7. Groundwater

7.1 Assessment approach

An assessment of the groundwater system at the site of the existing Stage 1 and proposed Stage 2 ash repository areas was conducted in September 2007. The assessment was based on existing monitoring data from a network of six wells collected by Delta Electricity between November 2001 and April 2007. Five of these monitoring wells are located at or close to the existing Stage 1 ash repository; one monitoring well is off-site. Due to the drought conditions that have prevailed in recent years, several on and off-site groundwater wells have frequently been dry, causing gaps in groundwater chemistry data corresponding to dry conditions since early 2004.

The assessment addresses the Environmental Assessment requirements provided by the Director-General of the Department of Planning (see Appendix C), covering the following key areas:

- Groundwater hydrology — assessing potential changes in infiltration to groundwater and discharge of groundwater.
- Groundwater quality — assessing the potential impacts on groundwater quality associated with the use of the proposed Stage 2 ash repository area and comparing regional surface water quality to water quality at groundwater discharge areas.
- Groundwater management and monitoring — identifying current management and monitoring activities and the need for any additional activities.

This study provides a baseline assessment of the hydrology and quality of groundwater in the study area. It investigated potential impacts to the groundwater system, provided recommendations for mitigation measures, and proposed a groundwater monitoring program to ensure mitigation measures are successful or enable modification to activities in accordance with monitoring outcomes. This chapter provides a summary of the key findings and conclusions of this assessment. Full details of the study can be found in Technical Report 1 in Appendix E.

Trials have been undertaken at Mount Piper to assess the likely infiltration of water through stored ash, and the potential impacts to the groundwater system. As the trials replicated actual conditions, it was considered that desktop hydrogeological modelling would not provide any further information. The decision to not undertake further modelling was discussed with the Department of Water and Energy on 27 August 2007 as this approach differs from the specifics of the Environmental Assessment requirements.

7.2 Site context

7.2.1 Landform, geology and soils

The proposed Stage 2 ash repository area is located within Kerosene Vale on the western slopes of the Great Dividing Range, approximately 880 metres above sea level. The proposed ash repository area lies on a generally flat plateau, with a slight slope towards the Coxs River in the south-west (ERM Hyder 2002). The area is dissected by several water bodies (including rivers and creeks) that drain the plateau in all directions. (See also surface water assessment in Chapter 8.)

The underlying geology of the Wallerawang region largely comprises Triassic- and Permian-aged sediments that form the western edge of the greater Sydney Basin sediments. The sediments consist largely of quartzite, siltstone, sandstone and claystone, with folded deposits comprising granite, adamellite and granodiorite.

The characteristic surface geology (as shown in Figure 7-1) in much of the Wallerawang region comprises the Shoalhaven Group (Berry Formation), including the Illawarra Coal Measures and outcrops of Narrabeen Sandstone.

Bore logs at the existing Stage 1 and proposed Stage 2 ash repository areas indicate that the geology of the site is generally characterised by sandy clay layers to between 5 and 7 metres below ground level underlain by shale and sandstone. Some bore logs also show deposits of coal and coaly siltstone of between 0.5 and 1.5 metres thickness interspersed with mudstone, siltstone and claystone at depths between 7 and 15 metres.

The main soil landscape in the area (Cullen Bullen) consists of moderately deep (up to 1 metre) yellow podsolic soils, soloths and yellow leached earths (ERM Hyder 2002). Soils associated with this soil landscape are generally limited by high water erosion risk, hard-setting surface, and moderately acidic to neutral conditions. Soil in the region is generally low to very low in nutrients, has a low nutrient-storage and water-holding capacity, and low pH buffering.

7.2.2 Groundwater

Groundwater in the study area flows west from the existing Stage 1 ash repository area towards the Lidsdale Cut (see Figure 7-2), which collects groundwater flow from up-gradient areas. Previous wet ash disposal (in use between the 1950s and 1990) caused elevated groundwater levels in the monitoring bores located on the downstream face of the active ash surface (Appendix C in ERM 2002). During this time the groundwater inflows to the Lidsdale Cut increased due to the elevated water levels and were sufficient for periodic overflows from the Lidsdale Cut to Sawyers Swamp Creek to occur (Appendix C in ERM 2002).

When wet ash disposal ceased at the site, water levels in the monitoring bores dropped and no overflow was observed from the Lidsdale Cut, suggesting that there had been some seepage from the wet ash into groundwater. The ash disposal at the proposed Stage 2 repository would involve dry ash, removing a potential source of water seepage to groundwater (that is, water from wet ash would not seep to groundwater as the ash would not be placed in a liquid form) as has been observed for Stage 1 dry ash placement. The potential for water infiltration to groundwater from the proposed dry ash placement activities are discussed in Section 7.4.1.

Previous reporting (Pacific Power, 1997 in ERM 2002) indicated that groundwater flows from the ash repository were relatively free of trace elements. Elevated levels of fluoride and boron were identified in the groundwater during assessment of three groundwater monitoring bores down-gradient of the ash repository, with zinc being the other major trace element present (ERM 2002).

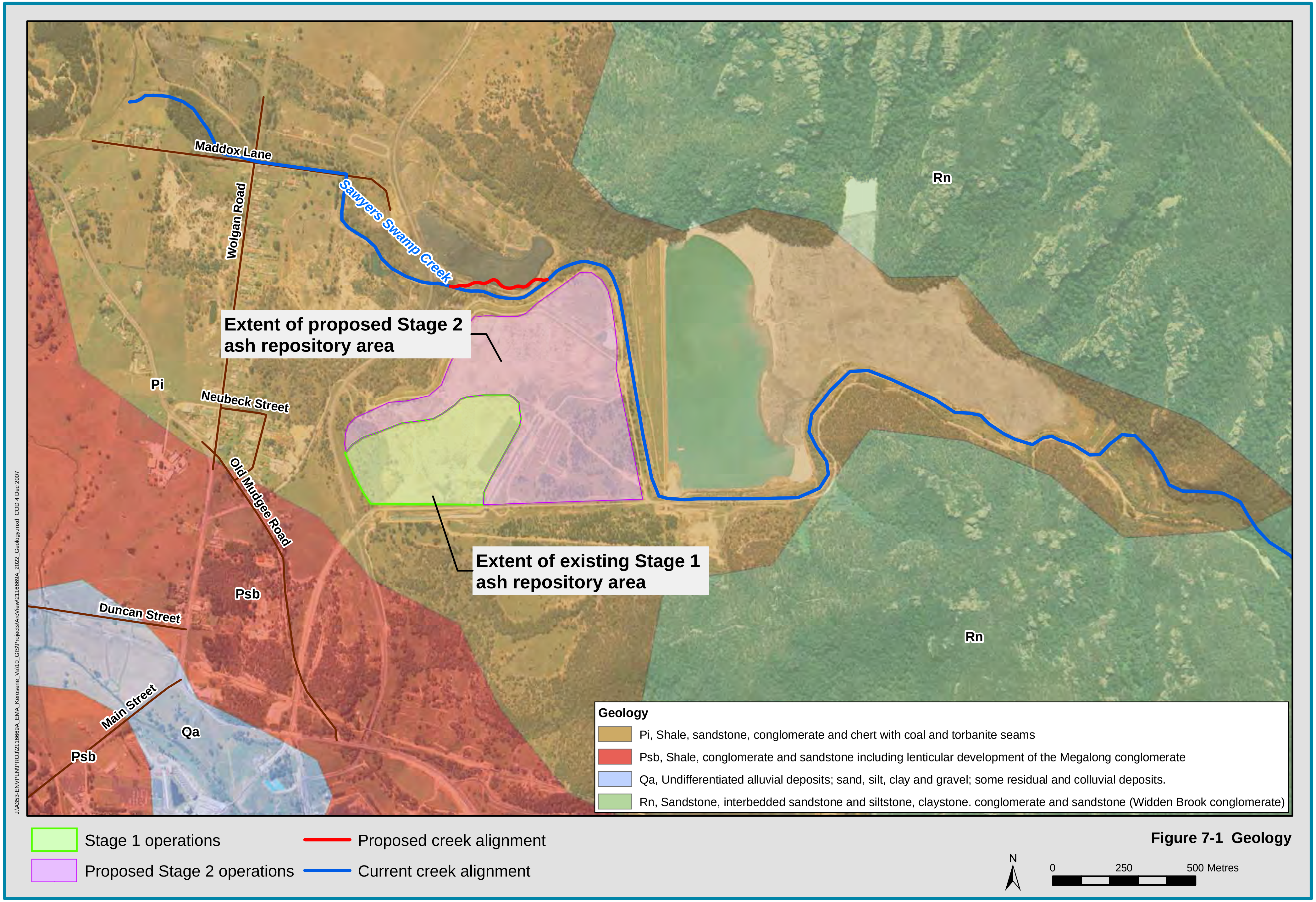
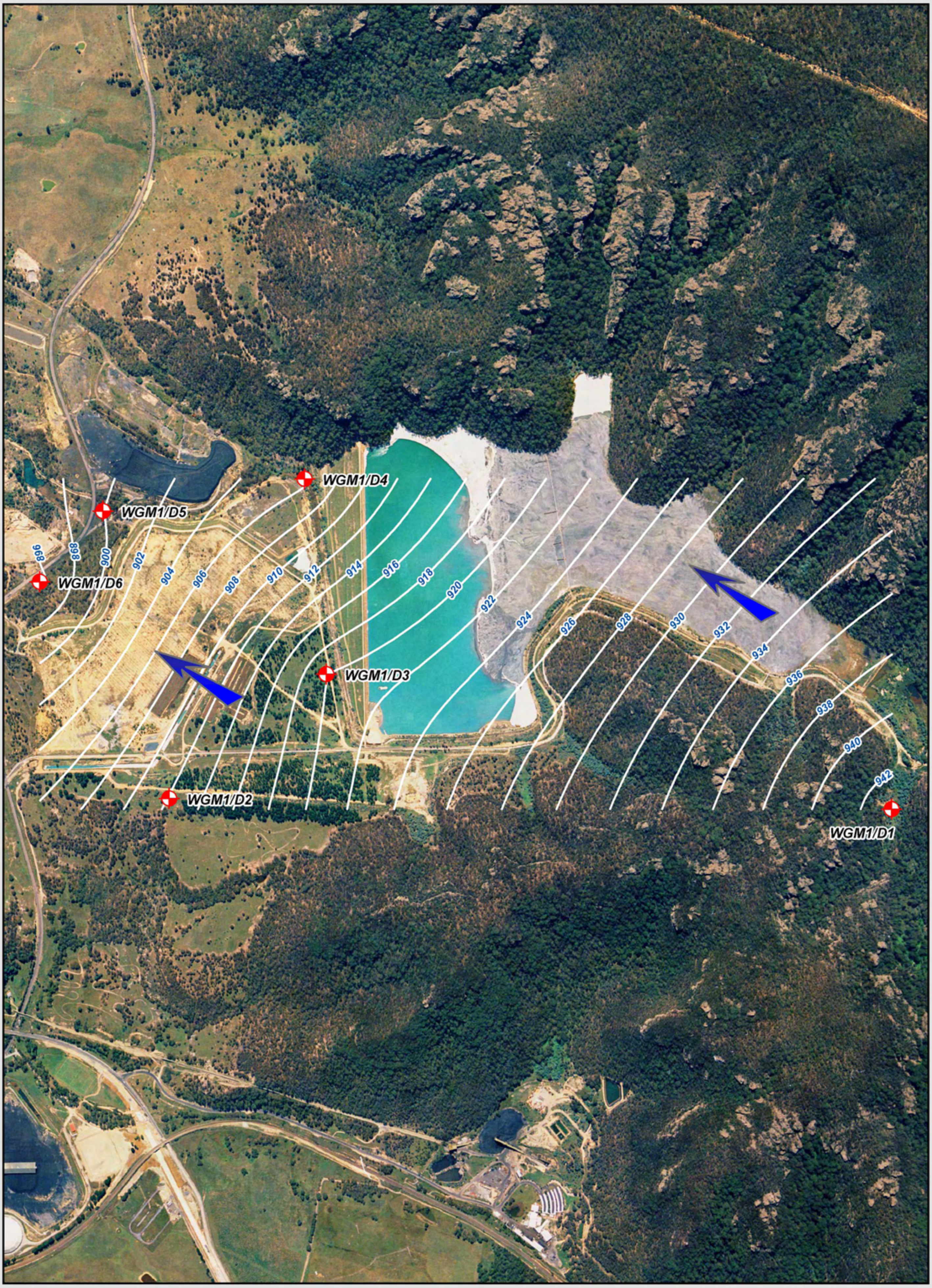


Figure 7-1 Geology



Groundwater bore

Estimated groundwater contour (18 Jan, 2006)

0 200 400 Metres

Figure 7-2 Groundwater hydrology

The Department of Water and Energy (former Department of Natural Resources) bore register identifies 89 existing groundwater bores within a 10-kilometre radius of the proposed Stage 2 ash repository. The bores are registered for irrigation, private domestic and stock use, with nine bores registered for government (other) and local government uses. The standing water level in the bores is recorded as less than 15 metres below ground level (mbgl). Water quality data for these bores indicates that salinity levels are generally good (<280 mS/cm (EPA 1997)) to fair (280–800 mS/cm (EPA 1997)) and pH is near neutral.

7.2.3 Groundwater-dependent ecosystems

A search of the Australian Water Resources Register (2005) did not identify any groundwater-dependent ecosystems in the vicinity of the proposed Stage 2 ash repository area. Some groundwater dependent ecosystems may be present in the vicinity of Sawyers Swamp Creek and the Lidsdale Cut, where groundwater seeps and springs have been observed. However, the vegetation in the area is already significantly degraded. As such, the proposal is considered unlikely to have a significant impact on any groundwater-dependent ecosystems. Aquatic ecology is further discussed in Section 9.

7.2.4 Regional water quality

The proposed Stage 2 and existing Stage 1 ash repository areas are part of the Coxs River catchment. Prior to commencement of operations at the Stage 1 area, the catchment was classified as disturbed, with some evidence that existing and historic land use activities had contributed to deterioration in local water quality (Appendix C, ERM 2002). Local creeks in the Lidsdale region provide water for industrial uses, particularly coal mines and power stations. Water from the Coxs River and its tributaries is also used for irrigation. There are no known areas of groundwater contamination in the vicinity of the existing and proposed ash repository areas. Surface water quality in the catchment is discussed in Chapter 8.

7.3 Existing conditions

7.3.1 Groundwater hydrology

Groundwater flow beneath the existing Stage 1 repository area is in a westerly direction with standing water levels between 1 and 12 metres below ground level (mbgl) (see Figure 7-2). The shallowest groundwater levels are observed in the vicinity of Sawyers Swamp Creek, with small seeps and springs also observed in the area. While there is some fluctuation in groundwater levels with time, these appear to be the result of natural variation. No increase in groundwater levels from bores under or close to the operational Stage 1 area was observed. Bores were occasionally observed to be dry, approximately corresponding to extended periods of low rainfall.

7.3.2 Groundwater quality

The groundwater monitoring data obtained from the six wells indicates that the pH values are slightly acidic (6.8–3.1), and over time, appear to be reasonably consistent, with some small seasonal variation. Low pH spikes are occasionally observed in bores where low water levels have been noted. There does not appear to be any significant difference in pH between monitoring bores located at the active ash repository area and at the up-gradient, off-site location. The pH range is consistent with regional water quality (see Section 8.2.6), but is slightly lower than the Australian and New Zealand Environment and Conservation Council (ANZECC) ecosystem protection and irrigation guidelines.

Concentrations of trace elements (magnesium, iron, cadmium, fluoride, zinc, manganese and boron) have been detected at concentrations greater than the ANZECC ecosystem protection guidelines in groundwater and surface water. Concentrations of these elements are higher at monitoring bores down-gradient of the active ash placement area than at up-gradient locations. Groundwater is known to infiltrate to surface water in some locations (such as the Lidsdale Cut) and detection of trace elements in the surface water suggests the source of groundwater maybe the existing Stage 1 repository. However, with the exception of boron, all concentrations were below ANZECC irrigation guideline values.

Given the low water infiltration rates and that water-retention times in the ash are long, it is likely that the trace element concentrations are representative of saturated concentrations within the ash (see Technical Report 1 in Appendix E for actual values).

7.4 Impacts to groundwater

The proposed Stage 2 ash repository area would be located on top of historical wet ash repository areas. Approximately 1,500 tonnes per day of dry ash is anticipated to be placed at the proposed Stage 2 ash repository (at approximately 15% moisture content) reaching a maximum height of approximately 940 metres AHD. The new dry ash would be placed over the capped ash in these areas. With capping in place, rates of infiltration to groundwater would be low and the risk of potential impacts reduced. The most likely groundwater impacts would be associated with, temporary reduction in pore space due to the weight of the additional ash placed, and minor temporary impacts from construction of the creek realignment. These processes could result in changed (increased) groundwater levels. Additional impacts from operation could include leaching of trace elements such as arsenic, boron, fluoride, zinc, selenium, barium and strontium from the ash into the groundwater. Groundwater infiltrating through the ash placed as part of Stage 2 activities is likely to discharge at the interface of the base of ash and the capping material of the historical ash placement, in the form of surface water discharge. This discharge would be captured as part of surface water management and associated controls as outlined in Section 8.

There is a possibility that groundwater levels may temporarily rise during construction due to compaction of the material causing increased pore pressures. However, the impact of this is expected to be minor, as there are naturally occurring seasonal variations. Historical data supports that any increase in groundwater level should be temporary and the naturally occurring conditions will return upon cessation of work.

Discharge areas are located to the north of the proposed Stage 2 ash repository area, close to the Swayers Swamp Creek and Lidsdale Cut areas. Construction activities to realign Sawyers Swamp Creek could affect these groundwater discharges. This creek has naturally low surface flows, and is likely to gain some flow from groundwater, seepage from SSCAD and surface water runoff. The design of the realigned creek is such that base flow would be maintained in the new section of creek to minimise any changes to discharge input to the creek. Potential impacts resulting from the proposed creek realignment would be minimal in relation to creek flow.

Given the current level of degradation of the waterway and current regional surface water quality, it is unlikely that any groundwater discharged to these areas would have a significant impact and as such the remainder of this section addresses operational impacts to groundwater as construction impacts are anticipated to be minor and temporary.

7.4.1 Groundwater hydrology

Groundwater levels and salinity

Infiltration of water through the ash does not appear to be significant. Capping of the placed and compacted dry ash would limit the infiltration of water into the groundwater system with open ash face areas kept to a minimum. An initial, and temporary, increase in groundwater levels may occur as the ash is placed and the mass overlying the historical ash repository area is increased causing an increase in pore pressure and reduction of pore space for water storage. Any increase in groundwater levels due to reduced pore space would be controlled by staging the ash stacking rates and ensuring that lifts are limited to small, incremental increases. This impact would dissipate with time.

Water level changes due to ash placement in the area have been observed in the past, and were not noted to have led to an increase in salinity. Potential salinity issues can be controlled by controlling groundwater level changes. In addition, as any water level increases would be temporary, no long-term salinity problems are foreseen as a result of the proposed Stage 2 activities. The proposed groundwater monitoring program should include monitoring of key salinity indicators.

Water infiltration to the ash repository

Infiltration rates to fly ash pads and the potential for trace elements in the ash to be mobilised to the groundwater system have been investigated through extensive field trials at Mount Piper Power Station (ERM Hyder 2002). The ash tested in the Mount Piper trial is considered to have comparable properties to that generated at the Wallerawang Power Station (ERM Hyder 2002). The results of the Mount Piper field trials are considered suitable to assess the likely infiltration of water to the proposed Stage 2 ash repository and the potential flow-on effects to the groundwater system. The Mount Piper trials replicated actual conditions; as such, it was considered that additional desktop hydrogeological modelling would not provide further information.

The Mount Piper field trials were undertaken over 2 years from 1996, during which time periods of wetter and drier than average rainfall conditions were experienced. The objective of the tests was to determine runoff, infiltration and evaporation for both capped and uncapped fly ash.

The results of the Mount Piper trials indicated that rates of infiltration on uncapped areas were very low, with an average rate of 0.59%; evaporation rates were around 95%. Infiltration rates on capped areas were less than 0.07% (or 1 millimetre). Although not tested during the trials, it is expected that following revegetation, these infiltration rates would likely decrease further. Additional mitigation factors for the proposed Stage 2 ash repository would include the presence of low permeability capping material at the base of the repository associated with the historical ash placement. In addition, areas of exposed ash face would be limited throughout the operating life of the repository through the implementation of a staged ash placement approach.

The rate of infiltration of water through the ash gives an indication of the transport of trace elements from the ash to groundwater. Based on the indicated low infiltration rates, it is expected that impacts to groundwater associated with mobilised trace elements would not be significant. The limited water that does infiltrate is likely to discharge as surface water runoff at the interface of the Stage 2 placement and the historical material.

Groundwater recharge and discharge areas

Groundwater discharge areas are located to the north of the proposed Stage 2 ash repository area, close to the Sawyers Swamp Creek and Lidsdale Cut areas. The potential for increased groundwater levels due to increased pore pressure from reduction of pore space could increase discharge to these areas. The volume of discharge would be monitored throughout operation of the proposal. As discussed above, this impact would be limited through the use of staged ash stacking and ongoing monitoring, and is anticipated to be temporary.

The discharge area likely to be most affected by the proposed Stage 2 ash repository operations would be a section of Sawyers Swamp Creek to the north. Sawyers Swamp Creek has a naturally low surface flow, which has been retained as part of the creek design outlined in Chapter 3.

Given the current level of degradation of the waterway and regional surface water quality, it is unlikely that any groundwater discharged to the areas described above would have a significant impact on baseline water quality. A more detailed discussion of water quality issues associated with the creek realignment is provided in Chapter 8.

7.4.2 Groundwater quality

Changes to groundwater quality as a result of the proposed Stage 2 ash repository are expected to be minimal. The low recharge to the groundwater system currently occurring through the historically placed ash and the anticipated low infiltration through the proposed Stage 2 ash repository indicates that relatively small volumes of water would be expected to pass through the ash to reach the groundwater system.

Current monitoring data show that trace elements of zinc, copper, lead, cadmium, barium, fluoride and boron are present in the groundwater down-gradient of the existing Stage 1 ash repository, indicating some leaching of these trace elements from the ash. However, concentrations in groundwater, while higher in some cases than the ANZECC ecosystem protection guidelines, are generally lower than the ANZECC irrigation guidelines. Furthermore, as discussed in Section 8.2.6, trace element concentrations in surface water at groundwater discharge locations are consistent with current regional water quality, but in exceedance of certain ANZECC guidelines in some cases (see Section 8.2.6 for surface water quality details).

Increasing the thickness of the ash layer would increase residence times of water, which has the potential to increase trace element concentrations. However, as current rates of water infiltration are low and the residence time of water in the ash is long, it is expected that saturated concentrations are already present in water infiltrated to groundwater. Therefore, an increase in trace element concentrations in groundwater is not anticipated.

The transport of any trace elements leached from the ash would likely be reduced due to sorption onto the clay soils that underlie the proposed Stage 2 ash repository (Mudd 2000).

Drainage from the proposed Stage 2 ash repository is discussed in Section 8.4.2. Runoff water from the proposed Stage 2 area would be collected and disposed of in a manner similar to that at the currently operating Stage 1 area.

7.5 Management of impacts

7.5.1 Summary of mitigation measures

Table 7-1 lists the impacts identified in Section 7.4 and the mitigation and management measures proposed to address them.

Table 7-1 Management of Stage 2 repository impacts on groundwater

Impact	Proposed management measure
Groundwater hydrology	
Increased groundwater levels due to increased mass overlying the historical ash repository area, resulting in increased pore pressure and reduction of pore space for water storage.	Stage the stacking rates and minimising the size of lifts along with ongoing monitoring.
Increased discharge close to the Sawyers Swamp Creek and Lidsdale Cut areas due to and increased pore pressure/reduction of pore space for water storage.	Staging the stacking rates and minimising the size of lifts along with ongoing monitoring.
Discharge of infiltration water at the interface of new ash placement and historical material.	Will be captured as part of surface water as described in Chapter 8.
Water infiltration to, and leachate from, the ash repository.	The exposed area of ash face would be limited to reduce the potential for infiltration of water to the groundwater system through the ash repository. Based on low rates of infiltration, it is expected that any impacts upon groundwater would not be significant.

7.5.2 Groundwater monitoring program

A detailed groundwater monitoring program, which also encompasses surface water quality at the likely groundwater discharge zones (Sawyers Swamp Creek), would be developed and implemented.

During the first 12 months of Stage 2 activities, groundwater monitoring would be undertaken on a monthly basis, and if impacts are not observed during this time, the program could then continue on a quarterly basis. The analytical suite currently undertaken by Delta Electricity (Table 7-2) would be maintained, however, low detection limit analysis for trace metals would also be undertaken to ensure that the guideline values are higher than the detection limit. Key salinity indicators would also be included in the analytical suite based on a review of data collected for Stage 1 activities.

Groundwater bores WGM1/D1, WGM1/D5 and WGM1/D6, from which data have not been available in recent times, would be included in the monitoring program. If it is determined that these bores have been lost or damaged, then they may be redrilled and constructed in a similar location. At least two new down-gradient wells to the north of the site and an additional up-gradient well would be considered to provide background groundwater information and allow for the slight relocation of placement activities from the existing Stage 1 area to the proposed Stage 2 area.

A detailed groundwater monitoring program would be established as part of the OEMP prior to the commencement of Stage 2 activities. The program and associated management measures would include trigger values which, if exceeded, would lead to implementation of appropriate responses.

Table 7-2 Current groundwater monitoring analytical suite

Category	Analyte
Field parameters	▪ pH ▪ conductivity ▪ alkalinity ($CaCO_3$) ▪ total dissolved solids
Anions	▪ chloride ▪ fluoride ▪ sulfate
Cations	▪ sodium ▪ potassium ▪ calcium ▪ magnesium
Metals	▪ arsenic ▪ silver ▪ barium ▪ boron ▪ cadmium ▪ chromium (III) and (VI) ▪ copper ▪ iron ▪ mercury ▪ manganese ▪ lead ▪ selenium ▪ zinc

8. Surface water

8.1 Assessment approach

The impacts on local and regional surface water resources as a result of the construction and operation of the proposed Stage 2 ash repository were assessed. The assessment includes impacts related to the use of the proposed Stage 2 area as well as impacts related to the proposed realignment of Sawyers Swamp Creek and other ancillary activities. The assessment addresses the Environmental Assessment requirements for consideration provided by the Director-General of the Department of Planning (see Appendix C). Full details of the proposed Sawyers Swamp Creek realignment and the results of the surface water assessment are provided in the Draft Sawyers Swamp Creek Rehabilitation Plan in Appendix B and Technical Report 2 in Appendix F.

The assessment addresses the following key areas:

- Catchment hydrology — assessing potential changes in catchment flows as a result of changes to the catchment surfaces, including the proposed creek realignment.
- Water quality — assessing the potential impacts to water quality resulting from the use of the Stage 2 ash repository.
- Water management and monitoring — reviewing current management and monitoring activities and identifying any additional requirements.

8.2 Site context

8.2.1 Drainage

The proposed Stage 2 ash repository is located within the upper catchment of the Coxs River (see Figure 8-1). The Coxs River forms part of the Hawkesbury-Nepean River system and flows to Lake Burragorang, which is part of Sydney's water supply.

Sawyers Swamp Creek flows in a westerly direction past the existing Stage 1 and proposed Stage 2 repository areas to join the Coxs River immediately to the north of the town of Lidsdale (approximately 2 kilometres downstream from the site).

The existing Stage 1 and proposed Stage 2 ash repository areas cover approximately 70 hectares immediately to the west of the embankment of SSCAD. The south-east corner of the site (the 'pine plantation area') has a slope of about 4%, while the remainder of the proposed Stage 2 area is relatively flat. The embankments of the Stage 1 ash repository area and the embankment wall of the historic ash dam are the dominant topographic features of the site. The existing ash repository currently has an elevation of approximately 920 to 940 metres AHD.

Site drainage is currently controlled in accordance with the Surface Water Management Plan for the Extension of the Kerosene Vale Ash Placement Area Phase 1, Work Instruction WWE-04 (June 2005) and Water Management Plan, Work Instruction WWE-05 (June 2005). Details are discussed below and shown in Figure 8-2.

Figure 8-1 Catchment area

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Water management at the site is based on the principle of separation of clean and dirty water as follows:

- Clean water comprises rainfall runoff from undisturbed areas including areas of ash repository that have been capped and revegetated.
- Dirty water comprises water collected from within disturbed areas including the exposed ash face, unvegetated capped areas, work areas, stockpiles and haul roads.

Clean water is diverted around exposed ash surfaces and disturbed areas in surface drains and discharged to Sawyers Swamp Creek to the east of the site. Runoff from the plantation area (south-east corner of the site) is directed to the return water channel.

Dirty water is collected within open drains around the perimeter of the ash repository area and discharged to a collection pond located at the north-east corner of the site. During operation of the Stage 1 area, this pond was moved as the ash face progressed in a northerly direction. The existing pond has a capacity of 3 megalitres and has been sized to allow storage of dirty water during the 24 hour, 10-year Average Recurrence Interval (ARI) event. Overflows from the collection pond flow to the return water channel (see Figure 8-2).

Runoff from the exposed ash areas is minimal due to the hydroscopic nature of the ash. Large quantities of moisture can be stored in the upper layers of the ash, evaporating during dry weather. Runoff only occurs during prolonged wet weather. Pilot studies undertaken at a nearby ash dam (Mount Piper Power Station) indicated that evaporation rates from the ash surface are around 95%, and infiltration rates are around 0.59%. As such, less than 5% of annual rainfall is discharged as runoff from the ash surface (ERM Hyder 2002).

The collection pond provides primary treatment of water through sediment removal. Water collected in the pond is re-used on site for activities such as dust suppression and moisture control of the ash. Excess water collected in the pond is pumped to a 25 megalitre storage dam as an interim measure for reuse on site at a later time. However, while the return water channel is operational, dirty water is released to this channel in favour of the 25 megalitre storage dam. It should be noted that the disturbed area from which water is captured is limited to 5 hectares at any time. This equates to less than 7% of the KVAR catchment area and less than 0.5% of the Sawyers Swamp Creek catchment. Due to the relatively small amount of water captured, downstream impacts are considered to be minimal. The exposed ash area is further limited to 1.5 hectares, which is less than 0.1% of Sawyers Swamp Creek catchment, further reducing the potential risk and impacts of the proposal on water quality, hydrology, and aquatic ecology.

Delta Electricity currently uses the return water channel to receive water from the SSCAD, which is then directed to the Wallerawang Power Station treatment plant. At the treatment plant, the water is neutralised before being directed to settling ponds and then, when necessary, is discharged to the Coxs River at a licensed discharge point in accordance with licence conditions.

Delta Electricity's Kerosene Vale Dry Ash Placement Environmental Management Plan (2005) requires that capping and revegetation of areas is completed with minimal delay. Erosion and sediment controls are implemented as interim water control measures. Once areas are capped and revegetated, runoff can be diverted to the clean water system. Additionally it is a requirement that all work on disturbed areas is ceased during heavy rainfall.

Figure 8-2 Existing site drainage

8.2.2 Existing Sawyers Swamp Creek alignment

The existing alignment of Sawyers Swamp Creek is significantly altered from its natural course. This is a result of previous mining and ash storage activities. The existing alignment of Sawyers Swamp Creek is shown in Figure 8-1.

Key modifications within the catchment that have led to the existing channel alignment include:

- Construction of the SSCAD, the original path of the creek passed through the middle of the existing SSCAD. A concrete channel was constructed to divert surface water from the upper reaches of Sawyers Swamp Creek around the southern boundary of the SSCAD.
- Mining and coal storage activities, the original path of the creek flowed through an area that has been used for coal storage.
- Construction of the Kerosene Vale ash repository, while the natural course of the creek is understood not to have passed through the repository area, the existing channel alignment has been influenced by the construction of the ash repository, currently flowing around the eastern and northern boundaries.

The creek now flows, as a concrete channel, around the southern boundary of SSCAD. From the spillway of SSCAD the creek follows a realigned route around the eastern and then northern boundary of the ash repository area (Stage 1 and 2). The creek in this area is considered degraded (the habitat and condition of the creek is discussed further in Chapter 9) and has steep, eroded banks. From here the creek flows through culverts under an internal road and then under the private haul road continuing on to meet its original course before joining the Coxs River (see Figure 8-1).

8.2.3 Existing Sawyers Swamp Creek flows

There are no flow records for Sawyers Swamp Creek. A hydrologic model was developed to determine flows generated from the catchment. Details of this modelling are provided in Technical Report 2 in Appendix F. The flows modelled in the creek immediately upstream of the section to be realigned are indicated in Table 8-1.

A hydraulic model of the existing channel was developed based on survey data for the area. This model provided an understanding of the flow regime within the existing and proposed creek alignments. The modelling indicated that flood flows generated from the catchment upstream of the ash repository are not contained within the existing main creek alignment.

The existing channel is broad and poorly defined in the bend near the coal storage area owned by Centennial Coal. At this location, the model predicts that a significant portion of flow would divert from the creek alignment during flood events. The diverted flows would travel in a north-westerly direction through the coal storage area.

Modelling predicts that during flood events of a 2-year average recurrence interval (ARI) and greater, spill out of the channel will occur. During extreme flood events (100-year ARI event) it is estimated that approximately half of the peak flow will leave the main channel and flow in a north-westerly direction.

Table 8-1 Existing flows in Sawyers Swamp Creek

Location	2-year ARI flow (m^3/s)	100-year ARI flow (m^3/s)
Prior to point where water leaves main channel	5.9	12.7
After point where water leaves main channel (in section to be realigned)	4.3	5.9

8.2.4 Existing channel condition

Sawyers Swamp Creek is a highly modified creek with little resemblance to its natural course in the vicinity of the site. The existing channel was constructed approximately 40 years ago, with little apparent effort to reinstate natural features or protect the channel bed and banks from erosion. The channel appears to be over-enlarged for the flows likely to be experienced; this is thought to be a result of over design of the excavated channel and ongoing bank erosion. As a result, the existing channel has steep, eroded banks, shallow flow, is congested with dense weed growth, has little variation in bed material, and little hydraulic diversity. Pool and riffle sequences are typical of streams of this nature, but are absent from this reach of the creek.

An assessment of the aquatic ecology of the creek concluded that the creek is in a relatively degraded condition, with sparse vegetation including both native and exotic species (see Chapter 9).

8.2.5 Water quality objectives

The ANZECC published the National Water Quality Management Strategy series, which aims to achieve the sustainable use of Australia's water resources by protecting and enhancing their quality while maintaining their economic and social development. The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000) form the central technical reference of the National Water Quality Management Strategy, which the federal and all state and territory governments have adopted for managing water quality. These guidelines provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters.

The ANZECC water quality guidelines provide a benchmark for water quality parameters to protect desired environmental values. Environmental values for waterways within Sydney's drinking water catchments are identified in the Drinking Water Catchments Regional Environmental Plan No. 1 (2007). The following values are identified for the catchment:

- Aquatic ecosystems.
- Recreational water — primary contact, secondary contact and visual use.
- Drinking water (raw water).
- Primary industries — irrigation and general water use, livestock drinking water and aquaculture and human consumers of aquatic foods.

8.2.6 Existing water quality

Sawyers Swamp Creek is the primary receiving water for any discharges from the existing and proposed ash repository areas, which also influences the quality of water reaching the Coxs River. Land use within the upper Coxs River catchment, including agriculture, coal mining and power generation, are known to have detrimental effects on the water quality in the region (The Ecology Lab 2007).

The primary constituents of the ash produced at the Wallerawang Power Station are silicon and aluminium (ash properties are detailed in Chapter 2). Water quality sampling undertaken during preparation of the REF for the Stage 1 area identified elevated concentrations (in comparison to ANZECC guideline levels) of boron, fluoride, aluminium, nickel, zinc and cadmium within the water in the SSCAD (ERM Hyder 2002).

Delta Electricity currently conducts water quality monitoring at four surface water locations in accordance with Work Instruction WWE-07 (Environmental Monitoring Plan). This monitoring includes water quality within the SSCAD, Dump Creek and two sites within Sawyers Swamp Creek. Recent water quality monitoring data is provided in Appendix F.

Water quality data collected by Delta Electricity over the period 1991 to 2000, was presented in the REF for Stage 1 operations in 2002 (ERM Hyder ERM 2002) at sites within Sawyers Swamp Creek and the Coxs River. The key findings of this assessment were:

- Conductivity levels in the Coxs River and Sawyers Swamp were highly variable with elevated levels occasionally recorded at all sites.
- Sulfate, calcium and sodium were the dominant ions.
- Iron concentrations were generally less than 0.2 milligrams per litre (mg/L), complying with the ANZECC guidelines for ecosystem protection.
- Manganese concentrations were on average 0.12 mg/L in Coxs River and slightly higher at 0.62 mg/L in Sawyers Swamp Creek (meeting the ANZECC ecosystem protection guidelines).
- Lead concentrations were 0.001 mg/L, complying with the ANZECC guidelines for ecosystem protection.
- Copper, zinc, and aluminium exceeded the ANZECC ecosystem protection guidelines in both the Coxs River and Sawyers Swamp Creek.
- Of the trace elements, median boron levels for the sampling period exceeded ANZECC guidelines, but median selenium levels were within guideline levels.
- Nitrogen concentrations exceeded ecosystem protection guidelines (0.0115 mg/L) at both locations, being 0.031 mg/L in Coxs River and 0.057 mg/L in Sawyers Swamp Creek.

Delta Electricity has continued monitoring at the same locations throughout the operation of the Stage 1 ash repository area (2002–2007). Water quality in Sawyers Swamp Creek (downstream of the junction with Dump Creek) has been similar over this period to that which was presented in the REF, indicating that operation of the Stage 1 area has not led to a detrimental effect on water quality. Median electrical conductivity was recorded at 1072 microsiemens per centimetre (µS/cm). Median pH was 6.3 (which is below the lower limit of the ANZECC ecosystem protection guideline). Boron concentrations remained above guideline criteria (with a median value of 1.4 mg/L recorded). The median value for selenium was within the ANZECC guidelines. The heavy metals copper and zinc recorded median values exceeding the ANZECC guidelines for ecosystem protection, as did cadmium and lead. Recent water quality data monitoring is provided in Appendix F.

8.3 Potential impacts

8.3.1 Hydrology

Construction

The construction phase of the proposed Stage 2 area would require the realignment of a section of Sawyers Swamp Creek and construction of a stability berm for the ash area embankments. These activities are not expected to change flows in Sawyers Swamp Creek.

Mitigation/management measures and controls to address the identified potential impacts associated with construction are discussed in Section 8.4.

Operation

Throughout operation of the proposed Stage 2 ash repository area, site drainage would vary as ash is placed and surface water is managed to prevent water quality impacts. It is proposed that the existing operational water management plan is adapted to the ongoing ash placement operations. This is likely to result in regular changes to the point where clean water is directed into Sawyers Swamp Creek to adapt to changing operations. While this would result in minor changes to flow along Sawyers Swamp Creek in the reach that flows alongside the ash repository, the net flow to the creek would not change. All flows would reach Sawyers Swamp Creek prior to the creek reaching the culvert crossing under private haul road resulting in a neutral impact on the creek when compared to existing conditions.

Following completion of operation of the Stage 2 ash placement area, the final landform would be capped and revegetated and all surface water from the area would enter the catchment as clean water. This would result in a slight increase in the overall flows entering the catchment as water would no longer be captured for reuse. This would return flow conditions in the catchment to closer to ‘natural’ conditions and result in a beneficial impact on the creek. It should also be noted that the change in volume of water would be insignificant in comparison to the flows generated from the upstream catchment due to the small proportion of the area from which the additional flows would be generated. The disturbed area for which water is captured and reused is limited to 5 hectares at any one time, equating to less than 0.5% of the total Sawyers Swamp Creek catchment area. As such no diversion of water to allow for this small impact on the catchment is proposed. As a result of the limited area, the downstream impacts of the proposal are minimal as they represent a very small component of the overall catchment. This is further discussed in Section 8.3.3 on cumulative impacts.

The initial design for the proposed realignment of a section of Sawyers Swamp Creek is discussed in the Draft Sawyers Swamp Creek Rehabilitation Plan in Appendix B. The results of the modelling of the proposed realigned channel indicate that:

- The 2-year ARI flow would be contained within the main channel.
- The 100-year ARI flow would be contained within the riparian zone.

One of the key objectives for rehabilitating Sawyers Swamp Creek is ensuring long-term stability of the proposed channel realignment. The approach taken in developing the concept design aimed to ensure a stable creek alignment and cross-section. The operational impacts of the proposed realignment and rehabilitation on hydrology and geomorphic stability relate mostly to additional features to be incorporated into the channel during detailed design.

The potential impacts would be predominantly positive. These features and potential impacts include:

- Incorporating pools and riffles into the channel design. Riffle sections would be designed with snags and rocks, which would be sized to ensure protection against erosion. Riffle sections would also be designed such that pools form at the bends upstream and at the termination of riffle sections (downstream). The formation of pools would result in slower flow velocities, which in turn would reduce the potential for scour and erosion.
- Incorporating vegetation within the creek bed and banks, which would increase channel roughness, resulting in reduced flow velocities close to the channel bank.
- Establishing riparian vegetation. Riparian zones would be established over a minimum of 20 metres from the top of the realigned channel banks. The planting of these areas with endemic species would enhance the stability of the land surrounding the creek and ensure the stability of the channel during flood flows.
- Naturalising the channel and incorporating riffle and pool sequences would increase channel roughness and reduce flow velocity (as discussed above). Modelling indicates that this may result in a marginal increase in the flow leaving the channel at the bend near the coal storage area during flooding events, and hence decrease flows down the realigned section.

8.3.2 Water quality

Construction

The construction phase activities, including realignment of Sawyers Swamp Creek, strengthening of the embankment walls, and excavation of the plantation area, have the potential to generate pollutants that could affect surface water quality. The primary impact to water quality during construction would be due to increased sediment loads as a result of exposed soil being conveyed to Sawyers Swamp Creek during storm events. Increased sediment delivery to waterways can smother benthic habitats and organisms, and can increase levels of nutrients, metals and other potential toxicants that attach to the sediment particles.

Other potential pollutants that may be expected to impact on water quality during the construction period include:

- Hydrocarbons and chemicals as a result of spills and leakages from construction vehicles or fuel/chemical stores on construction sites.
- General litter and gross pollutants from construction materials.

The construction of the creek realignment would be undertaken in a manner designed to minimise environmental disturbance and mitigate risks associated with this type of construction activity. Potential impacts relating to water quality to be considered could include:

- Delivery of remnant coal material from the coal storage area (through which the realigned creek would run) to the proposed creek realignment.
- Erosion and sedimentation associated with the realignment works. The construction of the proposed realignment would require stripping and stockpiling of topsoil and cutting of the new channel, some vegetation removal may also be required. All of these activities have the potential to result in increased erosion and sedimentation. In addition, erosion and/or scouring of the new channel could result from diversion of flows into the new channel.

Mitigation/management measures and controls to address the identified potential impacts associated with construction are discussed in Section 8.4. It is anticipated that this will result in a short term impact on water quality, but once completed and rehabilitated will result in a beneficial impact on water quality.

Operation

The proposed Stage 2 area operations would continue to result in exposed ash areas. There is a potential for pollutants in the ash to be mobilised in runoff from these areas. There is also potential for sediment to be mobilised in runoff from disturbed areas of the site and from capped areas prior to revegetation. However, the potential for pollutants to be discharged from the site would be low given that:

- Less than 5% of annual rainfall is expected to be discharged as runoff from the ash surface.
- Surface water from disturbed areas would be contained in a 3-megalitre water quality basin and re-used in on-site applications such as dust suppression and moisture control of the ash.
- Any collected dirty water that is not re-used on site would be treated at the Wallerawang Power Station prior to discharge via a licensed discharge point to the Coxs River.

These potential impacts are also associated with the existing Stage 1 area operations. Comparison of water quality monitoring data collected during operation of the Stage 1 area to data collected prior to use of this area indicate that the water management system is working effectively and that operations are not having a detrimental impact on water quality. It is anticipated that given the continued application of appropriate water quality management measures, the proposed Stage 2 operations would similarly not result in detrimental surface water quality impacts and due to their similarity to the stage 1 activities would result in a neutral impact on water quality.

The initial design for the proposed realignment of a section of Sawyers Swamp Creek is discussed in the Draft Sawyers Swamp Creek Rehabilitation Plan in Appendix B. The design for the proposed creek realignment has been developed with a focus on geomorphic stability, which aims to ensure an improvement in water quality within the creek through a reduction of sediment loads. Riparian corridors, extending 20 metres from the top of bank on both sides of the creek, would be incorporated into the creek realignment design. These areas would provide natural filters for stormwater runoff; assist in stabilising stream banks, and provide habitat and corridor functions for flora and fauna. As a result of these features of the creek realignment, it is anticipated that water quality within Sawyers Swamp Creek would improve following completion of the creek realignment and rehabilitation. In addition, modelling predicts that the proposed channel would be less prone to scour than the existing channel as a result of decreased flow velocities resulting in a beneficial impact on water quality.

Changes to groundwater in the area as a result of the operation of the proposed Stage 2 ash repository may also have some impact on water levels or water quality within Sawyers Swamp Creek. The groundwater levels in the area around the Lidsdale Cut and Sawyers Swamp Creek are shallow, and as such these areas have been identified as a potential groundwater discharge area.

The groundwater assessment that has been undertaken as part of this Environmental Assessment has noted that there is unlikely to be any additional impacts on groundwater from continued ash storage activities at the site, as the dry ash placement facility would be located on top of the historical wet ash placement facility. Further details are provided in Chapter 7 and Technical Report 1, Appendix E.

8.3.3 Cumulative impacts

The region surrounding the proposed Stage 2 development is characterised by agricultural, mining and power generation activities. These industries are traditionally water intensive activities, with Delta Electricity's two power operations (Mount Piper and Wallerawang) using approximately 24,000 ML of water each year. This water is taken from the Coxs River, Fish River Water Supply and Springvale mine.

In addition to these extractions both power operations and mining activities in the area have licences to discharge water into regional systems under set criteria — none of these discharge points are located in Sawyers Swamp Creek.

Sawyers Swamp Creek is a heavily modified creek which has undergone several realignments to allow for coal mining and power generation activities. The flow within the creek is now constrained by SSCAD located upstream of the proposal and further limited by culverts downstream of the proposal as the creek no longer follows its natural course.

It is generally recognised that the historical realignments and modifications have had a cumulative negative impact on aquatic ecology and the general quality of the creek in this area, with the current creek exhibiting an unstable morphology and a degraded ecological environment. With this cumulative impact in mind, the current proposal — whilst requiring the realignment of a section of the creek — will, in the long term, improve the quality of sections of the creek to address the long-term cumulative impacts. In this respect the design of the proposed creek realignment is such that it will address some of the existing stability and erosion issues for realigned sections as well as provide an improved quality creek in these reaches. In this respect the cumulative impact of this development on water quality and hydrology in conjunction with other regional activities is anticipated to be positive.

8.4 Management of impacts

8.4.1 Construction

Mitigation measures would be required to manage impacts that may result during the construction of the proposed Stage 2 ash repository. Erosion and sediment control measures would be detailed, as part of the CEMP and the Sawyers Swamp Creek Rehabilitation Plan, in accordance with Soils and Construction: Managing Urban Stormwater (Landcom 2004) prior to the commencement of construction. Mitigation measures set out in the plan would include:

- Installing erosion and sediment controls such as sediment basins, staked straw bales, and sediment fences.
- Ensuring appropriate planning of creek construction works to reduce the risk of sediment discharge to the existing waterway through limiting the length of time that soil is exposed.
- Restricting construction traffic to defined internal roads, and where required, operating wheel-cleaning areas at locations where vehicles leave the construction sites.
- Ensuring that chemicals and fuels are appropriately stored and bunded.

- Training of construction employees to implement spill-response procedures and implement, maintain and be aware of sediment and erosion control measures and requirements.

The construction of the creek realignment would be undertaken in a manner designed to minimise disturbance. The northern part of the proposed realignment site that has been previously used for coal storage would be prepared prior to the commencement of construction, including removal of any remaining coal to prevent the material entering the new creek channel.

Prior to cutting the creek channel, topsoil would be stripped and stockpiled to be replaced on cut surfaces prior to revegetation. Site layout and channel access points for excavation equipment would be located to protect established riparian vegetation, which provides a natural sediment filtering mechanism. The realigned creek channel would be formed in isolation from the existing channel, with flows diverted only following completion of environmental and erosion control features, revegetation and stabilisation to reduce the potential for erosion/scour of the new channel.

The topography of the area and the proposed construction sequence would minimise many of the risks associated with flooding and erosion during construction by isolating the creek realignment construction area from the existing creek. Runoff from the creek realignment works area would naturally flow in a northerly direction away from the existing creek.

Despite the low risk of the construction works, erosion and sediment controls would be implemented to manage erosion at source rather than relying solely on sediment capture at discharge. Natural vegetation would be maintained where feasible to minimise disturbed area, which can contribute to sediment loads. Should any clearing of riparian vegetation be required, exposed surfaces and slopes would be stabilised as soon as possible following completion of earthworks.

8.4.2 Operation

The existing water quality management system for the Stage 1 ash repository would be continued throughout the proposed Stage 2 operations. The existing plan would be updated and incorporated into a Water Management Plan Work Instruction. A drainage plan for ongoing operations is shown in Figure 8-3. Key operational water quality control measures would include:

- Diverting clean water around disturbed areas.
- Draining all runoff from disturbed areas to a collection pond that would provide primary treatment of the runoff through settling processes.
- Limiting the ‘dirty water catchment’ (the disturbed area) at any one time, with an exposed ash area of 1.5 hectares (equivalent to approximately 6 months ash placement), the same area as set out in the design of the collection pond during the preparation of the Stage 1 REF.
- Moving the 3 megalitre collection pond to appropriate locations (maintaining drainage of dirty water to the pond) as the new ash face progresses.
- Using water collected in the pond on site for dust suppression and moisture control of the ash, with any additional water directed to the return water channel for treatment at the Wallerawang Power Station prior to discharge to the Coxs River via the existing licensed discharge point when required.

- Directing any overflows from the pond to the existing 25-megalitre storage dam (the collection pond has been designed with capacity to contain the 24-hour, 10-year ARI storm event and is shown in Figure 8-2). Water collected in the storage dam would be reused on site or pumped to the return water channel and Wallerawang Power Station for treatment and discharge. This structure may be moved within the area indicated in Figure 8-3 to accommodate ash placement as the ash face moves towards this area, this will only occur when absolutely necessary to maximise the period for Centennial Coal to assess mining options in this area (see Chapter 12).
- Using the 25 megalitre storage dam as a retention area to contain overflows from the dirty water catchment during extreme storm events. Following such an event the collected water would be used on site or pumped to the return water channel and Wallerawang Power Station for treatment and discharge.

In addition to the above mitigation measures, other general maintenance measures that would be implemented to address potential water quality impacts associated with the proposed Stage 2 ash repository include:

- Capping and revegetating of completed areas would be undertaken as a priority, with disturbed areas limited to a maximum of 5 hectares at any one time.
- Installing erosion and sediment control measures to treat runoff from capped areas until vegetative cover is established.
- Restricting work in disturbed areas during heavy rainfall.

In addition to the above mitigation measures, the proposed creek realignment concept design has been developed with the intent to result in no change to existing flow regimes and to reduce the potential for scour/erosion and associated impacts. These measures would be further refined/considered during detailed design, including:

- Further assessment of the suitability of the channel design and opportunities to undertake any works required to assist in retaining flows within the channel section of the bend.
- Further assessments of appropriate design flow properties (such as velocity) in relation to soil type and proposed vegetation cover to further reduce the potential for scour/erosion.

The design of the proposed realignment will also incorporate interim measures for bed and bank stabilisation until vegetation established within the realigned creek.

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Figure 8-3 Proposed drainage plan

8.4.3 Monitoring

A detailed surface water monitoring program would be established in conjunction with a Surface Water Management Plan for the construction and operation of the Stage 2 area. The Surface Water Management Plan would indicate trigger values (based on the ANZECC water quality guidelines), which, if exceeded, would lead to an appropriate management response.

The monitoring program would be based on the existing monitoring undertaken at the site. This currently involves quarterly monitoring at four surface water locations across the site (two within Sawyers Swamp Creek, one within Dump Creek, and one within the SCCAD). The current monitoring provides assessment of the parameters listed in Table 8-2.

Table 8-2 Water quality monitoring parameters

Category	Parameter
Field parameters	pH, electrical conductivity, alkalinity ($CaCO_3$), total dissolved solids
Anions	Chloride, fluoride, sulfate
Cations	Sodium, potassium, calcium, magnesium
Metals	Arsenic, silver, barium, boron, cadmium, chromium (III) and (VI), copper, iron, mercury, magnesium, manganese, lead, selenium, zinc

Monitoring locations will be reviewed in conjunction with the development of the ongoing Groundwater Management Plan to ensure that potential impacts to Sawyers Swamp Creek associated with groundwater can be identified. Additional monitoring would be undertaken following wet weather events, with a minimum of two events recorded within the first 12 months of operation, to ensure that the implemented water quality controls are operating effectively and preventing impacts during wet weather events. This will be augmented and integrated with monitoring of aquatic ecology in reference river locations to ensure the rehabilitation of Sawyers Swamp Creek is successful. This is outlined in Chapter 9.

In addition to the proposed surface water monitoring program, monitoring and maintenance measures would be established for the proposed creek realignment and riparian zone and associated construction. Performance and completion criteria for the proposed realignment and riparian zone would be established and a program for monitoring and maintenance developed during the detailed design phase. The monitoring and maintenance program will include assessment of erosion and scour, management of exotic weeds, and contingency plans to address issues associated with the realigned channel and associated plantings in the riparian zone should they arise during both construction and post construction.

The realignment of Sawyers Swamp Creek would not commence until March/April 2009, and construction would not commence until all pre-construction measures are implemented.

9. Aquatic ecology

9.1 Assessment approach

An assessment of aquatic ecology in relation to the proposal was undertaken between June and August 2007 and involved a review of the existing information on the aquatic ecology, communities and water quality of the study area. This information was combined with field work undertaken in the study area in June 2007 to assist in the assessment of the potential impacts of the proposed Stage 2 ash repository area and associated channel relocation on aquatic ecology.

The study sought to provide a baseline description of potentially affected waterways, and to identify any threatened species, populations or ecological communities listed under the NSW *Fisheries Management Act 1994* (FM Act) and/or *Threatened Species Conservation Act 1995* (TSC Act), or the Commonwealth EPBC Act that occur or may potentially occur in the identified watercourses. The study also investigated potential impacts and provided recommendations for mitigation measures. This chapter provides a summary of the key findings and conclusions of this assessment, full details of the study can be found in the Technical Report 3 (see Appendix G).

The proposed Stage 2 ash repository activities would require the realignment of an approximately 380-metre section of Sawyers Swamp Creek.

9.1.1 Study areas

Two 100-metre-long sites were established in the areas along Sawyers Swamp Creek most likely to be affected by the proposed Stage 2 ash repository activities (sites 3 and 4). Site 3 was located in the section of Sawyers Swamp Creek to be realigned, and Site 4 was located further downstream, west of the haul road culvert and upstream of the Lidsdale Cut overflow (see figures 9-1 to 9-4).

Two 100-metre-long sites were also established at each of the control locations. Kangaroo Creek and Marrangaroo Creek were selected as control locations — watercourses independent of potential impacts resulting from the proposed Stage 2 ash repository against which any observed changes within Sawyers Swamp Creek following the expansion can be compared.

At each site, a standardised description of the adjacent land and the condition of riverbanks, channel and bed was recorded using a modified version of the riparian, channel and environmental inventory (RCE) (see Appendix 3 of Technical Report 3). Habitat descriptors included, but were not limited to:

- Geomorphological characteristics of the waterways, including substratum type.
- Flow regime of the waterways.
- Types of land use along the waterway.
- Riparian vegetation and in-stream vegetation.
- Presence of spawning areas.
- Presence of natural or artificial barriers to fish passage both upstream and downstream.

The waterway at each site was classified for fish habitat according to the NSW Guidelines and Policies for Fish Friendly Roads (Fairfull and Witheridge 2003).

Site visits were conducted during June 2007, sampling followed periods of high rainfall, and as a result, flows in creeks were higher than average. Given this and the operational time constraint presented by the imminent end of the AusRivAS autumn sampling window, there was some difficulty selecting completely unconfounded control sites.

9.1.2 Water quality

Physical-chemical water quality properties measured at each site included:

- electrical conductivity (ms/cm and µs/cm)
- salinity (ppt)
- temperature (degrees Celsius)
- turbidity (ntu)
- dissolved oxygen (mg/L and % saturation)
- pH and ORP (oxidation reduction potential: mV).

The water quality data collected in situ during site inspections were compared with the ANZECC (2000) water quality guidelines for upland rivers, which provide a schedule of trigger values for potential management response in freshwaters of south-eastern Australia.

These data represent a ‘snapshot’ view of water quality on the day sampled. Prevailing water quality at the site and potential impacts of the proposed activity on water quality are discussed further in chapters 7 and 8.

9.1.3 Macrophytes

Macrophytes were assessed within the first 0.5 metres from the banks at each site; attributes assessed included percentage cover, type (i.e. emergent, floating and submerged), identification of species present and identification of the dominant species. Each 100-metre site was divided into 4 x 25 metre subsections, to provide the replicate units necessary for the statistical procedures that may be carried out as part of future monitoring.

9.1.4 Macroinvertebrates

The edge habitat (along creek banks) of slow moving pools was sampled for invertebrates and surface dwelling animals at each site. The presence of larger, mobile macroinvertebrates was also recorded during electrofishing.

Macroinvertebrates in the edge habitats at five of the sites were sampled within the ‘autumn’ period (15 March to 15 June) in accordance with the rapid assessment method (RAM) based on AusRivAS (Turak et al. 2004). The AusRivAS protocol uses a model to determine the environmental condition of a waterway based on comparisons to a reference condition developed in the model. Site 1 on Kangaroo Creek could not be accessed during the initial field trip and an edge sample was collected later on 21 June, 6 days outside the AusRivAS autumn window although this is unlikely to significantly impact the assessment.

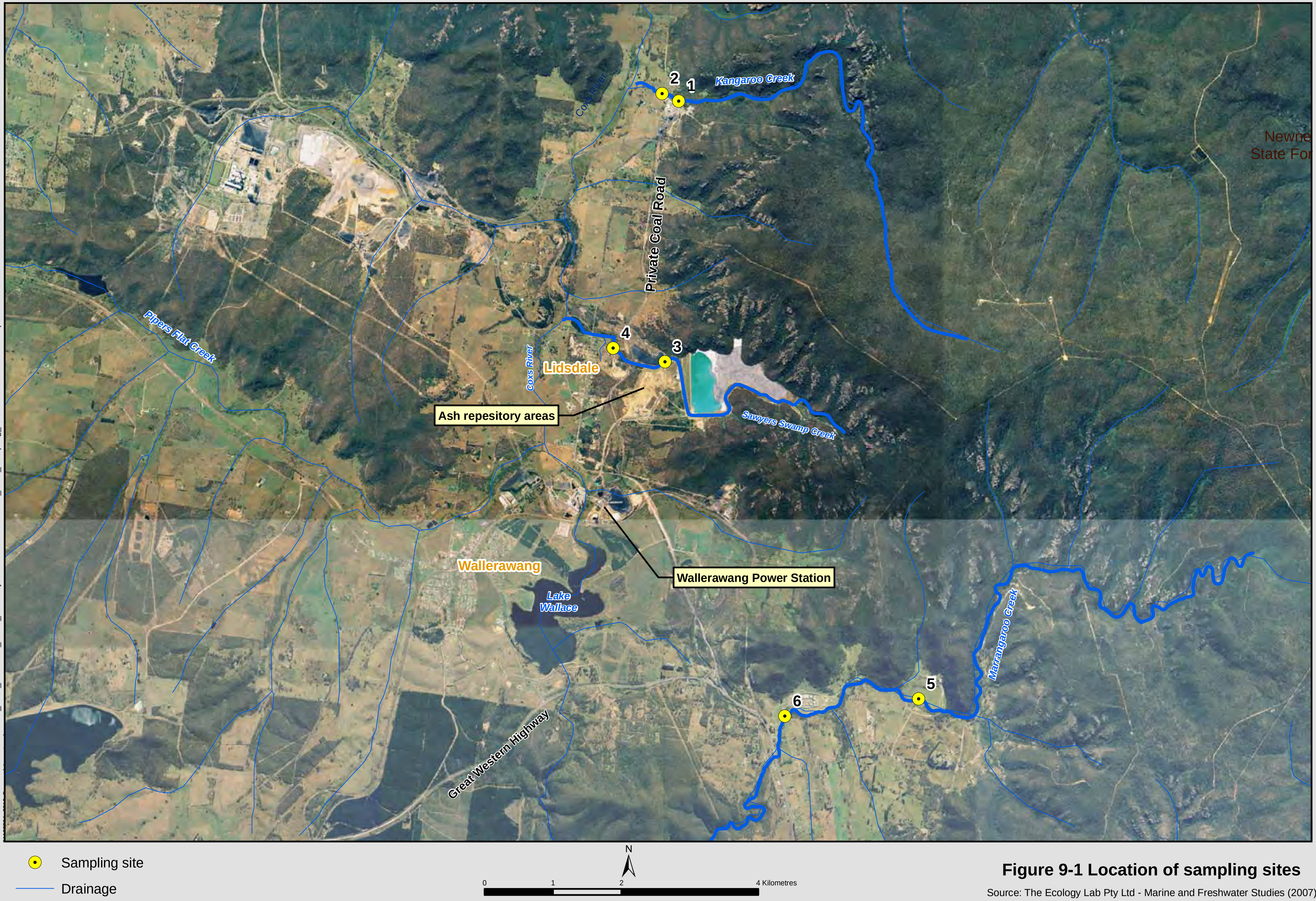

Figure 9-1 Location of sampling sites

Source: The Ecology Lab Pty Ltd - Marine and Freshwater Studies (2007)

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Figure 9-2 Kangaroo Creek: Location 1 (Sites 1 and 2)

Source: The Ecology Lab Pty Ltd - Marine and Freshwater Studies (2007)

Figure 9-3 Sawyers Swamp Creek: Location 2 (Sites 3 and 4)

Source: The Ecology Lab Pty Ltd - Marine and Freshwater Studies (2007)

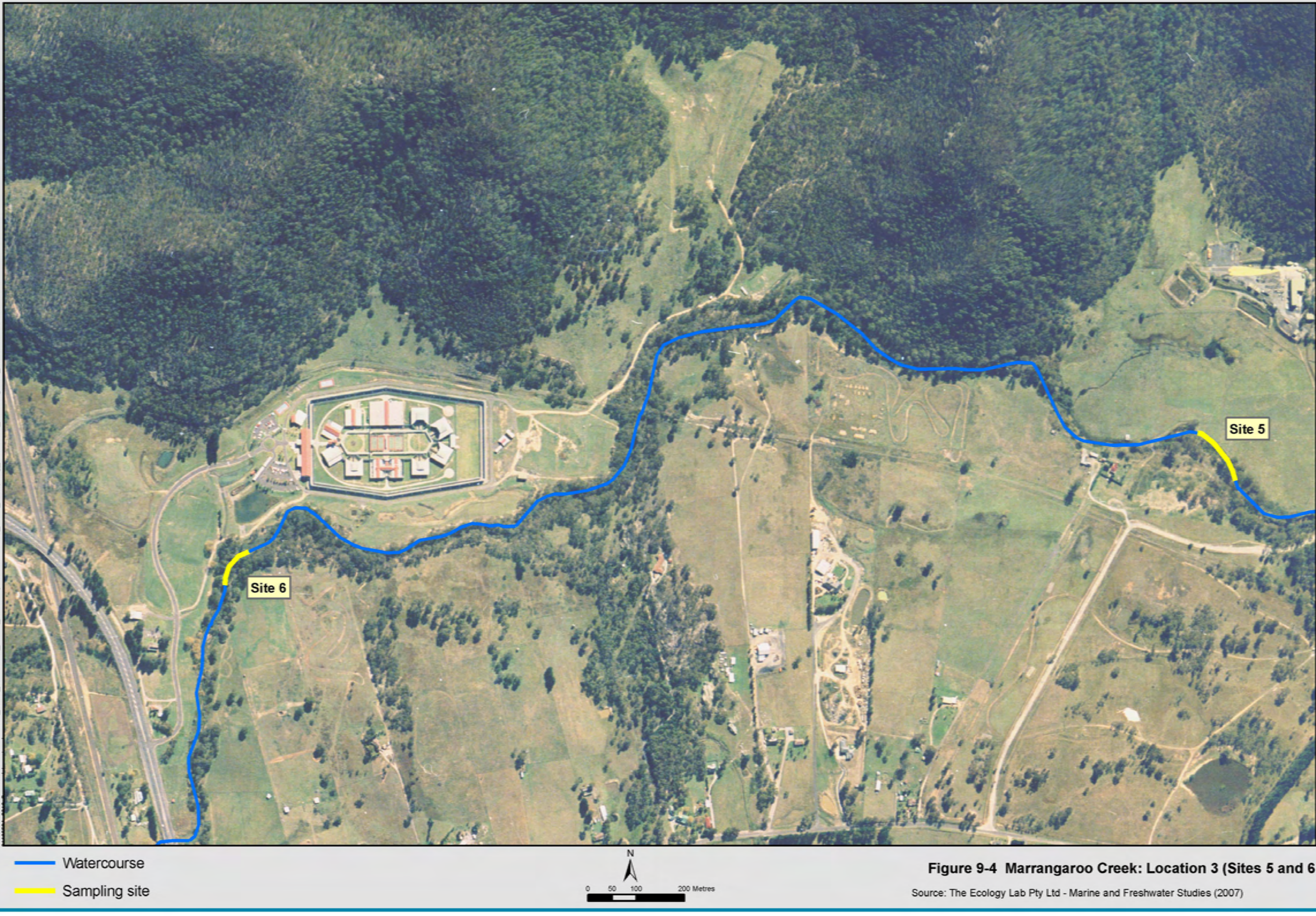

Figure 9-4 Marrangaroo Creek: Location 3 (Sites 5 and 6)

Source: The Ecology Lab Pty Ltd - Marine and Freshwater Studies (2007)

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9.1.5 Fish

Electrofishing, bait trapping and dip netting were used in appropriate habitats within each site to sample fish and mobile invertebrates. These techniques are non-destructive, and all but introduced pest species, such as the plague minnow (mosquito fish, *Gambusia holbrooki*), were returned unharmed to the water. All fish caught were identified and released as quickly as practicably possible. Any fish that could not be identified in the field was euthanised with clove oil and then preserved in 10% formalin solution and returned to the laboratory.

Further details on the sampling techniques used are provided in Technical Report 3 in Appendix G.

9.1.6 Laboratory and statistical methods

Animals in the AusRivAS macroinvertebrate samples were identified using a binocular microscope and counted to a maximum of 10 animals, as per the AusRivAS protocol. Taxa were identified to family level unless otherwise required by the model to identify to subfamily level. Some families of Anisoptera (dragonfly larvae) were identified to lower taxonomic resolution (species), because they could potentially include threatened aquatic species. Identification of animals was validated by a second experienced scientist performing quality assurance checks on each sample. Any animal whose identity was in doubt was sent to the DECC for confirmation.

The AusRivAS protocol uses a model to determine the environmental condition of a waterway based on comparison to a reference condition developed in the model. Details of the AusRivAS model and the indices it generates can be found in Technical Report 3 in Appendix G.

9.2 Site context

Sawyers Swamp Creek is the primary watercourse flowing through Kerosene Vale. The headwaters of Sawyers Swamp Creek occur to the east in the Newnes State Forest at 1160 metres AHD (ERM Hyder 2002). Sawyers Swamp Creek flows in a westerly direction past the site at 900 to 920 metres AHD and into the upper reaches of the Coxs River above Lake Wallace, about 2 kilometres north of the Wallerawang Power Station. Many of the tributaries in the area are ephemeral and even the Coxs River has variable flows a few kilometres upstream of Kerosene Vale, where the channel changes to a ‘chain-of-ponds’ form and then loses its distinctness in marshland. A more detailed description of the watercourses and hydrology of the area can be found in Chapter 8.

Sawyers Swamp Creek and its surrounding catchment are degraded as a result of previous and current land uses in the area. The Sawyers Swamp Creek channel is an artificial watercourse around the ash repository area, the result of realignment undertaken in the 1970s associated with mining and electricity production activities. The aquatic habitat and water quality in the area have been degraded by the land use practices of the last century (including industrial uses). The prevailing land use in the area is, and has been, characterised by wet and dry ash dams, active and now abandoned mine sites and mine spoil, and disturbed woodland.

The banks of the Sawyers Swamp Creek channel are eroded with variable riparian cover; where present, riparian cover comprises a mixture of native and introduced species. The channel substratum comprises mostly shale bedrock or soft clay and silt, the latter often supporting dense beds of emergent macrophyte vegetation such as Juncus species and cumbungi.

Kangaroo Creek and Marrangaroo Creek are located near to Sawyers Swamp Creek and share a similar orientation, elevation and origin. Both flow through catchments degraded by industry and/or agriculture near their confluence with the Coxs River, and both appeared (at the time of sampling) to have sufficient flows to allow sampling throughout the year, if required for a future monitoring program. Both watercourses have similar bank and riparian attributes to Sawyers Swamp Creek; however, the channel substratum of both creeks is dominated by sand in contrast to the clay of Sawyers Swamp Creek. Marrangaroo Creek is also larger, with greater flows. At the time of sampling, Marrangaroo Creek had in-stream woody debris and deep pool sections, and was considered to provide major fish habitat.

Dams downstream of the Sawyers Swamp Creek create Lake Wallace, Lyell Reservoir and Lake Burragorang. These dams do not include fishways, and thus have effectively fragmented fish populations and prevented the upstream spawning migration of adults.

9.2.1 Water quality

The water quality results for both Sawyers Swamp Creek and the control locations provided a preliminary indication of baseline aquatic ecosystem health in the potential impact and control locations through comparison with the ANZECC (2000) guidelines for upland rivers in south-eastern Australia. These data represent a ‘snapshot’ of water quality on the day of sampling. Physico-chemical water quality properties, and comparison with the ANZECC guidelines, are provided in Table 9-1.

Table 9-1 Regional water quality

Watercourse	Site	Conductivity (µs/cm) 30–350	pH 6.50–8.00	Dissolved oxygen (% sat.) 90–110%	Turbidity (NTU)
Kangaroo Creek	1	Within guidelines	Within guidelines	Variable	Within guidelines
	2	Within guidelines	Within guidelines	Variable	Within guidelines
Sawyers Swamp Creek	3	Above guidelines	Within guidelines	Below guidelines	Above guidelines
	4	Above guidelines	Variable	Below guidelines	Above guidelines
Marrangaroo Creek	5	Below guidelines	Below guidelines	Below guidelines	Within guidelines
	6	Below guidelines	Below guidelines	Within guidelines	Within guidelines

As indicated in Table 9-1, water quality within the two control creeks generally falls within the criteria set out in the ANZECC guidelines. However, both sites within Sawyers Swamp Creek indicated water quality outside of the guideline criteria for electrical conductivity (salinity) and also turbidity. As discussed in Chapter 8, the existing water quality in Sawyers Swamp Creek is consistent with the pre-Stage 1 activities water quality of the creek, indicating that Stage 1 activities have not led to a detrimental effect on water quality.

9.2.2 Aquatic communities

A previous survey of the vegetation communities in the study area identified a small number of aquatic plant species from the Cyperaceae, Juncaceae and Typhaceae families (ERM Hyder 2002). Two of the species recorded are introduced while other species present are relatively common, some favouring disturbed areas.

The aquatic communities in Sawyers Swamp Creek are associated with soft clay substratum, low flows and relatively dense but low diversity macrophytes and associated fauna. The faunal assemblages observed were relatively depauperate. The fish communities recorded in all three creeks were in a similar condition.

It is possible that the lower than expected diversity observed could have been a result of the timing of sampling, the prevailing weather conditions or the low water levels in the creek.

9.2.3 Aquatic fauna habitats

Previous surveys in the region of the upper Coxs River have revealed aquatic habitats dominated by the macrophytic vegetation, *Juncus* species and cumbungi, with associated invertebrate fauna including bivalves, gastropods, freshwater shrimp and insect larvae such as caddis flies.

The channel substratum of Sawyers Swamp Creek varies from shale bedrock (usually underlying shallow riffle habitat) to sections of soft clay and silt (associated with macrophyte beds and small pools). The channel is relatively straight due to its artificial origins, no sand, gravel or cobble habitat was observed. The creek supported dense stands of macrophytes, often dominated by *Juncus articulatus* and cumbungi.

Similar bank and riparian attributes to Sawyers Swamp Creek were evident in association with the control creeks; however, the channel substratum of both control creeks was dominated by sand. Kangaroo Creek had similar macrophyte assemblages to Sawyers Swamp Creek and both Kangaroo and Sawyers Swamp creeks were considered to provide minimal fish habitat (Class 3 waterways). Fish passage along Sawyers Swamp Creek was severely obstructed by numerous pipe culverts and a weir that appears to provide an upstream barrier under nearly all flow conditions. Marrangaroo Creek was larger and had greater flows. This creek had in-stream woody debris and deep pool sections, and was considered to provide major fish habitat (Class 1 and 2 waterways at the respective sites on Marrangaroo Creek).

The aquatic habitat and water quality of the area have been degraded by industrial and other land use practices over the last century. Many of the tributaries in the area are ephemeral, including the Coxs River, which has variable flows a few kilometres upstream of Kerosene Vale.

Gehrke et al. (1996) previously characterised the Coxs River as significant habitat for a number of fish species including the Macquarie perch. Sawyers Swamp Creek does not provide critical habitat for any aquatic taxa.

9.2.4 Aquatic flora

Macrophyte species in the two Sawyers Swamp Creek sites inhabited 30% and 7% of the channel wetted width respectively. All species recorded were emergent species, with *Juncus articulatus, Isolepis* species and cumbungi (*Typha domingensis*) dominant. Similarly, the emergent macrophyte vegetation Juncus species and cumbungi dominated the emergent macrophyte flora of Kangaroo Creek (covering 10 to 16% of the wetted width area). A further 0.5 to 2% of the wetted width area was inhabited by submerged macrophyte species such as Spiny Mudgrass (*Psuedoraphis spinescens*). At Marrangaroo Creek macrophyte species covered 4.5 to 10% of the channel, with three-quarters of this area represented by emergent macrophytes such as Juncus species.

In addition to the channel wetted width, the first 0.5 metres of the channel bank area was included in the survey, a considerable amount of which was vegetated with fern species, ranging from around 10% at Marrangaroo to around 4% and 6% at Kangaroo Creek and Sawyers Swamp Creek respectively.

9.2.5 Aquatic fauna

The faunal assemblages observed in Sawyers Swamp Creek were relatively depauperate. A previous study in a lower reach of the Coxs River recorded 14 to 30 macroinvertebrate taxa per site. However, during the current survey, the Sawyers Swamp Creek sites recorded 10 and 11 taxa respectively (The Ecology Lab 2007). It is possible that the lower than expected diversity of aquatic fauna could have been due to the sampling taking place at the end of the autumn window used by the AusRivAS model. Further, winter conditions prevailed in the Lithgow region at the time of sampling with snow falling during and prior to both sampling days. Similarly, very high rainfall was recorded prior to each sampling period and the resulting higher flows may have flushed many macroinvertebrates downstream, resulting in a reduced diversity in samples.

Macroinvertebrates

The samples collected from edge habitat areas yielded a total of 50 taxa, with 14 in Sawyers Swamp Creek, 31 in Marrangaroo Creek, and 32 in Kangaroo Creek. The Sawyers Swamp Creek samples were dominated by pollution tolerant taxa such as Chironominae and Tanypodinae (both members of Chironomidae) and Ceratopogonidae. Conversely, the control sites had a higher proportion of pollution sensitive taxa, such as Leptoceridae and Leptophlebidae at Marrangaroo Creek, and Telephlebidae and Gripopterygidae at Kangaroo Creek.

The difference in macroinvertebrate assemblages between the control and impact locations suggests that water quality has a significant effect on macroinvertebrate fauna. The water quality in Sawyers Swamp Creek may account for the differences encountered in the macroinvertebrate assemblages. However, the extent of such an effect is difficult to quantify based on the existing information available.

The survey results and AusRivAS assessments of the aquatic macroinvertebrate assemblage indicated that all three creeks were impaired relative to reference (undisturbed) conditions; however, Sawyers Swamp Creek shows greater signs of severe impairment. Marrangaroo and Kangaroo creeks were closer to reference conditions and had a greater number of taxa present than Sawyers Swamp Creek. The downstream sites at Marrangaroo

Creek and Kangaroo Creek were more diverse than upstream sites. The results indicate that Sawyers Swamp Creek is in poor health (in comparison to undisturbed conditions), the poor state of the creek is likely a reflection of past land use activities and historical disturbance, including realignment/channelisation of the creek.

Fish

Electrofishing and bait trapping resulted in a total of 11 fish being caught or observed across all three creeks. Mountain galaxias were the only fish recorded in Sawyers Swamp Creek. Three introduced species of fishes were recorded in Marrangaroo Creek (brown trout, rainbow trout and *Gambusia*). No fishes were recorded in Kangaroo Creek.

The results of the current survey were similar to the study of Gehrke et al. (1999) who found that fish assemblages in regulated (i.e. above dams) montane reaches (>700 metres elevation) of the Hawkesbury-Nepean River were characterised by Gambusia, smelt and the climbing galaxias, except in the extreme upper reaches above Warragamba Dam where only mountain galaxias were recorded.

Seven species of fish have been previously recorded in Lake Wallace and the upper Coxs River catchment. The majority of fish recorded in the Coxs River catchment are introduced; of these, the brown trout, the rainbow trout and Gambusia were recorded in Marrangaroo Creek during the current survey. Marrangaroo Creek, although flowing into the Coxs River beneath Lake Wallace, occupies a similar elevation and degraded catchment to Sawyers Swamp Creek.

That trout were not recorded in Sawyers Swamp Creek was expected, as this creek is not considered to provide particularly good habitat. Flows in Sawyers Swamp Creek tend to be low and the channel substratum does not provide the spawning habitat preferred by trout (i.e. gravel substratum) (McDowall 1996). Similarly, there are barriers to upstream passage of trout created by various suspended pipe culverts and a weir along the channel. Conversely, galaxias are renowned for their climbing ability and capacity to overcome barriers to passage such as those posed by culverts. The mountain galaxias have probably benefited from the absence of trout, as mountain galaxias species have been known to disappear from streams following the introduction of trout, which predate upon small fish such as galaxias. However, Sawyers Swamp Creek does not provide critical habitat for the mountain galaxias, as this species has a widespread distribution and is often locally abundant within its range (McDowall 1996). The mountain galaxias have been recorded on many occasions elsewhere throughout the Coxs River catchment (www.bionet.nsw.gov.au).

As previously discussed, there are various obstructions to flow and fish passage downstream of Sawyers Swamp Creek in the Coxs River catchment. Obstructions on the Coxs River include Wallerawang Dam and Lake Wallace 900 metres south of Wallerawang Power Station and 3 kilometres downstream of the junction with Sawyers Swamp Creek; further downstream, the Coxs River is again artificially impounded at Lake Lyell; and the regulated flows released from Lake Lyell then collect in Lake Burragorang above the Warragamba Dam. None of these dams have fishways, thus they present impassable barriers to most fish species (Gehrke and Harris 1996), thereby reducing upstream diversity of fish assemblages.

9.2.6 Threatened and protected species, populations and ecological communities

There are two threatened species with published ranges that include the general region of the study area (after McDowall 1996). The FM Act lists the Macquarie perch (*Macquaria australasica*) as a Vulnerable Species. The Macquarie perch and the Australian grayling (*Prototroctes maraena*) are listed under the Commonwealth EPBC Act as Endangered and Vulnerable respectively. No individuals of these species were observed during the current surveys.

No survey has recorded the presence of the grayling within the study area or in the wider Coxs River catchment. Grayling prefer watercourses with low turbidity and gravel substrata, and populations are very susceptible to barriers to passage due to the amphidromous life cycle of the species. If the grayling historically inhabited the upper region of the Coxs River prior to the construction of the various dams, it is not considered to be currently present in the study area due to the massive alteration in the species' reproductive pattern. As such, an assessment of significance for the potential impact of the proposed Stage 2 ash repository area on the Australian grayling is not required.

Macquarie perch usually inhabit the upper reaches of clear, freshwater watercourses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen et al. 2002; NSW DPI 2005). Previous Department of Primary Industry (Fisheries) surveys in 1992 and 1994 (www.bionet.nsw.gov.au) recorded the presence of the Macquarie perch in the Coxs River catchment, but never upstream of the Lyell Reservoir. No Macquarie perch have been recorded in surveys conducted in the Coxs River catchment above Wallerawang Dam, including Lake Wallace.

It is considered unlikely that Macquarie perch use the aquatic habitats in the area potentially affected by the proposed Stage 2 ash repository area, as Sawyers Swamp Creek does not contain suitable habitat.

In addition to unsuitable habitat, the many culverts along Sawyers Swamp Creek create a barrier to passage under most flow conditions, except for fish such as the galaxias, which are known to climb such barriers. Similarly, the dams creating Lake Wallace, Lyell Reservoir and Lake Burragorang do not include fishways, effectively fragmenting populations and preventing the upstream spawning migration of adults. Lake Wallace has also been heavily stocked with brown and rainbow trout, both of which are known to compete with the Macquarie perch. As such, an assessment of significance of the impact of the proposed Stage 2 ash repository activities on the Macquarie perch is not considered necessary.

9.3 Impacts on aquatic biodiversity

9.3.1 Storage of ash within the proposed Stage 2 area

The major potential impacts resulting from ash placement within the Stage 2 area relate to changes in water quality. It is possible that surface water runoff over exposed ash storage areas or leachate from infiltration and groundwater seepage could further degrade the water quality of Sawyers Swamp Creek. Water bodies receiving contaminated drainage may undergo changes to physical and chemical attributes — for example, in conductivity, pH, turbidity, and the concentration of trace elements and heavy metals. The potential water quality impacts of the proposed Stage 2 ash repository activities are discussed further in chapter 7 and Chapter 8.

9.3.2 Realignment of Sawyers Swamp Creek and construction of stabilisation structures

The realignment of Sawyers Swamp Creek would entail the loss of approximately 380 metres of the existing creek channel and associated aquatic habitat and assemblages. It should be noted that the existing stream channel does not constitute a natural waterway due to past realignment and channelisation. The creek realignment works could introduce several key threatening processes listed under the FM Act, the EPBC Act and the TSC Act regarding the degradation of native riparian vegetation and the removal of large woody debris.

There are a variety of potential impacts to upstream and downstream sections of Sawyers Swamp Creek that may occur as a result of the proposed realignment. The physical perturbations involved in constructing a new section of channel can affect a number of physical and chemical processes, which in turn may cause changes to aquatic ecology. These physical, chemical and ecological factors may interact, which can make it difficult to predict the spatial and temporal extent, and even direction, of potential impacts.

The proposed realignment would require the existing channel morphology, shoreline profile and/or riparian vegetation to be altered. This may result in changes to the hydrology and flow regimes, shade levels (temperature) and amount of detritus and woody debris, which in turn can affect water quality, substratum characteristics, macrophyte cover and the availability of foraging and spawning habitat; and therefore the distribution and abundance of dependent fauna (Gillespie et al. 2002). Again it must be noted that the existing channel morphology, shoreline profile and riparian vegetation are products of previous realignment works and other disturbance and are already in a degraded condition. The proposed realignment of Sawyers Swamp Creek represents an opportunity to return the creek to a condition closer to ‘natural’.

The construction of stabilisation structures and the replacement section of channel would involve major earthworks, and therefore the possibility of mobilising sediments into Sawyers Swamp Creek. Rainfall and/or diverted flows may deliver loose sediments contained on the banks and substratum of the newly constructed channel to the waterway. Sediments may be deposited further downstream, smothering existing habitat and macrophyte beds. The change to substratum composition would be likely to have concomitant effects on macrophytes, benthos and ultimately higher trophic organisms such as fish. The potential for erosion and sedimentation associated with the creek realignment is considered limited given the application of recommended controls and design features. These and the potential for erosion/sedimentation impacts are discussed in Section 8.3 and Section 8.4.

Potential impacts on aquatic ecology associated with construction of realigned creek channel and stabilisation structures include:

- Loss of habitat: the reduction of available deep water refuge areas for aquatic biota and smothering of important habitat features such as beds of aquatic macrophytes and gravel spawning grounds due to increased sedimentation. However, given the absence of deep water habitat due to the consistently low flows in the creek, loss of deep water habitat is considered unlikely.
- Decreased growth and increased mortality: suspended clay particles can clog the respiratory gills and/or feeding appendages of fish and aquatic macroinvertebrates.
- Reduction of water quality via increased turbidity, nutrient and/or contaminant levels.

- Increased turbidity could result in reduced light penetration and subsequently in reduced primary productivity/aquatic macrophytes, altering existing aquatic habitat.
- Increased nutrient levels may encourage algal growth with potential toxic algal blooms resulting in negative impacts on aquatic fauna.
- Contaminants, if present, bound up with sediments could be released during suspension in the water column.
- The magnitude and duration of potential impacts are difficult to predict, depending on a variety of factors, for example:
  - If the amount of sediment suspended in the water column is sufficient to have an adverse effect on the biology and ecology of the aquatic flora and fauna.
  - The type of sediment. The soils in the area appear to be largely clays. Clay sediments tend to stay suspended in the water column longer, and therefore, travel further downstream increasing the spatial and temporal extent of the potential impact. As such, impacts may be felt beyond Sawyers Swamp Creek and into the aquatic habitat (and recreational fishery) of the Coxs River and Lake Wallace.
- Mobile organisms may have the capacity to seek out more favourable conditions elsewhere and/or recolonise readily after the disturbance.
- The sensitivity of organisms to the particular form of disturbance. At present the aquatic macroinvertebrate assemblage in Sawyers Swamp Creek is more tolerant to pollution and higher turbidity than those at the control sites.

As discussed in Chapter 8, the proposed creek realignment and rehabilitation has been designed in consideration with the following objectives:

- Ensuring the geomorphic stability of the creek and the long-term stability of the realigned channel.
- Maintaining the existing hydrological flow regime of the catchment.
- Developing a naturalised channel, generating additional aquatic and riparian habitat and other local and regional ecological benefits.
- Providing a riparian buffer zone to assist in future protection and rehabilitation of the ecological value of Sawyers Swamp Creek.

In addition, rehabilitation of the creek in reaches not proposed to be realigned would focus on preserving and stabilising existing habitat.

9.3.3 Key Threatening Processes

Four Key Threatening Processes relevant to aquatic organisms were identified that may occur as a result of the construction and/or operation of the proposed Stage 2 repository area. These are listed under the FM Act, the TSC Act and the EPBC Act, and include:

- The degradation of native riparian vegetation along NSW watercourses.
- The removal of large, woody debris.
- The installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams.
- Predation by the plague minnow (*Gambusia holbrooki*).

In-stream woody debris provides a complex physical habitat for fish, such as refuge from predation and habitat for prey, as well as forming damming structures that create pools. Riparian vegetation is important to aquatic macroinvertebrate assemblages, and therefore to the fish species that feed upon them. It is a source of detrital plant matter and large woody debris. Riparian vegetation also acts as a buffer, protecting the watercourse from the effects of poor land use in adjacent areas. The NSW DPI Fish Habitat Protection Plan No. 1 generally applies to activities such as dredging, reclamation and de-snagging that may affect fish habitat in the form of snags, reed beds and other aquatic plants, and requires that (in some cases) approval be sought for such activities under the FM Act. However, as discussed in Section 4.2, Part 3A of the EP&A Act excludes the need for certain additional approvals, including approvals under sections 201, 205 and 219 of the FM Act (within which the above activity fall).

The key threatening process relating to the installation of in-stream structures will only be relevant if such a structure is included within the realigned section, such as if the realigned channel is required to pass under an access road. In-stream structures such as culverts may alter natural flows and can result in the elimination of seasonal cues that trigger spawning and reduce the frequency and intensity of flood flows. In-stream structures can also act as a barrier to fish passage under some or all flow conditions, thereby restricting the ability of fish to migrate upstream or downstream to access spawning or foraging habitat. The realigned section of the creek would not include these types of structures.

No Gambusia individuals were observed in Sawyers Swamp Creek during this survey; however, the species is believed fairly abundant in Lake Wallace and surrounding watercourses. As Gambusia proliferates in disturbed aquatic habitats, any impacts to the riparian vegetation, creek channel or water quality caused by the proposed Stage 2 ash repository could facilitate the introduction or expansion of Gambusia in Sawyers Swamp Creek.

Sawyers Swamp Creek has been subject to all of the above-listed Key Threatening Processes in the past. Large sections of the channel have previously been realigned, riparian vegetation is absent in many areas and large woody debris is scarce. Flow into Sawyers Swamp Creek is regulated by the SSCAD and numerous in-stream structures, such as culverts, have been positioned along its length.

9.4 Management of impacts

9.4.1 Sediment control

The potential for delivery of sediment into Sawyers Swamp Creek would be minimised through the implementation of standard construction and river restoration sediment and erosion control procedures, and through maximising the geomorphological stability of the realigned channel, through design and location as outlined in Chapter 8 and Appendix B.

Erosion and sediment controls would be installed prior to the commencement of any construction or earthworks and would take high flows into consideration. Potential erosion and sediment controls are discussed in Appendix B and would include the use of bunds, silt fences, silt curtains, drains and settlement ponds. With the exception of the creek realignment activities, earthworks would be avoided within 50 metres of the watercourse where feasible. Disturbed areas would be rehabilitated or revegetated following the completion of construction and any remaining spoil would be removed or re-used within proposed development activities.

The most geomorphologically stable route and channel design has been selected for the new channel. The application of the new section of channel will involve creating a more natural meandering channel, which would slow flow and reduce scour potential. Limited reinforcement could be used if necessary to reduce erosion if it occurs on toe bends. Loose soil in the sculptured banks and channel should be stabilised as much as possible with appropriate riparian and in-stream vegetation, the introduction of woody debris and the use of jute matting. The incorporation of these items into the design of the realignment is discussed in Chapter 8 and Appendix B.

9.4.2 Restoration

Practising established principles of rehabilitation on the realigned channel section should ensure compensation for the loss of the approximately 380 metres of existing aquatic habitat and minimise any possible ongoing impacts that the new channel may create.

The restoration program is consistent with state policy and legislation and identifies a clear set of objectives. Restoring the creek to its pre-European condition is unlikely to be feasible, given the lack of knowledge about the creeks' characteristics at this time and the other continuing impacts from within the catchment (such as seepage from SSCAD). Given the existing degraded condition of Sawyers Swamp Creek, creek restoration following realignment works would aim to rehabilitate the creek to 'better than existing' condition.

State government agencies have formalised the process of identifying objectives and constraints with respect to rehabilitation of streams by releasing guidelines and requiring the preparation of a works plan. Another source of guidelines and objectives includes *A rehabilitation manual for Australian streams* (Land and Water Resources Research and Development Corporation 2000).

A draft rehabilitation plan is provided in Appendix B.

9.4.3 Monitoring

A monitoring program as part of the proposed Stage 2 area would be implemented to establish the extent of any environmental impact, and to determine whether the proposed restoration of the realigned creek was successful in achieving its objectives.

The study would compare Sawyers Swamp Creek with the two control sites (Marrangaroo and Kangaroo Creek) from before to after the Stage 2 ash repository works. In this case another site would need to be established downstream of the realigned section so there is replication at the site level. Details of the identified control points are further outlined in Technical Report 3 in Appendix G of this report (see also figures 9-1 to 9-4).

9.5 Significance of impacts

The major impact resulting from the proposed Stage 2 area would be the loss of approximately 380 metres of existing aquatic habitat and associated assemblages, which also involves listed Key Threatening Processes related to the degradation of riparian vegetation and the removal of large woody debris. However, Sawyers Swamp Creek has previously been subject to the listed Key Threatening Processes. Large sections of the channel have been previously realigned, riparian vegetation is absent in many areas and large woody debris is scarce. Flow into Sawyers Swamp Creek is regulated by the SSCAD and numerous in-stream structures, such as culverts, have been positioned along its length.

Impacts on aquatic ecology may also occur as a result of the mobilisation of sediments into the channel from construction earthworks, downstream effects from changes to the channel morphology and changes to water quality from an increase/change in area of ash storage. Such impacts may be short term or ongoing. There are no threatened populations, species or communities present in the area potentially affected by the construction and operation of the proposed Stage 2 ash repository, nor does the study area provide critical habitat for any taxa. Sawyers Swamp Creek is a relatively degraded watercourse with poor water quality and a depauperate faunal assemblage. The dominant taxa are pollution tolerant and/or ubiquitous and abundant.

The use of standard practices relating to construction and sediment control and the rehabilitation of the newly formed channel in accordance with the draft rehabilitation plan should compensate for the initial biodiversity loss and prevent significant ongoing impacts. In addition, a monitoring program would demonstrate whether the proposed Stage 2 area works impacted on the aquatic ecology and if the creek restoration is successful, thereby allowing Delta Electricity to demonstrate the success of the project or adjust management strategies accordingly.

It is likely that the proposed Stage 2 works can be completed without any long-term effects on the aquatic ecology of the area by managing runoff from the ash surface, using standard sediment and erosion control procedures, using accepted guidelines for stream rehabilitation and continuing water quality monitoring.

It is considered unlikely that Macquarie perch use aquatic habitat in the area potentially affected by the Stage 2 ash repository works, as Sawyers Swamp Creek does not contain suitable habitat for the Macquarie perch. Similarly, if the Australian grayling historically inhabited the upper region of the Coxs River prior to the construction of the various dams, it is not considered to be currently present in the study area. As such, an assessment of significance for potential impacts associated with the proposed Stage 2 area on the Australian grayling and the Macquarie perch is not considered necessary.

The draft Sawyers Swamp Rehabilitation Plan will be implemented post-creek realignment and will include revegetation of in-stream and riparian zoned areas with appropriate endemic species. Rehabilitation/revegetation will be undertaken in consultation with relevant government agencies, including the Department of Planning, Department of Primary Industries (Fisheries) and the Department of Environment and Climate Change, and in accordance with the Department of Water and Energy’s (formerly DNR) guideline. Through the implementation of the proposed rehabilitation plan it is anticipated that the realigned section of Sawyers Swamp Creek would result in an improvement in the quality of this section of the creek.