) indicates 10 Shrub Swamps and 53 separate Hanging Swamps occur within the Project Application Area. Three Shrub Swamps associated with the Wolgan River Catchment are located within the area of the proposed workings, namely:

> Trail Six Swamp above LWs 1016-1017;

> Twin Gully Swamp which extends from Drainage Line 2 towards LWs 1010-1011;

> Tri Star Swamp above LWs 1004-1006.

A further five Shrub Swamps (Sunnyside Swamp, East Wolgan Swamp, Narrow Swamp North, Narrow Swamp South and West Wolgan Swamp) are located within this catchment to the south-west of the proposed workings and five Shrub Swamps (Sunnyside East Swamp, Carne West Swamp, Gang Gang Swamp South West, Gang Gang Swamp East and Carne Central) are located to the south-east in the Carne Creek catchment.

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 (DPI 2006b). The current distribution range of Murray Cod, Australian Grayling, Macquarie Perch indicates they are highly unlikely to occur in the Project Application Area. The cascades between the Newnes Plateau and Wolgan Valley would 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 (DPI 2007). The predicted distribution range of this species, however, does not extend much beyond Penrith (DPI 2007b), so it is highly unlikely to occur in the Project Application 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 (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 6.5).

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. 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, Sunnyside East, occurs in. 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 peat land 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). RPS (2013a) concluded that the Giant Dragonfly could potentially occur in the area of the proposed workings and 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 are listed as an EEC under the *TSC Act*. Ten Shrub Swamps occur within the Project Application Area (RPS 2013a) with three of these (Trail Six, Tri Star and Twin Gully Shrub Swamps) being located in the area of the proposed workings.

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 KTPs listed under the *FM Act* that are potentially relevant to the effects of the Project on aquatic ecology are:

> Degradation of native riparian vegetation along New South Wales water courses;

> Instream structures and other mechanisms that alter natural flows;

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

> The KTPs listed under the *TSC Act* that are potentially relevant to the effects of the Project on aquatic ecology are:

> 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 5.1.2 indicates this species is highly unlikely to occur in 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 four watercourses, Wolgan River, Carne Creek, Coxs River and its tributary Kangaroo Creek, that could potentially be impacted by the Angus Place Mine Extension Project. The upper reaches of the Wolgan River and three headwater sub-catchments of Carne Creek, situated to the west and east of the proposed workings respectively, have been included in this assessment because they may experience valley related movements and could be sensitive to such movements (MSEC 2013). The sections of Kangaroo Creek and Coxs River situated in the western part of the Project Application Area have been included in the assessment because some of the water that accumulates in the proposed underground workings may be released into these watercourses via Angus Place's licensed discharge point LDP001 and Springvale Mine's LDP009, if it cannot be transferred to Wallerawang Power Station (WPS) via the Springvale Delta Water Transfer Scheme (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 Angus Place's water quality monitoring in the Wolgan River, Coxs River and Kangaroo Creek 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), Kangaroo Creek (The Ecology Lab 2007) and of the Upper Coxs River sub-catchment derided from SCA (2010) is presented in Section 4.5. The aquatic ecological attributes of sites downstream of Twin Gully Swamp, Tri Star Swamp and Bird Rock Swamp are presented 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 in the upper reach of the Coxs River above Lake Wallace, Sites KCup and KCdn on Kangaroo Creek, 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**.

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, KCup, KCdn 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.

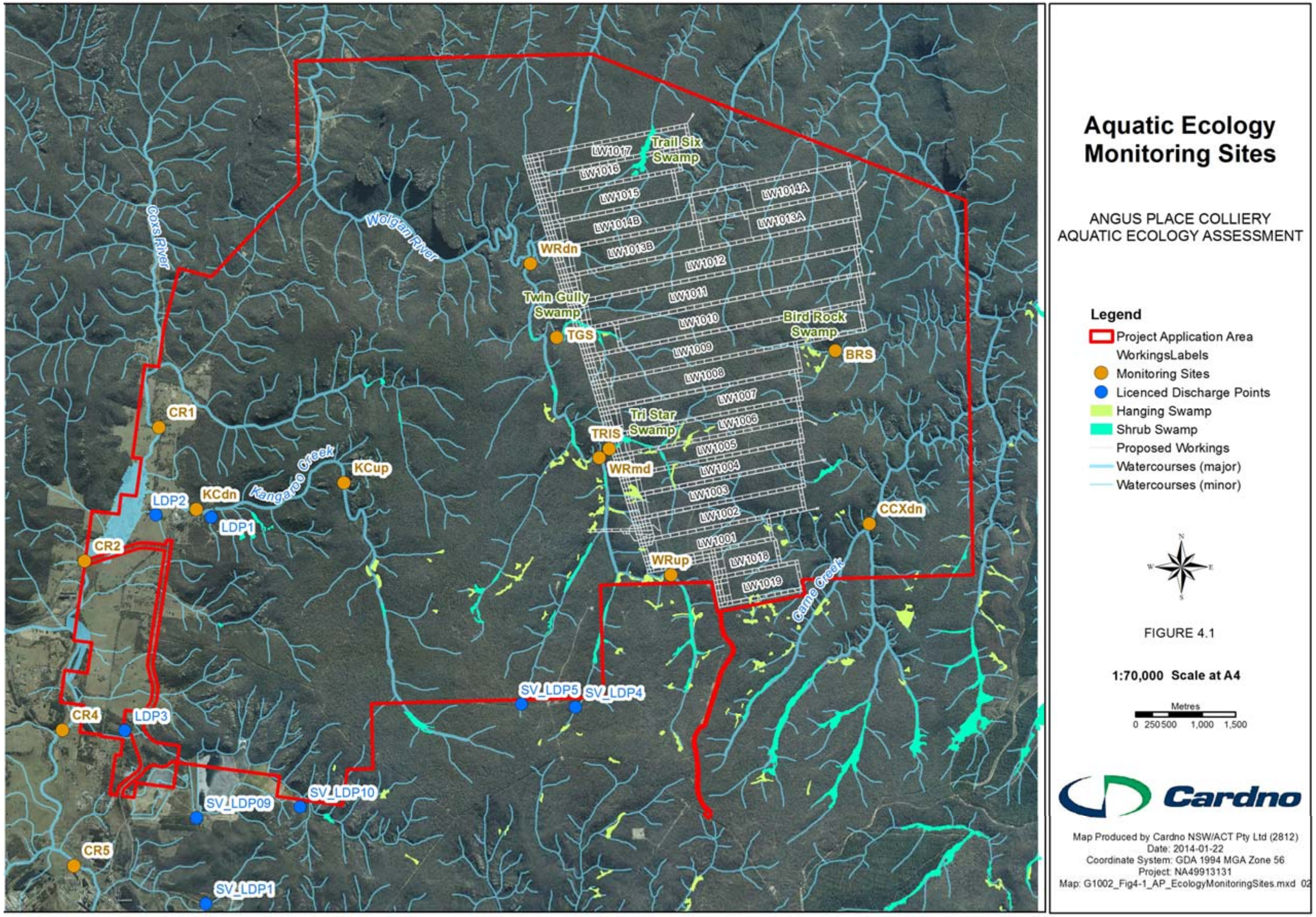

Figure 4-1 Map showing the location of the aquatic ecology monitoring sites relative to the proposed longwalls in the Angus Place Project Application Area.

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 LDP001 confluence.
CR2		228691	6305324	Site located at the haul road crossing, approximately 1km downstream of Angus Place LDP001 confluence
CR4		228361	6302773	Midstream site located at Maddox Lane road crossing.
CR5		228529	6300752	Midstream site located at Main St crossing, Wallerawang.
KCup	Kangaroo Creek	232588	6306501	Site located upstream of Angus Place pit top facilities and LDP001, and downstream of Longwalls 920-980.
KCdn		230368	6306102	Site located downstream of LDP001 confluence with Kangaroo Creek (adjacent pit top).
WRup	Wolgan River	237495	6305114	Wolgan River upstream site located above the Angus Place LDP006 and Springvale LDP004/005 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.

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). These trigger values provide an indication of 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, CR5 and KCdn 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 Upper 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 catchment has been degraded by the clearing of land for agriculture and grazing, mining operations, urban and industrial development and construction of impoundments. 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. Water from the Angus Place pit top operations is discharged to Coxs River via LDP002 and settling ponds. 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 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.

Kangaroo Creek is a first-order stream that originates on the Newnes Plateau at an elevation of 1180 m about 6.5 km east by north of the village of Lidsdale and flows for about 9 km generally north by west and then west before draining into the river. This creek traverses the existing underground workings of the Angus Place and Kerosene Vale mines. The Angus Place pit top is located where Kangaroo Creek leaves the vegetated escarpment valley and enters the broader agricultural floodplain valley of the Coxs River. Some of the groundwater that collects in the existing underground workings is pumped to the Angus Place pit top collection system and is then discharged to Kangaroo Creek via LDP001. This discharge is a significant contributor to surface water flow in the creek below LDP001. The reach of the creek upstream of LDP001 is ephemeral and relatively undisturbed.

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.

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 sphacelata)*, 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.

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

4.2.2.4 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 (**Appendix A**).

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).

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 sphacelata),* 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.

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

4.2.3.4 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 (**Appendix B**).

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 is located where Maddox Lane crosses Coxs River. The flow at this point is piped under the road 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

The elevated salinities at this site are likely to be due to the residual effect of the discharge from LDP1 combined with the effects of inflows from Wangcol Creek, a tributary of the Coxs River that receives discharges from Mt Piper Power Station, Pine Dale Coal Mine and Western Coal Services.

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 (**Appendix C**).

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 the Main Street, Wallerawang crossing of 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.

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 (**Appendix D**).

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

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.

4.2.6 Upstream Site KCup

KCup is situated on Kangaroo Creek upstream of Angus Place pit top facilities and LDP1 but downstream of longwalls 920-980.

4.2.6.1 Aquatic and Riparian Habitat

The river channel was narrow (average and maximum widths of 1.5 m and 4 m, respectively), meandering, and had steep sides incised to 2 m below the surrounding valley floor. The creek was shallow, with maximum and average depths varying from 0.8 m to 1 m and 10- 20cm, respectively. The site was surrounded by dense eucalypt woodland. The valley floor supported a dense cover of ferns, which provided fairly uniform trailing bank and overhanging vegetation along the length of the entire site. The stream discharged into a wide open bog that covered the valley floor. At this point, the channel form changed from an incised, deep box-shaped channel to a shallow broad seepage flow lacking a defined channel.

The instream banks were undercut in parts, with some sections flowing under logs that have been overgrown to form pseudo banks. Yabby burrows were evident in exposed stream sediment banks. The creek substratum was sandy with some boulder or bedrock outcrops in the channel. Mosses, fallen logs and detritus were prevalent. In Autumn 2012, it was noted that high flows up to 2 m above current levels had occurred since the previous survey and that some parts of the channel had been scoured out, woody debris and mosses had been removed, and some pools deepened and others infilled. The substratum during that survey consisted of unconsolidated sand and firm coarse sandy sediments with some large pebble, gravel and cobble sized fragments. Iron precipitate was observed on some parts of the substratum in Spring 2010, but was abundant and covered the substratum and submerged surfaces throughout the site during the subsequent surveys.

The RCE varied from 43.5-45, indicating the stream channel and adjacent features were subject to small-scale disturbance. The descriptors with low scores were those for lack of riffle/ pool sequences and stream bottom.

4.2.6.2 Water Quality

The baseline surface water quality measurements for KCup presented in **Table 4-10** show that:

> Electrical conductivity levels were low, ranging from 9-46 µS/cm, but only below the lower DTV (30 µS/cm) for slightly disturbed upland rivers in south-east Australia during three surveys (ANZECC/ARMCANZ 2000);

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

> pH levels were below the lower DTV (6.5 units) for slightly disturbed upland rivers in south-east Australia during all surveys;

> Turbidity levels were within the default trigger value range (2-25 NTU) during the three spring surveys, but below the lower DTV in the autumn surveys.

Table 4-10 Surface water quality measurements recorded during baseline surveys undertaken at Site KCup on Kangaroo 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
29/10/2010	11:02	10.64	46	56.6	5.68	7.5
08/06/2011	10:05	06.51	28	70.0	5.50	0.8
01/11/2011	10:31	09.99	28	71.4	5.54	3.9
29/05/2012	10:26	07.43	33	84.9	5.13	1.0
20/11/2012	13:10	11.24	09	56.5	5.68	10.4

4.2.6.3 Aquatic Plants and Algae

No aquatic macrophytes were observed. Small amounts of filamentous green algae were present throughout the site in Spring 2010, but none was recorded during subsequent surveys. Charophytes were recorded during all the surveys, except that in Spring 2010.

4.2.6.4 Aquatic Macroinvertebrates

A total of 24 macroinvertebrate taxa were collected during the baseline surveys, 21 of which were insect families (**Appendix E**). 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 Hydracarina (freshwater mites), Oligochaeta (freshwater worms) and Sphaeriidae (Pea Shells). The number of taxa collected per event varied from 13 to 17 (**Table 4-11**). Four taxa (Tanypodinae, Megapodagrionidae, Leptoceridae and Leptophlebiidae) were recorded every survey, and four taxa were recorded once (**Appendix E**).

In 2011 and 2012, the macroinvertebrate fauna at Site KCup was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 37% and 46% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4-11**).

The average SIGNAL2 scores for the initial survey was between 4 and 5, suggesting that the site was moderately degraded (**Table 4-11)**. The scores for the subsequent surveys ranged from 5.4 to 5.9, which is indicative of moderate degradation. Eight 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 (**Appendix E**).

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

Indicator	Survey Date				
	298/10/2010	08/06/2011	01/11/2011	29/05/2012	20/11/2012
Number of taxa	13	15	16	17	14
SIGNAL2 score	4.7	5.5	5.9	5.4	5.4
OE50 Taxa Score	NA	0.55	0.63	0.55	0.54
AUSRIVAS Bands	NA	B	B	B	B

4.2.6.5 Fish and Frogs

Mountain Galaxias (*Galaxias olidus*) was the only species of fish caught at KCup. It was found during three of the five surveys. No tadpoles were caught and no frogs were heard or observed.

4.2.7 Downstream Site KCdn

KCdn is located on Kangaroo Creek adjacent to the Angus Place pit top and downstream of its confluence with the LDP001 drainage. A large proportion of the flow at KCdn is Angus Place mine water discharged from the LDP.

4.2.7.1 Aquatic and Riparian Habitat

The channel of the creek was narrow (average and maximum widths of 1.0 m and 2 m, respectively), generally box shaped and meandering. It was shallow, with a maximum depth that varied from 0.8-0.9 m and an average depth of 0.3m. There were few backwaters within the site that were devoid of flow.

The riparian vegetation consisted mostly of native eucalypt forest with an open understorey of grasses and thick blackberry bushes. Wombat holes were observed along the riparian banks. The banks throughout most of the site were soft and muddy, undercut and unstable. The channel substratum was composed of unconsolidated sand, with some areas of firm sandy sediments. In Spring 2011, it was noted that mud had been deposited on stream banks and that the substratum in areas of low flow was covered in silt. In Autumn and Spring 2012, the edge areas were covered in silt. The edge habitats consisted of cumbungi stands, trailing bank vegetation and submerged edge grasses.

The total RCE score (28) was consistent across surveys and indicated the stream channel and adjacent features were moderately disturbed. The low score reflected the poor channel structure and condition of the substratum.

4.2.7.2 Water Quality

The baseline surface water quality measurements for KCdn presented in **Table 4-12** show that:

> Electrical conductivity levels were high, ranging from 873-1039 µS/cm, and greater than 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 all the surveys, except that in Spring 2011 when it was within the guidelines;

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

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

Table 4-12 Surface water quality measurements recorded during baseline surveys undertaken at Site KCdn on Kangaroo 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
28/10/2010	12:17	16.82	873	66.1	8.58	8.6
08/06/2011	12:01	12.00	947	75.8	8.66	10.8
1/11/2011	12:11	19.55	1039	91.1	8.47	9.2
29/05/2012	12:00	16.52	991	83.0	7.91	7.1
20/11/2012	13:45	21.00	987	76.5	8.21	12.1

4.2.7.3 Aquatic Plants and Algae

Two species of aquatic macrophytes were recorded at KCdn, with Cumbungi (*Typha* spp) being found during all the baseline surveys, but Jointed Rush (*Juncus articulatus*) observed on only two occasions.

No charophytes were observed. Small amounts of filamentous green algae were observed during all five surveys. In Autumn 2012, an algal mat was present in some of the low flow areas. In Spring 2012, submerged surfaces throughout the site were covered by an algal mat.

4.2.7.4 Aquatic Macroinvertebrates

A total of 39 macroinvertebrate taxa were collected during the baseline surveys, 34 of which were insect families (**Appendix F**). The insects included representatives from eight orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Hemiptera (true bugs), Megaloptera (dobsonflies), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Cyclopidae (copepods), Parastacidae (freshwater crayfish/yabbies), Oligochaeta (freshwater worms) Lymnaeidae (freshwater snails) and Nematoda (round worms). The number of taxa collected per event varied from 14 to 25 (**Table 4-13**). Gyrinidae and Hydroptilidae were the only taxa recorded each survey. Twelve taxa were recorded once (**Appendix F**).

In Autumn and Spring 2011, the macroinvertebrate fauna at Site KCdn was significantly impaired relative to the AUSRIVAS reference conditions and respectively lacked 30% and 45% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4-13**). The samples collected in

Autumn and Spring 2012 were rated severely impaired and lacked 56% and 65% of the expected families, respectively.

The average SIGNAL2 scores were generally ≥ 4, indicating the site was moderately degraded (**Table 4-13)**. The score for the Autumn 2012 survey, however, was 3.7, which is indicative of severe degradation. Twenty 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 4-13 Number of macroinvertebrate taxa recorded at Site KCdn on Kangaroo Creek and the average SIGNAL2 score, OE50 taxa score and AUSRIVAS band for each survey (NA = not analysed).

Indicator	Survey Date				
	28/10/2010	8/06/2011	1/11/2011	29/05/2012	20/11/12
Number of taxa	16	19	25	19	14
SIGNAL2 score	4.9	4.7	4.4	4.8	3.7
OE50 Taxa Score	NA	0.7	0.55	0.44	0.37
AUSRIVAS Bands	NA	B	B	C	C

4.2.7.5 Fish and Frogs

Mountain Galaxias (*Galaxias olidus*) was the only species of fish caught at KCup, but were found only in Autumn 2011. Tadpoles were caught in Spring 2010 and Autumn 2012, but no frogs were heard or observed.

4.3 Upper Wolgan River Catchment

4.3.1 Overview

The Wolgan River is an approximately 64 km long perennial stream that originates above Springvale Colliery 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 drainage lines in the western part of the Project Application Area flow into the Wolgan River.

The base surface water flows are small and derived from shrub swamps and perched aquifers. The river used to receive periodic inflows of mine water make from borehole 940 of Angus Mine 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 river bed comprises surface soils derived from the Burralow Formation of the Triassic Narrabeen Group, with sandstone bedrock outcropping in some locations (MSEC 2013).

The upper reaches of the Wolgan River have been undermined by longwalls extracted at Springvale Colliery and the previous longwalls at Angus Place Colliery were extracted up to 150 metres from the centreline of the river (MSEC 2013). An approximately 3 km reach of the Wolgan River is located within 600 m of the proposed Angus Place longwalls and a 0.9 km stretch is situated within 600 m of the proposed Springvale longwalls. The reach of the river to the east of the proposed Angus Place workings is a second order stream whereas that at the southern end of the workings is a first order stream.

Carne Creek is an approximately 19.5 km long stream that rises 2.5 km NW by W of Bungleboori on the Newnes Plateau and flows in a generally NNW 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 Newnes Plateau 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 more incised and are bordered by steep sandstone escarpments, which increase in depth and frequency with increasing distance downstream (MPR 2010).

An approximately 0.9 km reach of Carne Creek is located within 600 m of the proposed Angus Place longwalls. This reach is a second order stream, except for the arm closest to LWs 1018-1019 which is a first order stream. Four of the proposed Springvale longwalls (LW416-419) would be situated directly below a 2.0 km reach of the creek. One aquatic ecology monitoring site (CCXdn) has been established on Carne Creek. This site was added to the monitoring program in Autumn 2012 and was surveyed again the following spring.

4.3.2 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. The emergency LDPs will be relinquished as part of the Project.

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 subject to moderate disturbance.

4.3.2.2 Water Quality

The baseline surface water quality measurements for WRup presented in **Table 4-14** show that:

> Electrical conductivity 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 (% saturation) levels were below the lower DTV (90% saturation) during all the surveys, except that in Autumn 2012 when it was within the 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 2012, 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 4-14 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 G**). 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 4-15**). Ten taxa (Dytiscidae, Ceratopogonidae, Chironominae, Tanypodinae, Baetidae, Corixidae, Notonectidae, Hemicorduliidae, Lestidae and Leptoceridae) were recorded every survey, but 18 taxa were recorded once (**Appendix G**).

In 2011 and 2012, the macroinvertebrate fauna at Site WRup was significantly impaired relative to the AUSRIVAS reference conditions and lacked between 22% and 45% of the families expected to occur at reference sites with similar physical chemical characteristics (**Table 4-15**). The sample collected in Autumn 2011 was the most impaired.

Table 4-15 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

The average SIGNAL2 scores for the initial three surveys were < 4, indicating the site was severely degraded (**Table 4-15)**. 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 (**Appendix G**).

4.3.2.5 Fish and Frogs

No fish were caught or observed during the aquatic ecology surveys. 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 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-scale disturbance.

4.3.3.2 Water Quality

The baseline surface water quality measurements for WRmd presented in **Table 4-16** show that:

> Electrical conductivity levels were low, ranging from 30-38 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 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 4-16 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 H**). 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 4-17**). 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 H**).

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 4-17**). 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 4-17)**. Twelve taxa had SIGNAL2 scores ≤4, indicating they were tolerant of a variety of environmental conditions, including common forms of water pollution. Fourteen taxa had SIGNAL2 scores ≥ 7, indicating they were sensitive to pollution (**Appendix H**).

Table 4-17 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 (NA = not analysed).

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, 2012a and b). There is no indication that any frogs were heard or observed.

4.3.4 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-scale disturbance.

4.3.4.2 Water Quality

The baseline surface water quality measurements for WRdn presented in **Table 4-18** 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).

Table 4-18 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

4.3.4.3 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 all the surveys except those undertaken in Autumn 2010 and 2011.

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 I**). 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 4-19**). Eleven taxa (Dytiscidae, Gyrinidae, Chironominae, Tanypodinae, Tipulidae, Baetidae, Leptophlebiidae, Synthemistidae, Synlestidae, Gripopterygidae and Leptoceridae) were found during all four surveys (**Appendix I**). 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 4-19**). The samples collected during the spring surveys were rated as equivalent to the AUSRIVAS reference condition and lacked between 6% and 14% of expected taxa.

The average SIGNAL2 scores varied from 4.8 to 5.5 and were thus indicative of either moderate or mild degradation (**Table 4-19**). 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). Twelve taxa were considered to be sensitive to pollution (i.e. had SIGNAL2 scores ≥7) **(Appendix I)**.

Table 4-19 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 (NA = not analysed).

Indicator	Survey Date					
	9/06/2010	9/11/2010	26/05/2011	17/11/2011	24/05/2012	27/11/2012
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 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 5.5km from the headwaters of the catchment (**Figure 4-1)**.

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 0.4m. 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 4-20** 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 4-20 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 or charophytes were observed in Autumn 2012.

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 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) and Oligochaetes (freshwater worms).

More taxa were collected in Spring than in Autumn 2012 (**Table 4-21**), however, 17 of these were common to both surveys (**Appendix J**).

The average SIGNAL2 scores were ≥6.0, indicating the water was not degraded (**Table 4-21**). Seven taxa had SIGNAL2 scores (≤4), indicating they were tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix J**). Ten taxa had SIGNAL2 scores ≥ 7, indicating sensitivity to pollution.

Table 4-21 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 surface flow and water quality 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.

4.4.1 Upper Coxs River Catchment

4.4.1.1 Kangaroo Creek

Daily monitoring of flows at the weir on Kangaroo Creek commenced in November 2008. The data show that the mean daily flow per month since then has varied from 0.012 ML/d to 1.67 ML/d, with a mean daily flow over the year of 0.36 ML/d and that the 5^{th}, 50th (median) and 95^{th} percentile flows are 0 ML/d, 0.13 ML/d and 0.87 ML/d, respectively (RPS 2013c). The quality of the water at the flow monitoring point has not been assessed. Fortnightly monitoring of flows at sites on Kangaroo Creek upstream and downstream of LDP001 commenced in February 2011. The data for the downstream site show that the mean daily flow per month has varied from 1.52 ML/d to 18.5 ML/d, the mean daily flow over the year was 5.15 ML/d and the 5^{th}, 50th (median) and 95^{th} percentile flows were 1.55 ML/d, 3.96 ML/d and 8.53 ML/d, respectively (RPS 2013c). The data for the upstream site show that the mean daily flow per month since then has varied from 0 ML/d to 18.5 ML/d, with a mean daily flow over the year of 2.05 ML/d and that the 5^{th}, 50th (median) and 95^{th} percentile flows are 0 ML/d, 0.66 ML/d and 3.93 ML/d, respectively (RPS 2013c). The upper reach of Kangaroo Creek is therefore ephemeral and ceases to flow for approximately 20% of the time. Baseflow from the local groundwater system maintains the creek for some time after rainfall but not during prolonged dry weather periods (RPS 2013c).

At the upstream monitoring site on Kangaroo Creek, the following exceedances of ANZECC/ARMCANZ (2000) DTVs were noted: EC, Cadmium Turbidity, Nitrite as N occasionally, Turbidity sometimes and pH and Copper frequently. More exceedances were evident at the downstream monitoring site on this creek, with those for Turbidity, Cadmium and Total Phosphorus occurring occasionally, while those for EC, Copper, Total Nitrogen were frequent. The data suggest that the discharge from LDP001 elevates the pH, EC, total dissolved solids (TDS), barium, calcium, magnesium, potassium, sodium, Total Sulphur and alkalinity (carbonate, bicarbonate and total) levels at the downstream site. The pH, EC, TDS, Hardness as CaCO3, Sodium, Calcium, Magnesium, Boron, alkalinity and nitrite as N levels in the creek were an order of magnitude greater downstream than upstream of LDP001.

4.4.1.2 Coxs River

The flows at sites on the Coxs River upstream and downstream of the confluence with Kangaroo Creek have been monitored since February2011. The data for the upstream site show that the mean daily flow per month since then has varied from 0.97 ML/d to 8.97 ML/d, with a mean daily flow over the year of 3.49 ML/d and 5^{th}, 50th (median) and 95^{th} percentile flows of 0.1 ML/d, 2.25 ML/d and 11.99 ML/d, respectively (RPS 2013c). At the downstream site, the mean daily flow per month has varied from 0.39 ML/d to 25.7 ML/d, with a mean daily flow over the year of 6.01 ML/d and 5^{th}, 50th (median) and 95^{th} percentile flows of 0.34 ML/d, 4.57 ML/d and 17.5 ML/d, respectively (RPS 2013c).

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 site on the Coxs River. There is also a marked increase in the levels of

Nitrate as N and total Nitrogen as N between the upstream and downstream monitoring site on Coxs River. The levels of the latter, however, are greater than in the discharge and are therefore most likely due to other activities (e.g. farming). The pH, sodium and alkalinity levels were an order of magnitude greater downstream than upstream of the confluence with Kangaroo Creek.

4.4.2 Wolgan River Catchment

Fortnightly monitoring of flows at a site on the Wolgan River downstream of Angus Place commenced in January 2004. The data show that the mean daily flow per month since then has varied from 3.07 ML/d to 10.2 ML/d, with a mean daily flow over the year of 6.0 ML/d and that the 5th, 50th (median) and 95th percentile flows are 0.15 ML/d, 3.78 ML/d and 15,2 ML/d, respectively (RPS 2013c). The following exceedances of ANZECC/ARMCANZ (2000) DTVs were noted: pH and Nitrate as N occasionally, Total Nitrogen as N and Total Phosphorus sometimes and Aluminium frequently (RPS 2013c).

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 rivers 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). 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).

In June 2007, an investigation into the aquatic ecology of two sites on Kangaroo Creek was undertaken in relation to the proposed expansion of the Kerosene Vale Ash Repository (The Ecology Lab 2007). Site 1 was located downstream of Angus Place LDP001. The riparian vegetation at this site consisted of large eucalypt trees, blackberry and pasture grasses. *Juncus* sp. and Cumbungi (*Typha* sp.) were present towards the bottom of the site. The creek channel was relatively narrow and had a sandy substratum that was covered in dark silt deposited by mine water discharge. Woody debris and detritus were absent. Site 2 was located 200 m downstream of the Wolgan Road crossing. The riparian vegetation at this site consisted mainly of pasture grasses with occasional willow trees and blackberry bushes. The creek channel was generally narrow, although there were some braided sections. The substratum was mostly sandy, but there was evidence of silt from the discharge. The flow was strong and the creeks banks were loose and heavily eroded. Occasional clumps of *Juncus* sp. were present in narrower sections of the channel. The habitat at both sites was considered to be of minimal value for fish and no specimens were recorded. The conductivity, pH and turbidity levels at both sites were within the ANZECC/ARMCANZ (2000) guidelines, but dissolved oxygen levels were below the lower DTV. The RCE score for Sites 1 (32) and 2 (21) were indicative of moderate and large-scale disturbance respectively. AUSRIVAS samples of edge habitat yielded a total of 32 macroinvertebrate taxa, with 15 of these being found at Site 1 and 27 at Site 2. The macroinvertebrate fauna at Site 1 was found to be equivalent to the AUSRIVAS reference condition but that at Site 2 was severely impaired.

The NSW Office of Water Gauging Station No. 212054 is situated on the Coxs River below Angus Place but above Lake Wallace. Surface flows and the salinity of the water at this site have been monitored daily since 1992. The daily flow rate has varied from 0.3 ML/d to 5,320 ML/d, with a mean of 29.9 ML/d and 5^{th}, 50^{th} (median) and 95^{th} percentile flows of 2.9 ML/d, 12.2 ML/d and 86.6 ML/d, respectively. Salinity levels have varied, with a trend of increasing salinity evident between 1992 and 2007 followed by a marked reduction in salinity after 2010. Salinity levels above 600 µS/cm have been recorded for approximately 20 years (RPS 2013c).

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, just outside the national park, and Wolgan Gap gave mixed results, with some indicating slightly 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 the national park.

The Public Environment Report submitted to the Department of Environment and Heritage (DEH) 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;
- 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 downstream of the confluence with Kangaroo Creek (CR2) and with AP_ LDP003 (CR4) were in the poorest overall condition.

At the upstream site on Kangaroo Creek (KCup), the channel was incised to 2 m below the surrounding valley floor, had steep sides and meandered. Ferns were abundant on the valley floor and trailed across the creek banks and overhung the channel. Moss and fallen logs were present throughout the site. The substratum was sandy with some boulder or bedrock outcrops and a large amount of detritus. At the downstream site (KCdn), the channel was narrow, meandering and mostly box shaped. The banks throughout this site were undercut and unstable. The riparian vegetation consisted of native eucalypt forest with an understorey of grasses and thick blackberry along bank edges. The riparian and aquatic environment at KCup was in a better overall condition than that at the other sites in the catchment.

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, CR5 and KCdn 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 CR1 were always within the guidelines, but those at KCup were often below the lower DTV. The dissolved oxygen levels at all of the sites, except CR5, were generally below the guidelines and considerably lower in Kangaroo Creek than in Coxs River. The pH of the water at Sites CR2, CR5 and KCdn was more alkaline than the upper DTV (8.0 units), while that at KCup was more acidic than the lower DTV (6.5 units). The pH levels at CR1 and CR4, however, were generally within the guidelines. The turbidity levels at all six sites 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. 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 the other sites in the catchment. Jointed Rush and Cumbungi were the most widespread plants.

Filamentous green algae were found at all six sites. Charophytes were absent from KCdn and 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.

Filamentous green were observed at the three sites on the river during most surveys, with amounts varying from small to moderate. Charophytes were also recorded at all three sites, but were found on only one occasion at the upstream site. No algae were observed at the Carne Creek site.

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 macroinvertebrate fauna at the Kangaroo Creek sites was less diverse, with a total of 45 taxa recorded and numbers per site varying from 24 at KCup to 39 at KCdn.

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 fauna in Kangaroo Creek was more impaired with that at KCup being classed as significantly impaired on four occasions and that at KCdn being significantly impaired in 2011 but severely impaired in 2012.

The average SIGNAL2 scores indicated the upstream site on Kangaroo Creek (KCup) was in the best condition, being classified as moderately degraded during all surveys. The condition of the downstream creek site (KCdn) and the Coxs River sites varied from moderately to severely degraded, with Sites CR1 and CR5 being in the poorest condition.

The MDS plot shows that the macroinvertebrate assemblages at Sites KCup and KCdn on Kangaroo Creek were distinct from each other and from those at the Coxs River sites. The assemblages at CR1 show some overlap with those at CR2 but were distinct from those at CR4 and CR5 on the Coxs River (**Figure 4-2**).

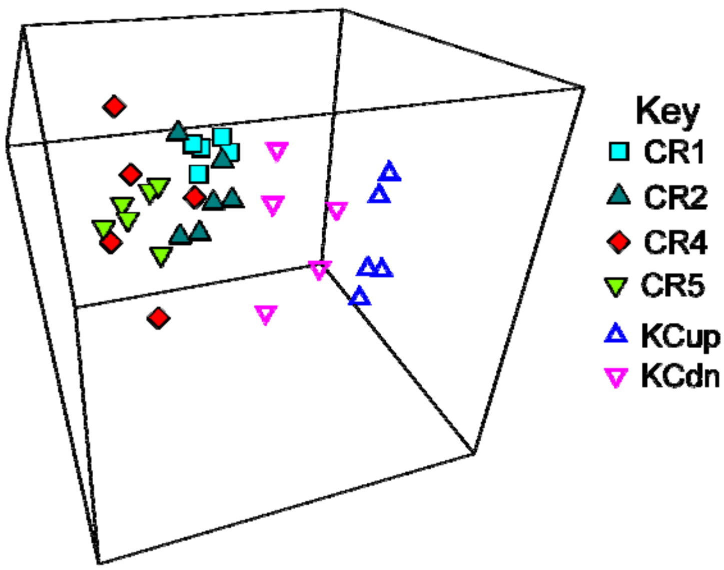

Figure 4-2: MDS plot comparing the multivariate structure of the aquatic macroinvertebrate fauna at the monitoring sites in the Coxs River catchment.

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 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.

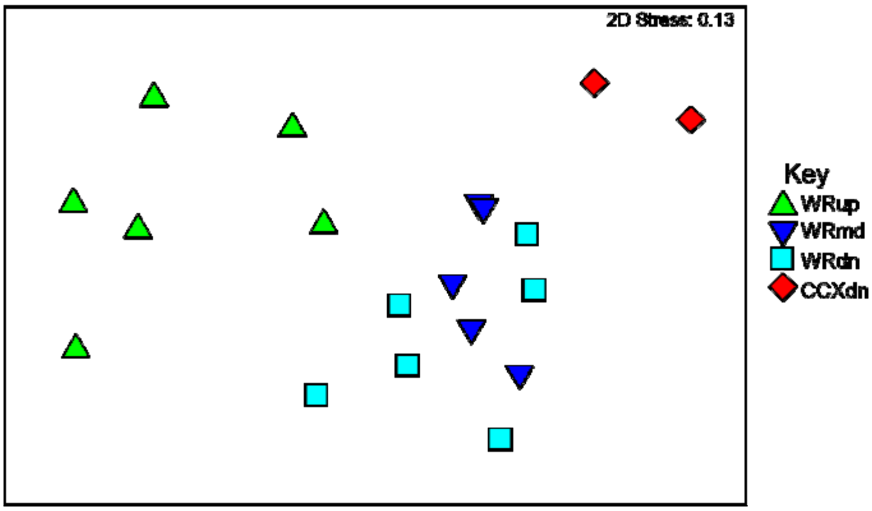

Figure 4-3: MDS plot comparing the multivariate structure of the aquatic macroinvertebrate fauna at the monitoring sites in the Wolgan River catchment.

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. Mountain galaxias was the only fish species recorded at KCup and KCdn. Tadpoles were observed at all the sites on the river and at KCdn, 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 only commenced 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. The discharge from LDP001 appears to have adverse effects on the condition of the aquatic habitats and quality of water at KCdn and CR2, but its effect on biological indicators is less clear with only SIGNAL2 and AUSRIVAS scores being poorer on average at KCdn than at KCup, and macrophytes being less diverse at CR2 than CR1.

5 Existing Environment – Aquatic Ecology of Drainages Downstream of Swamps

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 2013c). 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 these swamps are incised and bordered by steep sandstone escarpments, that increase in depth and frequency with increasing distance downstream (MPR 2012c).

In this section, the aquatic habitats, water quality, aquatic flora and fauna found at sites on drainages downstream of two of the Shrub Swamps in the Wolgan River catchment, Twin Gully Swamp (TGS) and Tri Star Swamp (TRIS), and Bird Rock Swamp (BRS), a Hanging Swamp in the Carne Creek catchment, are described. The Shrub Swamps are located above the proposed workings, with Twin Gully Swamp being above proposed LW1010 and Tri-Star Swamp above proposed LW1004 to LW1006. Bird Rock Swamp is situated to the east of proposed LW1007 to LW1009. The location of these sites is shown in **Figure 4-1** and their geographic co-ordinates are presented in **Table 5-1**.

The description of the aquatic ecological attributes of these three sites 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. A brief description of the results of Angus Place's surface flow and water quality monitoring undertaken in Twin Gully and Tri Star Swamps are presented in Section 5.3.

Table 5-1 Geographic coordinates and locality description of the baseline aquatic ecology monitoring sites situated in the drainages downstream of swamps in the Wolgan River and Carne Creek catchments.

Site Code	Catchment	Easting	Northing	Description
TGS	Wolgan River	235780	6308693	Twin Gully Swamp site sampled around 500m upstream of TGS tributary confluence with Wolgan River.
TRIS		236571	6307015	Tri Star Swamp site sampled around 250m upstream of TRIS tributary confluence with Wolgan River.
BRS	Carne Creek	239961	6308489	Bird Rock Swamp site sampled at the headwaters of a tributary to Carne Creek within the Bird Rock Flora Reserve.

Note that the AUSRIVAS predictive software has not been used to analyse the macroinvertebrate data, because it is unlikely that the fauna at reference sites comparable to sites downstream of the sites has been modelled. 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).

5.1 Wolgan River Catchment

Twin Gully Swamp and Tri Star Swamp drain to the west from Sunnyside Ridge and discharge to the middle and downstream ends respectively of the Wolgan River within the study area. The water level monitoring that has been undertaken at Angus Place indicates Twin Gully Swamp and the south-eastern section of Tri Star Swamp are permanently waterlogged systems, but the north-eastern section of Tri-Star Swamp is only waterlogged periodically. The water level in permanently waterlogged swamps is relatively stable and is relatively unaffected by changes in climatic conditions (RPS 2013b). The water level in these swamps depends mainly on aquifer recharge, with rainfall inflows being minor contributors. The water level in periodically waterlogged swamps, however, changes considerably and fairly rapidly in response to significant rainfall events and emergency discharge events. Groundwater monitoring indicates the water level in these swamps usually fluctuates by about 1 m but increases of up to 2 m can occur after significant rainfall events (RPS 2013b). Aquifer recharge does not contribute significantly to baseflow in periodically waterlogged swamps. The quality of water in the swamps in the vicinity of the Angus Place Project Application Area has not been monitored, so the baseline aquatic ecology monitoring program (MPR 2010, 2011a and b; 2012a and b; 2013) is the only source of information on this attribute.

Neither Twin Gully nor Tri Star Swamp has been disturbed previously by mine water discharge or longwall mining. Four Shrub Swamps (Sunnyside Swamp, East Wolgan Swamp, Narrow Swamp North and Narrow Swamp South) situated to the south-west of the Project Application Area have been disturbed by past mining.

5.1.1 Twin Gully Swamp (Site TGS)

Twin Gully Swamp is dominated by *Baeckea linifolia*, *Grevillea acanthifolia*, *Gleichenia dicarpa* and *Sphagnum cristatum* (Centennial 2012b). Site TGS is situated adjacent to a rock pagoda approximately 500 m upstream of the Twin Gully Swamp tributary's confluence with the Wolgan River (**Figure 4-1**).

5.1.1.1 Aquatic Habitat

Site TGS is located in a narrow gorge with cliff faces abutting the narrow valley floor. It receives a constant supply of dripping water from the southern cliff wall. The valley floor at the upper end of the site was covered with dense heath vegetation, primarily coral ferns and sword grass and these have overgrown the drainage channel. In some areas there was no observable channel or surface water, suggesting that the flow had either gone underground or broadened to a wide shallow seepage flow in the swamp bed. The drainage channel was narrow and shallow and formed a series of bedrock cascades. The pool had maximum and average widths of 2 m and 1 m, respectively and a maximum depth that varied from 0.3-1.0 m.

Moss was prevalent on channel edges and cliff faces. Some of the pools in the channel were covered by a dense canopy of ferns. The aquatic habitats represented along the pool edge included trailing bank vegetation, detritus, undercut banks and logs. The channel substratum was initially sandy with particulate material and fine detritus overlying a bedrock base, but in subsequent surveys was found to be mostly bedrock with some sand and silt accumulations. Large boulders occurred throughout the site. In Autumn 2012, it was noted that the pools had been scoured out since the previous survey. During three surveys, it was noted that the substratum and/or trailing bank vegetation were covered in silt.

The total RCE score varied from 48 to 49 across surveys, indicating the stream channel and adjacent features were subject to minimal disturbance.

5.1.1.2 Water Quality

The baseline surface water quality measurements for TGS presented in **Table 5-2** show that:

> Electrical conductivity levels were generally very low, ranging from 22-26 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 all of the surveys, except that in Autumn 2012;

> pH levels were below the lower DTV (6.5 units) and considerably lower in Spring 2011 and Autumn 2012 than during the initial and subsequent surveys;

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

5.1.1.3 Aquatic Plants and Algae

No macrophytes were observed. Filamentous green algae were present during all surveys, with amounts varying from very small to moderate.

Table 5-2 Surface water quality measurements recorded during baseline surveys undertaken at Site TGS downstream of Twin Gully Swamp (Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia).

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
10/11/2010	9:19	11.34	23	66.8	5.20	ND
24/05/2011	9:33	8.33	22	80.7	5.41	15.1
17/11/2011	9:57	12.15	26	76.6	4.19	6.2
23/05/2012	9:52	6.41	26	92.8	4.68	2.8
27/11/2012	8:19	12.24	ND	81.4	5.38	17.5

5.1.1.4 Aquatic Macroinvertebrates

A total of 28 macroinvertebrate taxa were collected during the baseline monitoring events, 24 of which were insect families (**Appendix K**). 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 Hydracarina (freshwater mites), Oligochaeta (freshwater worms), Dugesiidae (flatworms) and Gordioidea (hair worms).

The number of taxa collected per survey varied from 15 to 19 (**Table 5-3**). Seven taxa (Gyrinidae, Tanypodinae, Leptophlebiidae, Telephlebiidae, Megapodagrionidae, Gripopterygidae and Leptoceridae) were recorded during every survey while six taxa were found once (**Appendix K**).

The SIGNAL2 scores varied from 5.4 to 5.9, suggesting the site was mildly degraded (**Table 5-3**). Eleven taxa had low SIGNAL2 scores (≤4), indicative of tolerance of a variety of environmental conditions, including common forms of water pollution (**Appendix K**). Nine taxa had SIGNAL2 scores ≥ 7, indicating they are sensitive to pollution.

Table 5-3 Number of macroinvertebrate taxa recorded at Site TGS downstream of Twin Gully Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date				
	10/11/2010	24/05/2011	17/11/2011	23/05/2012	27/11/2012
Number of taxa	15	17	16	19	18
SIGNAL2 score	5.87	5.65	5.66	5.37	5.50

5.1.1.5 Fish and Frogs

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

5.1.2 Tri Star Swamp (TRIS)

Tri Star Swamp is a permanently wet, groundwater fed system dominated by *Baeckea linifolia*, *Gleichenia dicarpa, Grevillea acanthifolia, Lepidosperma limicola* and *Leptospermum grandifolium* (Centennial Angus Place 2012b). Site TRIS is situated approximately 250 m upstream of the Tri Star Swamp tributary's confluence with Wolgan River (**Figure 4-1**).

5.1.2.1 Aquatic Habitat

Water was observed seeping from the cliff face on both sides of the site. The valley floor adjoining the lower end of the site was covered with dense swamp and heath vegetation, including coral ferns and sword grass, which had overgrown the drainage channel. In some areas there was no observable channel or surface water. During the first three surveys, the channel was narrow, with maximum and average widths of 1.5 m and 0.8 m, respectively and generally shallow (less than 15 cm deep). The maximum depth varied from 0.3 -

0.8 m. During the Autumn 2012 survey, it was noted that flows up to 1 m above previous levels had occurred and that these had resulted in overland flow in new areas and that maximum and average depths had increased to 1.0 m and 0.4 m, respectively.

The aquatic habitats at the pool edge included trailing bank vegetation, rushes, detritus, undercut banks and logs. The channel substratum consisted mainly of bedrock, but with accumulations of sand and fine silty matter in areas isolated from flow and deeper pools. Moss was present on the banks of channel throughout the site. During three surveys, it was noted that the substratum was covered in silt.

The total RCE score was high (48) and consistent across surveys, indicating the stream channel and adjacent features were subject to minimal disturbance.

5.1.2.2 Water Quality

The baseline surface water quality measurements for TRIS presented in **Table 5-4** show that:

> Electrical conductivity levels were generally very low, ranging from 18-24 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 surveys, but within the guidelines otherwise;

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

> Turbidity levels exceeded the upper DTV in Autumn and Spring 2011, but were within the DTV range (2-25 NTU) during the other surveys.

Table 5-4 Surface water quality measurements recorded during baseline surveys undertaken at Site TRIS downstream of Tri Star Swamp. Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	µS/cm	%saturation	pH Units	NTU
9/11/2010	13:43	11.59	19	73.2	5.64	ND
23/05/2011	14:28	8.07	18	85.9	5.70	29.2
16/11/2011	14:25	12.11	24	100.2	5.39	64.5
21/05/2012	13:52	7.14	23	95.6	5.13	13.3
26/11/2012	13:16	13.08	0	84.5	5.57	14.5

5.1.2.3 Aquatic Plants and Algae

Three different aquatic macrophytes were recorded during the baseline monitoring. The first plant was observed in Spring 2010 and tentatively identified as a member of the family Cyperaceae (sedge). Bulbous Rush was recorded in Autumn and Spring 2011 and Autumn 2012. 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.

Charophytes were recorded in Spring 2010 and Autumn 2011, but not in subsequent surveys. Filamentous green algae were present, with amounts varying from very small to moderate.

5.1.2.4 Aquatic Macroinvertebrates

A total of 32 macroinvertebrate taxa were collected during the baseline monitoring events, 26 of which were insect families (**Appendix L)**. The insects included representatives from the same eight orders as TGS plus an additional order the Megaloptera (dobsonflies). The other taxa were Hydracarina (freshwater mites), Collembola (springtails), Oligochaeta (freshwater worms) and Sphaeriidae (pea shells) and Gordioidea (hair worms).

The number of taxa collected per survey varied from 14 to 21 (**Table 5-5**). Five taxa (Tanypodinae, Leptophlebiidae, Synthemistidae, Leptoceridae and Philorheithridae) were found every survey, while eleven were sampled once (**Appendix L**).

The SIGNAL2 scores varied from 5.4 to 5.8, suggesting the site was mildly degraded. Fourteen taxa had low SIGNAL2 scores (≤4), indicating they are tolerant of a variety of environmental conditions, including common forms of water pollution (**Appendix L**). Nine taxa had high SIGNAL2 scores (≥ 7), indicative of sensitivity to pollution.

Table 5-5 Number of macroinvertebrate taxa recorded at Site TRIS downstream of Tri Star Swamp and the average SIGNAL2 score for each survey

Indicator	Survey Date				
	9/11/2010	23/05/2011	16/11/2011	21/05/2012	26/11/2012
Number of taxa	15	17	15	14	21
SIGNAL2 score	5.47	5.76	5.73	5.71	5.43

5.1.2.5 Fish and Frogs

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

5.2 Carne Creek Catchment

The headwater sub-catchments of Carne Creek support Shrub Swamps and Hanging Swamps, none of which has been undermined or subjected to mine discharge.

5.2.1 Bird Rock Swamp (BRS)

Bird Rock Swamp is situated on an unnamed tributary on the western side of Carne Creek. The unnamed tributary flows to the east from Sunnyside Ridge through Bird Rock Flora Reserve and joins Carne Creek midway along the study area. The lower part of the tributary flows through narrow steep sided escarpment, which falls over 80m in altitude over the last 700m before joining Carne Creek (MPR 2012c). Site BRS is situated at the headwaters of a tributary to Carne Creek within the Bird Rock Flora Reserve.

5.2.1.1 Aquatic Habitat

The drainage channel along most of the site was completely overgrown with dense vegetation. The riparian vegetation was unbroken and forest eucalypts extended down to the middle of the drainage line. During the first three surveys, the swamp channel was narrow, with maximum and average widths of 1.0 m and 0.4 m respectively, had a maximum depth that varied from 0.2-0.6 m but was mostly shallow (depth less than 0.1 m). In Autumn 2012, it was noted that flows up to 1 m above previous water levels had occurred and that these had carved new flow paths in some parts of the site, increased the maximum depth of pools to 1.2 m and maximum and average width of the channel to 2.0 m and 0.5 m, respectively.

The aquatic habitats represented at the pool edge included trailing bank vegetation, detritus, undercut banks and logs. The substratum consisted mainly of bedrock with accumulations of sand and pebbles, and fine silty matter in areas isolated from flow evident until Autumn 2012 when they had been scoured away. Boulders were present throughout the site. In Spring 2012, fine silty matter was observed in areas of low flow.

The total RCE score was high (48) and consistent across all surveys, indicating the stream channel and adjacent features were subject to minimal disturbance.

5.2.1.2 Water Quality

The baseline surface water quality measurements for BRS presented in **Table 5-6** show that:

> Electrical conductivity levels were generally low, ranging from 39-48 µS/cm, but within the default trigger value (DTV) range (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 otherwise;

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

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

Table 5-6 Surface water quality measurements recorded during baseline surveys undertaken at Site BRS downstream of Bird Rock Swamp. Shading indicates values are outside the ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed upland rivers in south-east Australia

Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen	pH	Turbidity
		°C	μS/cm	%saturation	pH Units	NTU
10/11/2010	12:53	11.24	39	77.2	4.60	ND
24/05/2011	13:02	9.45	41	78.3	5.21	10.5
17/11/2011	12:35	11.61	39	97.4	4.16	11.2
23/05/2012	13:00	8.64	48	94.6	4.88	4.1
27/11/2012	11:21	12.39	0	84.9	4.51	13.5

5.2.1.3 Aquatic Plants and Algae

No aquatic macrophytes were observed. Very small amounts of filamentous green algae were observed in Spring 2010, but none was found subsequently.

5.2.1.4 Aquatic Macroinvertebrates

A total of 25 macroinvertebrate taxa were collected during the baseline monitoring events, 22 of which were insect families (**Appendix M**). The insects included representatives from eight orders: Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Lepidoptera (butterflies and moths), Neuroptera (lacewings), Odonata (dragonflies), Plecoptera (stoneflies) and Trichoptera (caddis flies). The other taxa were Parastacidae (freshwater crayfish/yabbies), Erpobdellidae (leeches) and Oligochaeta (freshwater worms).

The number of taxa collected per event varied from 10 to 19, with more taxa being collected during the last three surveys (16-19) than the two earlier surveys (10-13) (**Table 5-7**). Six taxa (Tipulidae, Leptophlebiidae, Synthemistidae, Austroperlidae, Gripopterygidae and Leptoceridae) were found every survey, but six were recorded once (**Appendix M**).

The SIGNAL2 scores varied from 5.6 to 6.5 and were thus indicative of mild to no degradation (**Table 5-7**). Ten taxa had low SIGNAL2 scores (≤4), indicating tolerance to a variety of environmental conditions, including pollution (**Appendix M**). Eight taxa had SIGNAL2 scores ≥7, indicating they were sensitive to pollution sensitive.

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

Indicator	Survey Date				
	10/11/2010	24/05/2011	17/11/2011	23/05/2012	27/11/2012
Number of taxa	10	13	17	16	19
SIGNAL2 score	5.60	6.00	6.47	5.63	5.74

5.2.1.5 Fish and Frogs

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

5.3 Surface Water Quality Monitoring Program

The Angus Place Surface Water Quality Monitoring Programs also provides information on variation in surface flows and water quality in Twin Gully Swamp and Tri Star Swamp.

The flows in Twin Gully Swamp and Tri Star Swamp have been monitored since February and July 2011, respectively. At Twin Gully Swamp, the mean daily flow per month since then has varied from 0.21 ML/d to 6.08 ML/d, with a mean daily flow over the year of 1.23 ML/d and 5th, 50th (median) and 95th percentile flows of 0.17 ML/d, 0.78 ML/d and 2.73 ML/d, respectively (RPS 2013c). At Tri Star Swamp, the mean daily flow per month has varied from 0.05 ML/d to 15.5 ML/d, with a mean daily flow over the year of 1.48 ML/d and 5th, 50th (median) and 95th percentile flows of 0.053 ML/d, 0.2 ML/d and 1.09 ML/d, respectively (RPS 2013c).

RPS (2013c) has compared the water quality measurements from these swamps with the ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in south-east Australia. At Twin Gully Swamp, pH, aluminium, copper and total phosphorus levels were frequently, total nitrogen as N were sometimes and turbidity, cadmium, zinc and nitrogen as ammonia were occasionally above their respective DTVs. At Tri Star Swamp, pH levels were consistently, Aluminium and Copper were frequently, Nitrate as N, Total Nitrogen as N and Total Phosphorus were sometimes and turbidity levels were occasionally in excess of their respective DTVs. Low flows combined with decomposition of organic matter and local geology are believed to have contributed to the acidity of the water in these swamps, which may in turn have caused the leaching of aluminium from soils (RPS 2013c).

5.4 Summary

5.4.1 Aquatic Habitat

At the sites downstream of the Shrub Swamps, water was observed seeping from the cliffs. The valley floor adjoining some sections of these sites was covered with dense swamp and heath vegetation which had overgrown the drainage channel. The drainage channel along most of the site downstream of the Hanging Swamp was completely overgrown with dense vegetation. The channel substratum at all the sites consisted mainly of bedrock, but with some sand and silt accumulations. Boulders were present throughout the sites downstream of the Twin Gully and Bird Rock swamps. Moss was prevalent along the banks downstream of the Shrub Swamps. There was evidence that high flows had resulted in scouring of habitats, deepening of pools and new flow paths. The total RCE scores for the three sites were high, indicating there was minimal disturbance of riparian and aquatic habitats.

5.4.2 Water Quality

The electrical conductivity of the water downstream of Bird Rock Swamp was low, but within the ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in south-east Australia. The electrical conductivity levels of the water downstream of Twin Gully Swamp and Tri Star Swamp were below the lower DTV. The dissolved oxygen levels at all three sites were frequently below the lower DTV, but more so downstream of Twin Gully Swamp. The pH of the water downstream of Twin Gully Swamp and Bird Rock Swamp was more acidic than that below Tri Star Swamp, but levels at all sites were below the lower DTV. The turbidity levels downstream of the Twin Gully and Bird Rock swamps were within the guidelines, but those downstream of Tri Star Swamp exceeded the upper DTV on two occasions.

5.4.3 Aquatic Plants and Algae

No aquatic macrophytes were observed downstream of Twin Gully Swamp or Bird Rock Swamp. Three different aquatic macrophytes were recorded downstream of Tri Star Swamp: a plant tentatively identified as a member of the family Cyperaceae (sedge), Bulbous Rush and Swamp Clubrush, with the latter being the most reliable identification. Filamentous green algae were present in small to moderate amounts downstream of the Shrub Swamps, but only recorded once downstream of the Hanging Swamp. Small amounts of charophytes were observed on occasion downstream of Tri Star Swamp.

5.4.4 Aquatic Macroinvertebrates

The macroinvertebrate samples collected downstream of the swamps yielded considerably fewer taxa (25-32) than those collected at the upstream (43) and downstream (39) sites on the Wolgan River. The site downstream of Tri Star Swamp supported the most diverse fauna, followed by that downstream of Twin Gully

Swamp. Considerably fewer taxa were collected per survey, with numbers per site ranging from 10-21. The samples contained representatives of 39 insect families, four crustacean and worm taxa and one taxon each of bivalves, freshwater mites, leeches and springtails. Less than a quarter of the taxa found at each site were recorded every survey.

The sites downstream of the Twin Gully and Tri Star swamps were mildly degraded, whereas that downstream of Bird Rock Swamp varied from mildly to not degraded.

The macroinvertebrate assemblages downstream of Bird Rock Swamp (BRS) were distinct from those downstream of the Shrub Swamps (**Figure 5-1**).

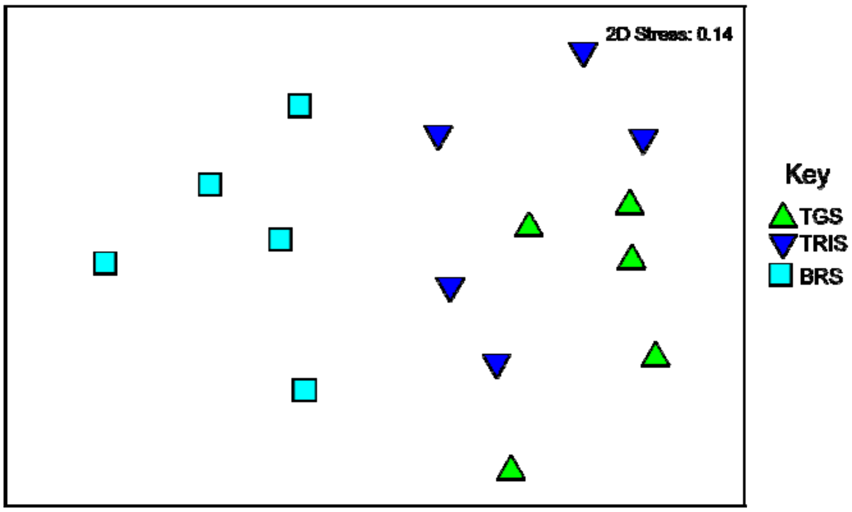

Figure 5-1: MDS plot comparing the multivariate structure of the aquatic macroinvertebrate fauna at Sites downstream of Twin Gully Swamp (TGS), Tri Star Swamp (TRIS) and Bird Rock Swamp (BRS). Sites that have similar assemblages are grouped together on the graph, while those with dissimilar assemblages are relatively dispersed from each other.

5.4.5 Fish and Frogs

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

5.4.6 Conclusions

The biannual baseline monitoring undertaken at Sites TGS, TRIS and BRS 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.

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 cycling of nutrients, movement and transfer of energy and materials through the sediments and maintenance of to the maintenance of voids, alteration of reduction-oxidation gradients, enhancing the release of organic carbon and 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 targeting the shallow groundwater below individual swamps and near-surface unconfined aquifer in the Banks Wall Sandstone below the Project Application Area are described (See Sections 6.2 and 6.3, respectively). The location of the boreholes 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 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 Springvale 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 Project Application Area based on the reports prepared by the specialist groundwater consultants (Adhikary and Wilkins 2013; RPS 2013b) is presented in Section 6.1. The results of the groundwater monitoring program in the swamps undertaken by Angus Place are outlined in Section 6.2. This information provides a context for the pilot stygofauna study and for the impact assessment in Section 8.

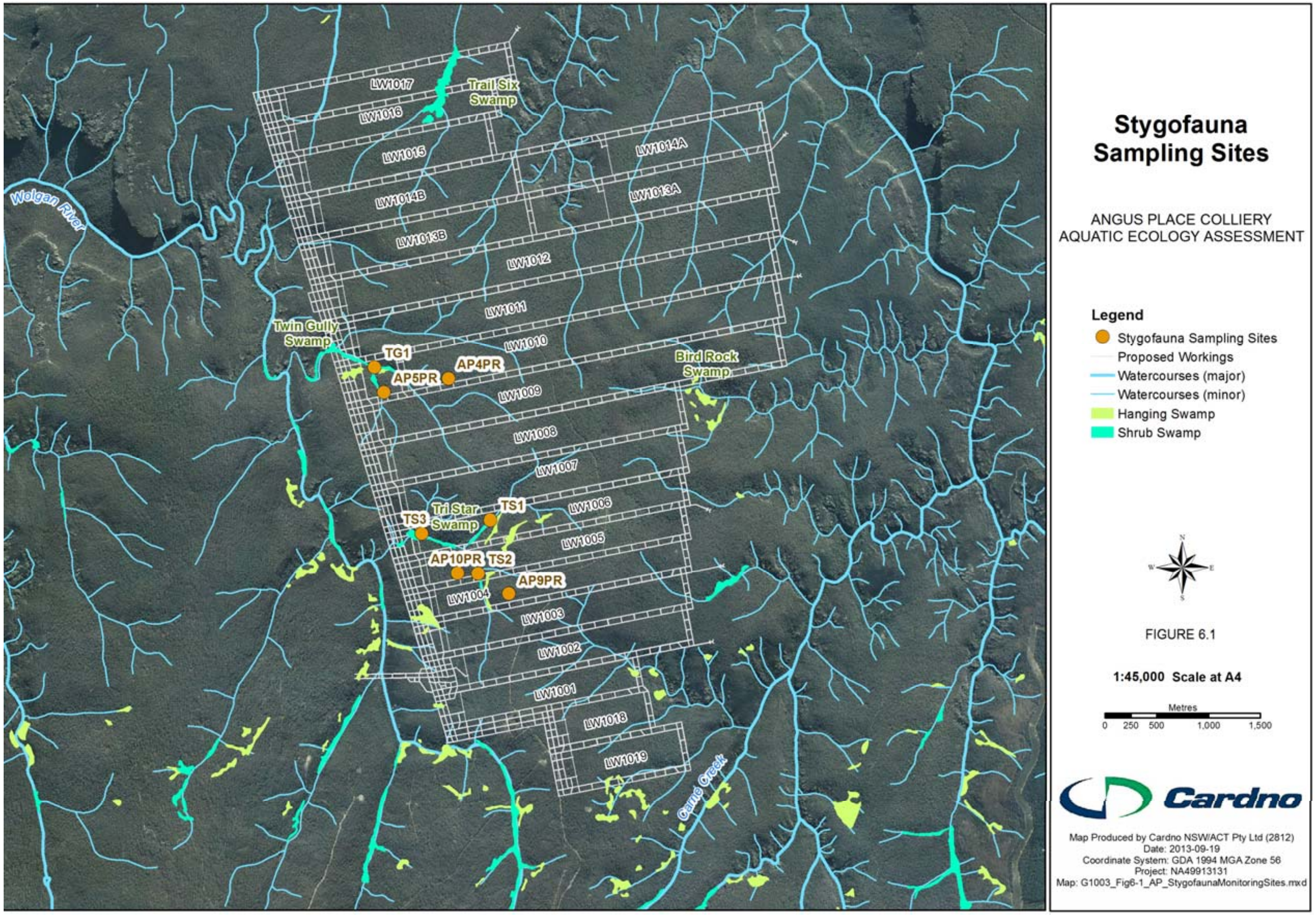

Figure 6-1 Map showing the location of the boreholes used in the stygofauna pilot survey relative to the proposed longwalls.

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)
AP4PR	Banks Wall Sandstone Aquifer - Deep	237155	6308656	16	15.5
AP5PR	Banks Wall Sandstone Aquifer - Shallow	236530	6308525	16	15
AP9PR	Banks Wall Sandstone Aquifer - Deep	237738	6306577	8	8
AP10PR	Banks Wall Sandstone Aquifer - Shallow	237243	6306778	16	15
TG1	Twin Gully Swamp - water level	236438	630876	7	2
TS1	Tri Star Swamp - upstream	237559	6307289	17	15
TS2	Tri Star Swamp - upstream	237443	6306772	8	5
TS3	Tri Star Swamp - downstream	236897	6307159	7	3

6.1 Groundwater Systems Relevant to the Project

The aquifers and aquitards that occur below the proposed 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

Three of the swamp boreholes (TG1 on Twin Gully Swamp, TS2 and TS3 on Tristar Swamp) are located in permanently waterlogged sections of the swamps, with the standpipes at Sites TG1 and TS2 being upstream relative to the main swamp inflows and that at TS3 being downstream (RPS 2013b). The fourth borehole, TS1, is located upstream of the main inflows in a section of the Tri Star Swamp which is periodically waterlogged.

Stygofauna samples were collected using a hand-hauled weighted bailer, with the volume of water sampled from the swamp bores varying from 2 L (TG1) to 15 L (TS1) (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 such studies 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 I**.

6.2.1 Water Quality

The dissolved oxygen, pH and Oxidation Reduction Potential (ORP) levels were similar at the two sites situated upstream relative to the main swamp inflows (**Table 6-2**). The conductivity and turbidity levels recorded at TS2, however, were much higher than at TG1. Considerable differences in water quality were also evident across the three sites in Tri Star Swamp, with Site TS1 in the periodically waterlogged area having the lowest conductivity, dissolved oxygen and pH and turbidity levels, but similar ORP levels to the other sites and Sites T2 and TS3 differing in conductivity and dissolved oxygen levels, but having similar pH, OPR and turbidity levels.

6.2.2 Stygofauna

No animals were found in the samples collected at the TG1 borehole. This may reflect the small volume (2 litres) of water sampled.

The samples collected from borehole TS1 on Tri Star Swamp yielded a total of 310 invertebrates representing eight taxa (**Table 6-3**). Only one of these invertebrates, a cyclopoid copepod, was considered to be likely stygofauna. The two specimens each of Acarina (mites) and Tardigrada (water bears) collected were considered possible stygofauna. The other taxa recorded were either terrestrial or associated with saturated soils. The TS2 samples yielded a total of three animals, one of which was a nematode and could potentially be a member of the stygofauna. The other two animals were tipulid flies which are normally found in association with saturated soils. The TS3 sample contained one ostracod, which was classified as likely stygofauna. It should be noted that the volume of water sampled at TS2 (5 L) and TS3 (3 L) was much smaller than at TS1 (15 L) and that may be why fewer invertebrates were found (Appendix I).

Table 6-2 Water quality measurements recorded at the boreholes on Twin Gully (TG1) and Tri Star Swamps (TS1-3) prior to stygofauna sampling.

Site	Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen		pH	ORP	Turbidity
			°C	µS/cm	%saturation	mg/L	Units	mV	NTU
TG1	10/05/2012	14:05	12.98	67	64.3	6.0	5.85	460	57.8
TS1	10/05/2012	15:18	12.49	32	28.8	2.7	4.32	479	37.5
TS2	10/05/2012	11:21	11.96	110	62.2	5.9	6.17	480	131.8
TS3	10/05/2012	12:15	10.51	46	92.3	9.1	6.02	477	130.4

Table 6-3 Invertebrates recorded during stygofauna sampling undertaken at three boreholes used to monitor groundwater levels in Tri Star Swamp.

Taxon	TS1	TS2	TS3
Acarina	2		
Collembola	1		
Cyclopoida	1		
Tipulidae	1	2	
Nematoda	298	1	
Oligochaeta	2		
Ostracoda			1
Tardigrada	2		
Terrestrial	3		
Number of Likely Stygofauna	1		1
Number of Possible Stygofauna	4	1	
Unlikely Stygofauna	3	1	
Total number of taxa	8	2	1

6.3 Shallow Unconfined Aquifer in the Banks Wall Sandstone

Stygofauna samples were collected from ridge boreholes that are used in the monitoring of groundwater levels in the near-surface unconfined aquifer in the Banks Wall Sandstone at Angus Place. Two of the boreholes (AP5PR and AP10PR) target the shallow part of this aquifer and two (AP4PR and AP9PR) the deeper part.

Samples were collected using a hand-hauled weighted bailer, with the volume of water sampled from the ridge boreholes varying from 8 litres (AP9PR) to 15.5 litres (AP4PR) (MPR 2012c). The low yield at AP9PR was due to difficulties encountered in lowering and retrieving the bailer. Water quality measurements were based on samples collected from 1-2 m below the bore water surface. Stygofauna are understood to have been collected by lowering the bailer to the bottom of the bore and agitating the sediments and water column. The depth of the shallow ridge (aquifer) bores, however, is known to have ranged from 30 m to 60 m (MPR 2012).

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

6.3.1 Groundwater Quality

The dissolved oxygen measurements for boreholes AP4PR, AP5PR and AP10PR were similar and ORP levels were similar at AP4PR and AP5PR and at AP9PR and AP10PR, but there was no consistency in the other variables (**Table 6-4**). The measurements taken in the two boreholes that target the shallow part of the aquifer were thus similar only with respect to dissolved oxygen, while those taken in the boreholes targeting the deeper part of the aquifer differed in all parameters. This suggests that the water samples may either have been taken at different depths or from different aquifer systems. The high turbidity recorded at AP4PR and AP10PR suggest that sediment is present in the upper level of the bore. This could be due to the recent construction of the boreholes or other disturbance within the aquifer.

6.3.2 Stygofauna

The samples collected from the ridge boreholes yielded a total of nine invertebrates, representing five taxa. The samples from bore hole AP10PR contained most of these animals, one of which was a syncarid crustacean from the family Bathynellidae, a likely stygofaunal taxon, while another (Acarina) was considered possible stygofauna. The samples from the other boreholes each yielded one taxon, but only the nematode found at AP5PR was potentially a member of the stygofauna.

Table 6-4 Water quality measurements recorded at the ridge boreholes prior to stygofauna sampling

Site	Date	Time	Temperature	Electrical Conductivity	Dissolved Oxygen		pH	ORP	Turbidity
					%saturation	mg/L			
AP4PR	6/06/2012	09:45	11.55	89	73.0	7.0	4.83	412	425.2
AP5PR	6/06/2012	11:00	11.99	66	72.9	6.9	5.48	425	69.3
AP9PR	8/06/2012	13:34	13.05	42	67.6	6.3	5.11	518	39.1
AP10PR	8/06/2012	12:18	13.33	30	75.9	7.0	4.77	532	229.4

Table 6-5 Invertebrates recorded during stygofauna sampling undertaken at four continuously monitored aquifer piezometers used to monitor groundwater levels in the near-surface unconfined aquifer in the Banks Wall Sandstone.

Taxon	AP10PR	AP4PR	AP5PR	AP9PR
Acarina	5			
Collembola		1		
Nematoda			1	
Bathynellidae (Syncarida)	1			
Terrestrial				1
Number of Likely Stygofauna	1			
Number of Possible Stygofauna	1		1	
Unlikely Stygofauna		1		1
Number of taxa	2	1	1	1

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. One likely and four possible stygofauna taxa were found in the boreholes targeting the aquifer below Tri Star Swamp, while one likely and two possible stygofauna taxa were found in those targeting the unconfined aquifer in the Banks Wall Sandstone. The samples collected from boreholes targeting the aquifers below swamps in the Springvale Project Application Area also yielded small number of invertebrates. 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 boreholes targeting the unconfined aquifer in the Banks Wall Sandstone below the Springvale Project Application Area also yielded few invertebrates, with only one being a likely stygofauna taxon and two possible stygofauna taxa.

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 to target the aquifer associated with the Banks Wall sandstone were located in the mid to lower half of the western side of the Angus Place 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 pilot 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 column 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 further parts of the aquifer (Hancock and Boulton 2008). The use of pumps, however, may be limited by bore construction characters, water table depth and time constraints. The low yields from 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 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 in Section 1.2);

> The description of the existing biophysical environment of the Coxs River, Wolgan River, Carne Creek and the drainages downstream of the Twin Gully, Tri Star and Bird Rock swamps presented in Sections4 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 recharge and discharge to streams and baseflows (Adhikary and Wilkins 2013; RPS 2013b) and surface water quality (RPS 2013c).

The potential impacts on aquatic ecology associated with the construction, operation, decommissioning and rehabilitation phases and measures that could be used to avoid, minimise or manage such impacts are described in Sections 7.1-7.3. 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 7.4. The potential for cumulative impacts on aquatic ecology is discussed in Section 7.5. 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 to allow access to the proposed mining area in the east;

> seven additional dewatering borehole facilities and associated power and pipeline infrastructure on Newnes Plateau;

> water transfer boreholes and pipeline infrastructure at the existing Ventilation Facility site (APC-VS2);

> A downcast ventilation shaft (APC-VS3).

The dewatering bore would be excavated using a drill rig, lined and then fitted with appropriate bore casing and a pump. The borehole would be installed within a secure compound and connected to the power supply. The existing access tracks from Sunnyside Ridge Road to the dewatering borehole facilities will also be extended and upgraded, while that to the downcast ventilation shaft will be upgraded.

7.1.1 Potential Impacts

General construction activities 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 could temporarily increase the sediment load in swamps, drainage lines and watercourses downstream thereof;

> Runoff from cleared areas and stockpiles of soil could also transfer sequestered nutrients, organic matter and contaminants into watercourses and swamps;

> Accidental release of lubricating oils, hydraulic fluids and fuel from construction equipment could result in the inflow of toxic hydrocarbons into 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 upgrade and extension of the existing access tracks from Sunnyside Ridge Road to the dewatering borehole facilities and proposed downcast ventilation shaft has the potential to increase soil erosion/sedimentation;

> The construction of access tracks over watercourses 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, could either impede or prevent passage of fish and other aquatic organisms.

The construction of dewatering boreholes could also potentially lead to:

> Discharge of groundwater to the surface and changes to the quantity and quality of surface water, if drilling intercepts a confined aquifer where groundwater is under pressure;

> Contamination of surface water with drilling muds/fluids, drilling additives, oils and lubricants which may be toxic to aquatic fauna and flora.

The likelihood of the above impacts occurring depends on the proximity of the streams, swamps and their associated drainage lines to the construction works and whether appropriate management measures are implemented.

The subsidence caused by construction of the underground roadways is expected to be negligible and will occur at depth, so will not affect the surface aquatic environment. If the construction of the proposed underground roadways results in groundwater inflows, these would be discharged into Kangaroo Creek through LDP001 as part of the normal site mining operations.

The ventilation shaft, dewatering borehole facilities and associated power and pipeline infrastructure, water transfer boreholes and pipeline infrastructure to the existing Ventilation Facility site will generally be constructed on ridge lines and mid slopes. The construction of these facilities could potentially result in runoff into some of the drainage lines associated with the Wolgan River and headwater sub-catchments of Carne Creek (**Figure 1-1**). The magnitude of such runoff would depend on the area of clearance, the extent of soil disturbance and tree removal, slope of the land and whether soil stabilisation works are undertaken. These drainage lines are unlikely to contain aquatic habitat. There is, however, a possibility of sediment deposited in these drainage lines being dispersed downstream into the Wolgan River and Carne Creek during significant rainfall events, with the extent of dispersion of sediment plumes depending on the prevailing flows. The aquatic flora and fauna that occur in these streams could therefore experience temporary, localised increases in sediment load and turbidity during such events. The aquatic flora and fauna living in sections of the river downstream of such drainages are likely to be fairly tolerant of temporary increases in sediment load, as these would occur naturally during significant rainfall events. It is therefore unlikely that any temporary, localised increases in sediment load resulting from the proposed construction works would have significant effects on aquatic biota. Cumulative impacts from construction of multiple facilities along the eastern edge of the proposed workings are also considered unlikely, as these would not be built simultaneously.

The upper reach of the Coxs River and Kangaroo Creek are situated to the west of the proposed longwalls and would not therefore be impacted by the proposed construction activities.

7.1.2 Avoidance, Mitigation and Management Measures

Impacts associated with general construction works would be minimised by:

> Limiting the area of vegetation that is cleared and land that is disturbed during construction of the proposed dewatering boreholes, ventilation shaft, water transfer boreholes, pipeline infrastructure and access tracks;

> Developing and implementing a Sediment and Erosion Control Plan to protect any swamps and drainage lines immediately downstream of the construction areas;

> At each construction site, 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.

The runoff from areas disturbed during construction of the ventilation shaft facility will be collected and treated in a Sediment Pond prior to its discharge into one of the unnamed streams within the Wolgan River catchment (RPS 2013c). This will necessitate the addition of a new LDP to EPL467.

The location of dewatering boreholes at the eastern end of the proposed longwalls would avoid potential impacts on the two drainage lines traversing the northern part of the Project Application Area. Construction of the dewatering boreholes at the eastern end of specific longwall panels would also avoid potential impacts on Twin Gully Swamp, Tri Star Swamp and various unnamed Hanging Swamps and their drainages situated on the western side of the Project Application Area. The potential for direct impacts on drainage lines in the southern part of the area and on the Hanging Swamps and Ione Shrub Swamp and their drainages situated near the eastern end of the proposed longwalls could be avoided by not installing the boreholes above longwalls that are overlain by these features.

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 down slope from the boreholes 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.

Construction works in the vicinity of watercourses, if required, should be done in accordance with the DPI Policy and Guidelines for Fish Habitat Conservation and Management (See Section 3.2.4.2) (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 DPI Policy and Guidelines for Fish Habitat Conservation and Management (DPI 2013). 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

Centennial Angus Place proposes to use the retreat longwall mining method to extract coal from the Lithgow Seam. Nineteen new longwall panels (LW1001 to LW1019) would be extracted to the east and the southwest of Centennial's existing operations at Angus Place Colliery.

During mining operations, the water that accumulates in the underground workings (i.e. mine water make) needs to be removed to maintain operational safety. At present, approximately 18.5 ML/d of mine water make from the Angus Place and Springvale Collieries is removed at dewatering boreholes equipped with submersible pump(s) and transferred via the SDWTS to Delta Electricity's Wallerawang Power Station for use in their cooling towers. The transfer from the Springvale Mine currently has priority, so only about 30% of the water is from the Angus Place Mine. If the SDWTS is not operational, mine water make from Angus Place is discharged from LDP001 into Kangaroo Creek from where it flows into the Coxs River. Angus Place EPL 467 currently permits up to 2,000 KL/d (2 ML/d) of water to be discharged into the creek via LDP001.

The combined volume of mine water make from the Angus Place and Springvale Mine Extension Projects will increase to 25 ML/d in 2015, reach a peak of about 45 ML/d in 2024/25 and then decline to 26 ML/d in 2032 following completion of mining at Springvale in 2025 (RPS 2013c). Mining and dewatering at Angus Place will continue until 2032, with a peak production of approximately 29 ML/d occurring in 2026. The increased inflow to the underground mine workings at Angus Place will be managed through increased discharge to LDP001 and increased use of the SDWTS. The latter has a capacity of 30 ML/d, but may be upgraded to 50 ML/d at a later stage to accommodate the increased inflows. If the upgrade goes ahead there will be increased discharge to the Coxs River via Springvale's LDP009.

The water balance modelling based on existing infrastructure indicates there would be a marked increase in the discharge of excess mine water make through LDP001 between 2019 and 2020, a high level of discharge would be maintained until 2025, but thereafter it would drop to minimal levels (RPS 2013c). In 2022, when the transfer from Springvale Mine to the SDWTS peaks, an average of 13 ML/d of water from Angus Place would be transferred to the SDWTS, 6.3 ML/d of water would need to be discharged into Kangaroo Creek via LDP001 and 0.3 ML/d would need to be discharged into Coxs River via LDP002 (RPS 2013c) In 2030, when the groundwater inflow from Angus Place peaks, an average of 28.6 ML/d of water would be transferred to the SDWTS and 0.05ML/d and 0.3 ML/d would be discharged through LDP001 and LDP002, respectively.

If the capacity of the SDWTS is upgraded to 50ML/d by 2022, an average of 24.6 ML/d of water from Angus Place would be transferred to the SDWTS, 0.05 ML/d of water would need to be discharged into Kangaroo Creek via LDP001 and 0.3 ML/d would need to be discharged into Coxs River via LDP002 (RPS 2013c).

If transfer to Wallerawang Power Station from the SDWTS is not possible, either 13.0 ML/d or 28.6 Ml/d would need to be discharged to LDP001. If only the Angus Place Mine Extension Project is approved either all mine water make will be discharged at LDP001 or a commercial arrangement will be entered into with Springvale to maintain access to the pipeline.

The volume of the discharge through LDP002 will not change over time under either scenario (RPS 2013c).

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 - reduced downward subsidence or 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 - 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 not undermine the sections of the Wolgan River and Carne Creek that traverse the Project Application Area, but will undermine their drainage lines. MSEC (2013) has provided subsidence predictions for Longwalls 1001-1019 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 1001-1019 (MSEC 2013)

Type of Ground Movement	Wolgan River	Carne Creek
Subsidence	<20 mm	<20 mm
Upsidence	80 mm	25 mm
Valley closure	140 mm	50 mm
Tilt	less than 0.2 mm/m.	No measurable change
Compressive strains	0.5-1.0 mm/m	Less than 0.5 mm/m

The predicted impacts of these movements on the physical stream attributes outlined by MSEC (2013) and the consequences for 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 strains as the maximum predicted subsidence resulting from extraction of the longwalls is less than 20 mm but would experience compressive strains due to valley related movements;

- The maximum predicted tilt (< 0.2 mm/m) would result in a small change (< 1in 5000) in the natural gradient of the river, but this is unlikely to cause significant changes in the levels of ponding, flooding, scouring of the river banks or stream alignment;
- The compressive strains due to the valley closure movements are expected to vary from less than 0.5 mm/m to 1 mm/m, so fracturing of the river bed is unlikely, but if it does occur, it would be isolated, shallow, discontinuous and minor in nature and therefore unlikely 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, and proposed LW1001 to LW1019 would be situated further away from the river, their extraction 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, shallow, isolated, discontinuous fracturing of the riverbed does occur this 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 is more likely to 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 minor, 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 approximately 0.9 km reach of Carne Creek situated within 600 m of the proposed longwalls were:

- The creek is expected to experience less than 20 mm subsidence, 25 mm upsidence, 50 mm closure and compressive strains of less than 0.5 mm/m due to the valley closure movements;
- The small magnitude of these predictions suggests that extraction of the longwalls is unlikely to have any adverse impacts on the physical attributes of the creek.

Given the above, there are unlikely to be any significant or measurable physical subsidence impacts on this reach of Carne Creek or any significant consequences for its aquatic ecology.

The key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of the drainage lines that traverse the proposed workings were:

- 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 longwalls are likely to experience low subsidence and compressive strains of less than 2 mm/m;
- The maximum predicted tilt (20 mm/m) that would be experienced represents a change in grade of 1 in 50, which is smaller than the natural gradients, so an effect on surface flows along the drainage line are unlikely;
- 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 localised areas (e.g. 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 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 that would persist until the cracks are infilled by sediment. 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 cracked are infilled with sediments during subsequent flow events. These 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. 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 concentrations of salts, iron and other metals and reductions in dissolved oxygen levels. Increases in iron staining could also smother aquatic habitats and sessile biota. These effects are expected to be localised and transient. 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 key points identified by MSEC (2013) in their assessment of the impacts of ground movements on the physical attributes of the swamps and their drainages are:

> Extraction of the longwalls is not expected to cause any substantial change in the grade so there are unlikely to any adverse changes in ponding or scouring or significant changes in the distribution of stored surface waters within the swamps;

> In the swamps above the proposed longwalls, mining is expected to result in minor, isolated fracturing of the bedrock, but this would only be visible where there is shallow or exposed bedrock and temporary due to their infilling with soil during subsequent flow events along the drainage lines;

> In Twin Gully Swamp and the Shrub Swamps along the Wolgan River, the tensile and compressive strains are unlikely to be of sufficient magnitude to cause significant fracturing of bedrock;

> Valley related upsidence movements could result in the dilation of the strata beneath drainage lines and diversion of some surface water flows beneath parts of the shrub swamps;

> As the drainage lines upstream of the swamps are mostly ephemeral, most of the runoff during heavy rainfall would flow over the beds and not be diverted into the dilated strata below;

> Diversion of flows into the dilated strata would occur during low flows, so weathering of freshly exposed minor fractures in the sandstone rocks could result in minor, localised, transient increases in concentrations of iron, manganese, aluminium, zinc and nickel and increases in iron staining along the drainage lines;

> There could also be a localised reduction in the quantity of the water within the drainage lines but, as the water is likely to re-emerge a short distance downstream, there is unlikely to be any adverse impact on the overall quantity of water flowing from the catchment.

> There is not expected to be any net loss of water from the Shrub Swamps, because these are gaining systems fed by perched aquifers.

> Changes in flows were reported along Kangaroo Creek after the extraction of LW940, but no loss of surface water flows or adverse impacts on the other drainage lines has been reported during previous mining activities.

Given the above, there are unlikely to be any significant physical subsidence impacts on the swamps or their drainage lines.

In the drainage lines downstream of Shrub Swamps that have small base flows, fracturing of bedrock could lead to temporary loss of aquatic habitat and connectivity, but this would be restored once the cracks are infilled by sediment. Such losses would be less important in ephemeral drainage lines, because aquatic habitat would be present only during flow events and for a short time thereafter. The diversion of surface water into sub-surface layers could result in minor, localised, transient impacts on the quality of the water in the drainage lines at and immediately downstream of the point where surface flows re-emerge. The resulting consequences for aquatic ecology of any physical subsidence impacts that do occur in the drainages are therefore not expected to 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, shrub swamps and their drainages which in turn, will affect their baseflows. Groundwater flow to shrub 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 impacts on swamps and their drainage lines will be smaller than those that occur naturally as a result of seasonal variation (Adhikary and Wilkins 2013). Mining will change the water head in most shrub swamps by a few centimetres on average. 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 drop down 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. The water that infiltrates is expected to re-emerge as surface flow further downstream and contribute to baseflow within the drainage line. They also pointed out that the previous longwall extraction at Angus Place has not had any detectable effects on surface flows or shallow groundwater levels.

Given the above, it is highly unlikely that there would be any measurable effects on the aquatic ecology of streams or the drainages 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 Kangaroo Creek and the Coxs River. The volume of discharge from LDP001 into the creek and thereby the river is, however, predicted to increase between 2019 and 2025. The routine monitoring of the discharge at LDP001 undertaken since January 2010 shows that the flow rate as varied from 0.35 ML/d to 20.4 ML/d with a median of 3.29 ML/d. The average volume discharged (6.3 ML/d) in 2022 (the critical year when mine water make production from both mines will peak) will be three times greater than is currently permitted (2 ML/d) and almost two times greater than the median discharge since January 2010. The increase in the volume of the discharge is likely to affect the flow regime, geomorphology, water quality, aquatic habitat and aquatic biota of these streams, with impacts depending on the prevailing level of river flow.

The marked increase in discharge rate 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 creek and 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 marked increase in discharge flow would also 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 (Bunn and Arthington 2002). The latter are unlikely to persist, as they would be flushed away during the next natural high flow event. An increase in the stability of the edge habitat due to continuous discharges during low and moderate flow periods could also 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. An increase in the depth and stability of aquatic habitats could facilitate the establishment and spread of exotic species.

The release of large volumes of mine water make between 2019 and 2025 would change the quality of the water in Kangaroo Creek downstream of the discharge point and in the Coxs River downstream of its confluence with the creek. 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 Angus Place 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 streams for dilution, which is in turn dependent on flow, inflows from tributaries and other discharge points and the distance to Lake Wallace.

The majority of constituents discharged at LDP001 were consistent with the ANZECC/ARMCANZ (2000) criteria. The EC levels, however, were always greater than the upper DTV and Filtered Copper, Filtered Zinc and Total Nitrogen as N concentrations were frequently greater than the 95% trigger value (RPS 2013c). The monitoring undertaken at sites on Kangaroo Creek and the Coxs River upstream and downstream of the influence of LDP001 suggests that the discharge also elevates the pH, total dissolved solids, barium, calcium, magnesium, potassium, sodium, Total Sulphur and alkalinity (carbonate, bicarbonate and total) levels. The extent of the mixing zone and hence the potential for dilution of the discharge constituents during low, moderate and high flows is unknown.

The potential for an increase in salinity of the water in the creek and river is of particular concern, as the flow data from the Surface Water Monitoring Program indicates the median EC level at the upstream sites on Kangaroo Creek (65 µS/cm) and the Coxs River (107 µS/cm) are approximately an order of magnitude lower than that of the discharge from LDP001 (1,010 µS/cm). The median EC levels at the downstream sites on the creek (770 µS/cm) and river (513 µS/cm) are also lower. The records also show there is considerable variation in the salinity, with levels at the upstream sites on Kangaroo Creek and Coxs River varying from 37-818 µS/cm and 63-372 µS/cm and those at the downstream sites in the creek and river varying from 93-1,130 µS/cm and 53-1,030 µS/cm, respectively.

A salt mass balance model has been used to predict the EC levels in the Coxs River downstream of its confluence with Kangaroo Creek as a result of the discharge under normal flow (median of 4.6 ML/d) and dry conditions (95th percentile flow of 0.3 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 462 µS/cm in 2019 to 696 µS/cm in 2020, peak at 717 µS/cm in 2021 drop back to 712 µS/cm in 2024 and fall to 462 µS/cm in 2025. If drought conditions prevailed, the EC levels would increase from 888 µS/cm in 2019 to 963 µS/cm in 2020 and remain around this level until 2025 when they would drop to 888 µS/cm. If the capacity of the SDWTS is increased to 50 ML/d, the minimal discharge from LDP001 would reduce EC levels from 462 µS/cm in 2013 to 132µS/cm in 2014 under normal conditions and from 888 µS/cm in 2013 to 342 µS/cm in 2014 under dry conditions. The effect on the salinity regime of Kangaroo Creek has not been modelled.

If the SDWTS is not upgraded, the contribution of Angus Place mine water make to the increase in salinity of the Coxs River would vary between 0 µS/cm and 618 µS/cm under normal conditions and from 0 µS/cm to 858 µS/cm under dry conditions. If the system is upgraded, it would vary between 0 µS/cm and 33 µS/cm under normal conditions and from 243 µS/cm to 426 µS/cm under dry conditions (RPS 2013c).

The greatest changes in salinity and hence potential for impact on aquatic biota in the creek and river would occur between 2019 and 2020 (increase) and 2024 and 2025 (decrease) if the capacity of the SDWTS remains at 30 ML/d and between 2013 and 2014 (decrease) if the system is upgraded. The magnitude of the change would be greater if the SDWTS is upgraded, but it would prevail for a shorter period of time.

The changes in the salinity regime of the creek and river adjacent to and downstream of LDP001 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). A review of the effects of salinity on aquatic biota in Australian freshwater systems indicates direct adverse biological effects are unlikely to occur unless EC levels exceed around 1000 mg/L (approximately 1,500 µS/cm) (Hart *et al.* 1991). This suggests that the aquatic biota in the river is unlikely to be impacted by the salinities resulting from the change in discharge. There is, however, evidence that relatively low salinities (800-1000 µS/cm cause changes in macroinvertebrate assemblages (Horrigan *et al.* 2005) and that tolerance varies with life cycle stage (Kefford *et al.* 2004). Most of the information that is available on the effects of salinity on aquatic biota is derived from short-term (72-96 hour) acute tolerance tests conducted under laboratory conditions that are not comparable with the changes likely to occur during the Project. It should also be noted that the latter will occur over a much shorter timeframe than those that occur naturally and will be sustained for longer periods than in the past. The rapidity of the changes may well be problematic for aquatic biota. Our poor understanding of the long-term and indirect effects of salinity on aquatic biota and the environmental impacts of different salt concentrations and release schedules (Marshall and Bailey 2004; Horrigan *et al.* 2005) makes it difficult to predict the impact of the change in discharge characteristics on aquatic biota. From the above discussion, it is likely that impact of the change in flows and quality of the water on the aquatic flora and fauna would be moderate in the immediate receiving waters of Kangaroo Creek and small to moderate in the Coxs River below the confluence, because this is a bigger system and has a greater capacity.

The order of magnitude of differences in total alkalinity levels at the upstream and downstream monitoring sites on Kangaroo Creek and Coxs River is also of concern, as this water quality parameter also has a significant effect on aquatic biota.

The aquatic biota is likely to recover after discharges have ceased, but recovery will be slow because the opportunity for replenishment of biota from upstream populations is limited in upper catchments.

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

Centennial Angus Place proposes to minimise the potential physical impacts on the two significant watercourses arising from mine-induced subsidence by setting the proposed longwalls between 240 m and >600 m back from the centreline of Wolgan River and at least 400 m away from Carne Creek. The proposed east to north-east to west south-west orientation of the longwalls also ensures they are aligned with the general horizontal stress direction. The potential for impacts on Tri Star Swamp and Trail 6 Swamp and their drainages would be minimised by reducing the overall void widths of the longwalls below them from 360 to 261 metres. The proposed LW1010 has been setback so that Twin Gully Swamp will not be directly undermined.

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 Wolgan River, Carne Creek and the drainages downstream of the swamps should be monitored periodically during and after the extraction of Longwalls 1001-1019. The existing monitoring sites (WRup, WRmd and WRdn) on the Wolgan River, Site CCXdn on Carne Creek and sites downstream of Twin Gully Swamp (TGS), Tri Star Swamp (TRIS) and Bird Rock Swamp (BRS) would serve as potential impact sites. Before mining commences, it is recommended that further biannual monitoring be undertaken at Site CCXdn and that another monitoring site be established on the branch of Carne Creek closest to the eastern end of Longwalls 1013A and 1014A. This is necessary to establish an adequate baseline for this watercourse. Concomitant monitoring should also be undertaken at appropriate reference sites on nearby watercourses that will not be affected by mining. The inclusion of reference sites in the monitoring program would enable impacts occurring during and after mining to be distinguished from natural variability.

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 injection grouting, should be used in areas where fracturing of controlling rock bars and/or stream and swamp bed leads to protracted diversion of stream flow and drainage of pools and swamps;
> 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

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 licenced discharge points.

The impact of the discharge of mine water make on aquatic ecology would be minimised by ensuring it meets the conditions specified in the Angus Place Environment Protection Licence 467. The limit on the volume of the discharge from AP_LDP001 has recently been reduced from 30,000 KL/d (30 ML/d) to 2,000 KL/d (2 ML/d), 100 percentile concentration limits on oil and grease (10 mg/L), pH (6.5-9.0 units) and total suspended solids (30 mg/L) and a 90 percentile concentration limit on pH (6.5-8.5 units). An increase in the permitted volume of discharge to the original 30,000 KL/d would need to be approved by NSDW EPA.

In addition, it is recommended that:

> Appropriate measures be used to minimise the potential for erosion and sedimentation at the licenced discharge point, in the section of Kangaroo Creek downstream thereof and in the Coxs River downstream of its confluence with the creek and that the extent of erosion should be monitored regularly;
> Effects of changes in the quality of other constituents of the receiving water should be taken into consideration, because some of the chemical constituents of the mine water make may have ecotoxic effects on aquatic biota and its temperature may differ from that of the receiving water.

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 Angus Place 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 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 and rehabilitation phases of the Project impacts on aquatic 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 (DPI 2008). 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 (DPI 2012). 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 the Wolgan River bed does occur during extraction of the 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. Mining is unlikely to have any adverse impacts on aquatic habitats in Carne Creek. 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 Application 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 (DPI 2012). 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 Application Area. Potential habitat for the larval stage could be lost or become isolated, if fracturing of the river bed in the Wolgan River 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. Mining is unlikely to have any adverse impacts on aquatic habitats in Carne Creek. 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 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 alongside Kangaroo Creek and the upper reach of Coxs River could be affected by the change in flow regime resulting from increased discharges via LDP001. 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 into Kangaroo Creek via LDP001 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 Kangaroo Creek and the reach of the upper Coxs River below its confluence. 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 Limitation

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.

The Project Application Area is bordered by Gardens of Stone National Park to the north and north-east, Newnes State Forest and Birds Rock Flora Reserve to the east, the existing Angus Place Colliery longwalls (LWs 19-26) to the west and existing and proposed Springvale Colliery longwalls to the south (**Figure 7-1**). The various activities that take place within these areas could potentially affect the Wolgan River, Carne Creek, Coxs River and its tributary Kangaroo Creek and the drainages located downstream of various swamps in the Wolgan River Catchment, including Twin Gully Swamp, Tri Star Swamp and Bird Rock Swamp.

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 that Project Application Area. The existing Angus Place longwalls were extracted up to 150 metres from the centreline of the river (MSEC 2013). The proposed longwalls in the Angus Place Project Application Area would not undermine the river, but would undermine its drainage lines. The Wolgan River is likely to experience valley related movements during the extraction of the proposed Angus Place longwalls and could be sensitive to these movements (MSEC (2013). However, as the existing mining has not caused any significant fracturing or surface water flow diversions along the Wolgan River and the proposed Angus Place and Springvale longwalls would be setback from this watercourse, their extraction is unlikely to result in any significant fracturing or surface water flow diversions (MSEC 2013). The drainage lines in the western part of the Angus Place Extension Area that drain into the Wolgan River could experience the full range of predicted subsidence movements. 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 Project Application Area. The headwaters of Carne Creek are also likely to experience valley related movements during the extraction of the proposed Angus Place longwalls and could be sensitive to these movements (MSEC (2013). The movements that would occur during mining of the proposed longwalls are expected to be small and would not therefore have any significant impact on the physical attributes or the instream ecology of the creek.

The drainage lines in the eastern part of the Angus Place Project Application Area and the northern part of the Springvale Project Application 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.

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).

7.5.3 Mine Discharge

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. These discharges were originally continuous but now occur only when there are operational issues with the SDWTS. No mine water has been discharged into Wolgan River by Springvale since April 2010. Springvale LDP004 and LDP005 will be relinquished as part of the Springvale Mine Extension Project. Mine water has not been discharged into Carne Creek.

The reach of the Coxs River immediately above Lake Wallace receives inflows from two tributaries that have been impacted by mining, with Neubeck Creek receiving acid 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 base of the Sawyers Swamp Creek ash dam (The Ecology Lab 2007). 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 the river immediately below the confluences with these tributaries receives periodic inputs from five licensed discharge points associated with WPS. 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 potentially result in further degradation of the reach of the river between its confluence with Kangaroo Creek 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. The predicted peak outflow from the Angus Place Mine would occur after completion of other mining projects in the Coxs River catchment, so the potential for cumulative impact is small.

Mine water discharge has impacted on four swamps (Narrow Swamp North, Narrow Swamp South, East Wolgan Swamp and Junction Swamp) that have been undermined (Goldney *et al.* 2010). Mine subsidence ground movements and erosion from nearby roads may also have contributed to the impacts observed. Centennial has acknowledged that past practices, such as discharge of large quantities of mine water and construction of various roads and access paths, have resulted in impacts to some swamps and their drainages this and have developed management plans and a mine layout that would reduce the risk of future mining-related impacts. These measures would minimise impacts on swamps and drainage lines overlying the Angus Place and Springvale Project Application Areas, none of which have been undermined previously.

7.5.4 Other Activities

The Wolgan River and Carne Creek catchments may have been impacted by the clearing of vegetation for existing fire and access roads and construction of existing Angus Place and Springvale mine surface infrastructure. The impact is likely to have been limited because these occupy only a small area.

The Wolgan River, Carne Creek, swamps and their drainage lines could also potentially be 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, motor biking and hunting (Centennial 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 due to mining activities.

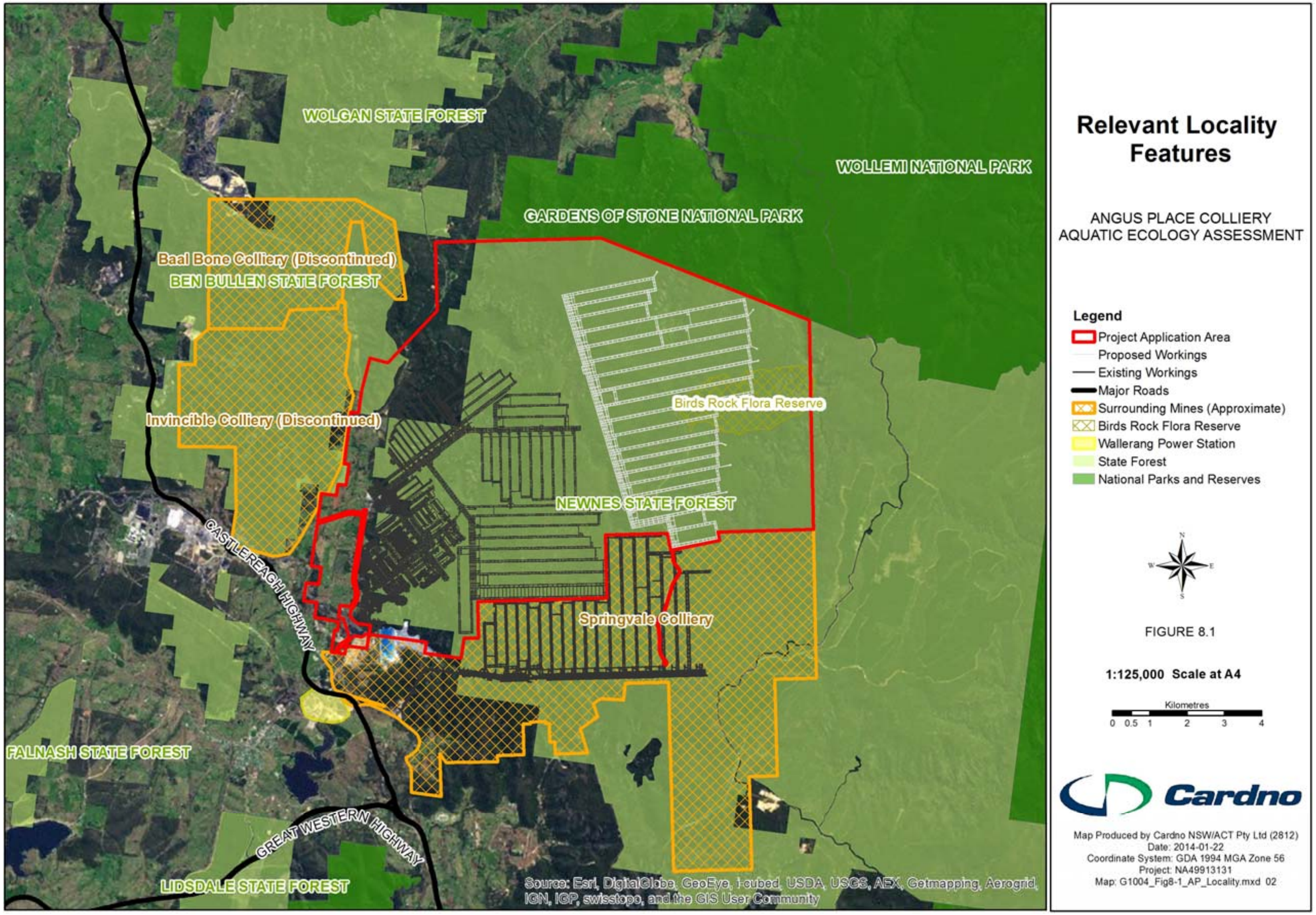

Figure 7-1 Map showing the position of the Angus Place Mine relative to other developments and national parks

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 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.

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, manage and/or offset impacts on stygofauna.

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 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 therefore unlikely to have any 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, 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 lead to changes in groundwater quality, including elevated iron, manganese and aluminium levels. Sub-surface fractures resulting from subsidence could potentially 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 availability 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.

The hydrogeological modelling (Adhikary and Wilkins 2013) indicates mining would have the following effects:

> 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;
> The aquifer containing the Lithgow seam would become unsaturated above the longwall panels;
> A 15-70 m thick unsaturated region would develop in the aquifer below the Mt York claystone layer;
> There would be a slight (3%) desaturation of the aquifers above the Mt York claystone;
> 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 Discharge and Recharge

The extraction of the longwall panels will affect groundwater discharge to and recharge from swamps. The impacts, however, will be smaller than those that occur naturally as a result of seasonal variation (Adhikary and Wilkins 2013). This suggests that the impact on stygofauna associated with the perched aquifers is unlikely to be significant.

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 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 contribute to baseflow within the drainage line. It is important to note that the shallow subsidence caused by previous mining operations has not reduced surface flows or shallow groundwater levels. There is consequently unlikely to be any detectable effects on aquatic ecological attributes in the drainages immediately downstream of the swamps.

8.2.2 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 boreholes, reduce the volume of saturated sediments and reduces 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.

8.2.3 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 Phase

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 form 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 the shallow regional groundwater or the deep confined groundwater system or any stygofauna that may exist within these systems. 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 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 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 four registered bores within 5 km and 46 registered bores within 10 km of the centre-point of the Project (RPS 2013b). Three of the nearby bores target the AQ4, AQ3 and AQ1 aquifers respectively, but no information is available on the fourth bore. The bores located within 10 km of the Project are mostly monitoring bores that target the deep groundwater system, four of which abstract water from the Lithgow Seam. Another bore extracts water from the Lithgow Seam 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.

RPS (2013b) has shown that past and present mining activities have had a considerable impact on the level of water in the deep groundwater system, particularly in the Lithgow Seam, AQ1 and AQ4, but no mining-related impacts are evident in AQ6.

Hydrogeological modelling has 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. There is insufficient information available at present to determine the likelihood or magnitude of such impacts.

9 Conclusions

The information available on instream ecology and the aquatic ecology of the drainages downstream of the swamps and proposed works 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 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 direct 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

Cardno
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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

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			28/10/2010	9/06/2011	2/11/2011	31/05/2012	21/11/12	
	Notonemouridae	Stoneflies	X	X	X	X	X	6
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						

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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

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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
Ephemeroptera	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
	Hydridae	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

APPENDIX E

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE KCup AND THEIR SIGNAL2 SCORES

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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			X	X	4
	Scirtidae	Marsh Beetles		X	X	X	X	6
Diptera	Athericidae	Flies			X			8
	Ceratopogonidae	Biting Midges	X		X	X	X	4
	Chironominae	Bloodworms	X	X	X		X	3
	Orthocladiinae	Bloodworms	X		X	X		4
	Tanypodinae	Bloodworms	X	X	X	X	X	4
	Tipulidae	Crane Flies			X	X		5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	8
Hemiptera	Notonectidae	Backswimmers	X	X			X	1
Mecoptera	Nannochoristidae	Scorpionflies		X	X	X		9
Megaloptera	Cordyalidae	Dobsonflies	X	X	X		X	7
Odonata	Synthemistidae	Dragonflies	X			X		5
	Telephlebiidae	Dragonflies		X	X	X		9
	Megapodagrionidae	Damselflies	X	X	X	X	X	5
Plecoptera	Gripopterygidae	Stoneflies	X		X		X	8
	Notonemouridae	Stoneflies					X	6
Trichoptera	Leptoceridae	Caddis Flies	X	X	X	X	X	6
	Philorheithridae	Caddis Flies		X		X	X	8
	Polycentropodidae	Caddis Flies		X				7
Non-Insects	Hydracarina	Freshwater Mites		X	X	X	X	6
	Oligochaeta	Freshwater Worms	X	X		X		2
	Sphaeriidae	Pea Shells				X		5

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APPENDIX F

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE KCdn AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			28/10/2010	8/06/2011	1/11/2011	29/05/2012	20/11/12	
Coleoptera	Dytiscidae	Diving Beetles			X		X	2
	Gyrinidae	Whirligig Beetles	X	X	X	X	X	4
	Hydraenidae	Scavenger Water Beetles			X		X	3
	Hydrophilidae	Scavenger Water Beetles			X		X	2
	Scirtidae	Marsh Beetles				X		6
Diptera	Ceratopogonidae	Biting Midges	X		X		X	4
	Chironominae	Bloodworms		X				3
	Orthocladiinae	Bloodworms		X	X	X	X	4
	Tanypodinae	Bloodworms	X	X	X			4
	Culicidae	Mosquitoes			X			1
	Simuliidae	Black Flies	X	X	X	X		5
	Stratiomyidae	Soldier Flies	X		X	X	X	2
	Tipulidae	Crane Flies	X	X		X	X	5
Ephemeroptera	Baetidae	Mayflies		X		X		5
	Leptophlebiidae	Mayflies	X	X	X			8
Hemiptera	Corixidae	Lesser Water Boatmen		X		X		2
	Notonectidae	Backswimmers	X	X	X			1
	Veliidae	Small Water Striders	X				X	3
Megaloptera	Cordyalidae	Dobsonflies				X		7
Odonata	Aeshnidae	Dragonflies		X				4
	Gomphidae	Dragonflies		X	X			5
	Hemicorduliidae	Dragonflies			X			5
	Synthemistidae	Dragonflies	X	X		X	X	5
	Telephlebiidae	Dragonflies	X	X	X	X		9
	Coenagrionidae	Damselflies				X		2
	Megapodagrionidae	Damselflies			X			5
	Synlestidae	Damselflies	X		X			7
Plecoptera	Gripopterygidae	Stoneflies		X	X	X		8

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			28/10/2010	8/06/2011	1/11/2011	29/05/2012	20/11/12	
	Notonemouridae	Stoneflies		X	X			6
Trichoptera	Ecnomidae	Caddis Flies			X			4
	Hydrobiosidae	Caddis Flies	X					8
	Hydropsychidae	Caddis Flies			X	X		6
	Hydroptilidae	Caddis Flies	X	X	X	X	X	4
	Leptoceridae	Caddis Flies	X	X		X	X	6
Non-Insects	Cyclopidae	Copepods			X	X	X	*
	Parastacidae	Freshwater Crayfish/Yabbie	X		X	X	X	4
	Oligochaeta	Freshwater Worms				X		2
	Lymnaeidae	Freshwater Snails		X				1
	Nematoda	Round Worms			X			

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APPENDIX G

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE WRup AND THEIR SIGNAL2 SCORES

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
	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

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	
	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
	Oligochaeta	Freshwater Worms	X			X		X	2
	Dugesiidae	Flatworms						X	2

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APPENDIX H

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
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

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**	
	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

Angus Place Mine Extension Project

APPENDIX I

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE WRdn AND THEIR SIGNAL2 SCORES

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	Bloodwor ms	X	X	X	X	X	X	3
	Orthocladiinae	Bloodwor ms	X		X	X	X		4
	Tanypodinae	Bloodwor ms	X	X	X	X	X	X	4
	Culicidae	Mosquitoe s	X						1
	Simuliidae	Black Flies		X	X		X		5
	Tipulidae	Crane Flies	X	X	X	X	X	X	5
Ephemero ptera	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	Backswim mers	X	X		X	X		1
	Veliidae	Small Water Striders		X				X	3
Mecoptera	Nannochoristidae	Scorpionfli es						X	9
Megalopter a	Cordyalidae	Dobsonflie s			X				7
Odonata	Gomphidae	Dragonflie s	X						5
	Hemicorduliidae	Dragonflie s		X					5
	Synthemistidae	Dragonflie	X	X	X	X	X	X	5

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	
		s							
	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

Angus Place Mine Extension Project

APPENDIX J

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE CCXdn AND THEIR SIGNAL2 SCORES

Cardno®

Shaping the Future

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

Angus Place Mine Extension Project

APPENDIX K

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE TGS AND THEIR SIGNAL2 SCORES

Cardno

Shaping the Future

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			10/11/2010	**24/05/2011**	**17/11/2011**	**23/05/2012**	**27/11/2012**	
Coleoptera	Dytiscidae	Diving Beetles		X		X	X	2
	Elmidae	Riffle Beetles	X		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	3
	Orthocladiinae	Bloodworms				X		4
	Tanypodinae	Bloodworms	X	X	X	X	X	4
	Tipulidae	Crane Flies	X			X		5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	8
	Oniscigastridae	Mayflies	X					8
Hemiptera	Veliidae	Small Water Striders		X			X	3
Mecoptera	Nannochoristidae	Scorpionflies		X		X	X	9
Odonata	Synthemistidae	Dragonflies	X	X	X	X		5
	Telephlebiidae	Dragonflies	X	X	X	X	X	9
	Megapodagrionidae	Damselflies	X	X	X	X	X	5
Plecoptera	Gripopterygidae	Stoneflies	X	X	X	X	X	8
Trichoptera	Calocidae/Helicophidae	Caddis Flies	X		X			9
	Ecnomidae	Caddis Flies		X	X	X	X	4
	Hydrobiosidae	Caddis Flies		X				8
	Hydropsychidae	Caddis Flies					X	6
	Hydroptilidae	Caddis Flies	X		X	X	X	4
	Leptoceridae	Caddis Flies	X	X	X	X	X	6
	Philorheithridae	Caddis Flies		X	X	X	X	8
Non-Insects	Hydracarina	Freshwater Mites				X	X	6

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			10/11/2010	**24/05/2011**	**17/11/2011**	**23/05/2012**	**27/11/2012**	
	Oligochaeta	Freshwater Worms	X			X		2
	Dugesiidae	Flatworms			X			2
	Gordioidea	Horsehair Worms		X				5

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APPENDIX L

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE TRIS 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	
Coleoptera	Dytiscidae	Diving Beetles				X	X	2
	Elmidae	Riffle Beetles	X				X	7
	Gyrinidae	Whirligig Beetles	X	X	X		X	4
	Hydrophilidae	Water Scavenger Beetles			X			2
	Scirtidae	Marsh Beetles	X	X		X		6
Diptera	Ceratopogonidae	Biting Midges	X					4
	Chironominae	Bloodworms	X	X		X	X	3
	Orthocladiinae	Bloodworms			X		X	4
	Tanypodinae	Bloodworms	X	X	X	X	X	4
	Tipulidae	Crane Flies	X	X	X		X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	8
Hemiptera	Notonectidae	Backswimmers					X	1
	Veliidae	Small Water Striders		X		X		3
Mecoptera	Nannochoristidae	Scorpionflies			X	X	X	9
Megaloptera	Cordyalidae	Dobsonflies		X				7
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	5
	Telephlebiidae	Dragonflies	X	X	X	X		9
Plecoptera	Austroperlidae	Stoneflies		X				10
	Gripopterygidae	Stoneflies		X	X	X	X	8
	Notonemouridae	Stoneflies					X	6
Trichoptera	Ecnomidae	Caddis Flies				X	X	4
	Helicophidae	Caddis Flies					X	10
	Hydropsychidae	Caddis Flies		X	X		X	6
	Hydroptilidae	Caddis Flies					X	4
	Leptoceridae	Caddis Flies	X	X	X	X	X	6

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			9/11/2010	**23/05/2011**	**16/11/2011**	**21/05/2012**	**26/11/2012**	
	Philorheithridae	Caddis Flies	X	X	X	X	X	8
Non-Insects	Hydracarina	Freshwater Mites	X		X			6
	Collembola	Springtails		X				1
	Phreatoicidae	Isopods					X	4
	Oligochaeta	Freshwater Worms	X		X			2
	Sphaeriidae	Pea Shells	X	X		X		5
	Gordioidea	Horsehair Worms					X	5

Angus Place Mine Extension Project

APPENDIX M

MACROINVERTEBRATE TAXA RECORDED DURING EACH SURVEY OF SITE BRS AND THEIR SIGNAL2 SCORES

Order	Taxon	Common name	Survey Date					SIGNAL2 Score
			10/11/2010	24/05/2011	17/11/2011	23/05/2012	27/11/2012	
Coleoptera	Dytiscidae	Diving Beetles					X	2
	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	3
	Orthocladiinae	Bloodworms			X		X	4
	Simuliidae	Black Flies		X	X	X	X	5
	Tipulidae	Crane Flies	X	X	X	X	X	5
Ephemeroptera	Leptophlebiidae	Mayflies	X	X	X	X	X	8
Lepidoptera	Pyralidae	Moths		X				3
Neuroptera	Neurorthidae	Lacewings			X			9
Odonata	Synthemistidae	Dragonflies	X	X	X	X	X	5
	Telephlebiidae	Dragonflies			X		X	9
Plecoptera	Austroperlidae	Stoneflies	X	X	X	X	X	10
	Gripopterygidae	Stoneflies	X	X	X	X	X	8
	Notonemouridae	Stoneflies				X		6
Trichoptera	Ecnomidae	Caddis Flies	X			X	X	4
	Hydrobiosidae	Caddis Flies		X	X		X	8
	Hydropsychidae	Caddis Flies			X	X	X	6
	Leptoceridae	Caddis Flies	X	X	X	X	X	6
	Philopotamidae	Caddis Flies		X	X	X	X	8
	Polycentropodidae	Caddis Flies			X		X	7
Non-Insects	Parastacidae	Freshwater Crayfish/Yabbie		X				4
	Erpobdellidae	Leeches					X	1
	Oligochaeta	Freshwater Worms	X	X	X	X		2