STRATFORDCOAL
Part of the Yancoal Australia Group






Stratford Extension Project
Environmental Impact Statement

APPENDIX G

AQUATIC ECOLOGY ASSESSMENT

On Thursday 28 June 2012, Yancoal Australia Limited was listed on the Australian Stock Exchange and merged with Gloucester Coal Ltd (GCL) under a scheme of agreement on the same date. Stratford Coal Pty Ltd is now a wholly owned subsidiary of Yancoal Australia Limited. Any reference to GCL in this Appendix should be read as Yancoal Australia Limited.

Stratford Extension Project

Aquatic Ecology Assessment

April 2012

Prepared for:

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Executive Summary

This report has been prepared for the Stratford Extension Project (the Project) proposed by Stratford Coal Pty Ltd, a wholly owned subsidiary of Gloucester Coal Ltd. The report presents information on the aquatic ecology of the local area to inform an Environmental Impact Statement for the proposed continuation and extension of open cut coal mining and processing activities at the Stratford Coal Mine and Bowens Road North Open Cut (BRNOC) (both mines are referred to collectively as the Stratford Mining Complex).

The scope of this report includes an assessment of aquatic habitat, flora and fauna present in the local area (including targeted sampling for aquatic species or communities listed in the New South Wales [NSW] *Fisheries Management Act 1994*; NSW *Threatened Species Conservation Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*), and the likely impacts to these aspects from the Project.

Background

The Stratford Mining Complex is situated in the Manning River Catchment (part of the Karuah Manning sub-region and the greater Hunter-Central Rivers Catchment) in the Gloucester Valley, approximately 100 kilometres (km) north of Newcastle. The existing mine is located either side of Avondale Creek, which flows approximately 900 metres (m) from the mine area to the junction with the Avon River and then approximately 10 km into the Gloucester River. The Gloucester River eventually meets the Manning River to the north, which flows to the sea near Taree.

The survey area for this assessment included Avondale Creek, Dog Trap Creek, Avon River and other ephemeral creeks within the Project area, immediately upstream of and downstream of the Project area.

Avondale Creek is a small meandering stream that passes through a mixture of heavily wooded native forest in the upper escarpment and cleared, grazing country in the lower sections. The lower sections of the stream have very high natural salinity levels as a result of saline groundwater discharges. The salinity levels are inversely proportional to stream flow levels. The riverbed is characterised by a hard clay or bedrock base overlain by fine gravels.

Some parts of Avondale Creek currently support permanent wetlands in the area between Bowens Road and Parkers Road, and immediately south of Parkers Road. These wetlands are considered unlikely to be natural. Rather, they are the result of low level damming by elevated earthworks associated with road construction across the swampy ground. Traditionally, this area has been used for dairy and beef production, and remnants of former dairy infrastructure are present along Avondale Creek.

The Avon River is a slow flowing river that flows 800 m west of the Project area, although there is fast flow in the river at times. The riverbanks have a narrow riparian zone consisting of a mixture of native and introduced tree and shrub species and the surrounding catchment has largely been cleared, with cattle grazing being the main agricultural activity. The riffle zone of the riverbed is characterised by course gravel and cobble riffles on a hard clay base, while the pool substrate is fine sand to silt.

Dog Trap Creek drains the forested escarpment area north-east of the Project area and flows westward into Avondale Creek. During normal flow conditions, the stream is fast flowing with a course sand and gravel substrate on a clay base. The downstream area is heavily impacted by cattle grazing and has a minimal riparian zone consisting mainly of Eucalyptus and Casuarina species. The stream banks and bed are impacted by cattle activity, with areas of bank erosion.

An ephemeral creek occurs within the Project area in the northern arm of the eastern clean water diversion drain, approximately 800 m below the discharge point. This creek feeds into Avondale Creek and is relatively undisturbed. This creek is characterised by a dense native riparian zone, undisturbed stream banks, some macrophytes, substrate consisting of gravel and sand on a hard clay base.

Survey Details

Invertebrate Identification Australasia (IIA) has undertaken biological monitoring from 2000 to 2010 within the Project area and surrounds. Biological monitoring has included physiochemical water quality sampling and the sampling of macroinvertebrates. This report compares previous survey results obtained by IIA with results recorded during the recent surveys by frc environmental.

Aquatic habitat condition (including water quality parameters), aquatic flora, aquatic macroinvertebrates, fish and other aquatic vertebrates (e.g. turtle and platypus) were surveyed from 6 to 12 June 2011.

Surveys were undertaken at nine sites (sites AC, W8 and W5 located on Avondale Creek; sites AR, W1 and W2 located on Avon River; Site W3 located on Dog Trap Creek; Site S3 [an ephemeral creek feeding into Avondale Creek]; and Site SD7 [a sediment dam located 200 m north of the BRNOC]). Six of these sites have been previously surveyed by IIA (i.e. sites W1, W2, W3, W5, W8 and S3).

Habitat for Aquatic Fauna

In-stream habitat at all sites was dominated by aquatic vegetation (i.e. macrophytes), woody debris and overhanging/trailing bank vegetation. Boulders present along Avondale Creek provided additional habitat. Channel diversity was low at all sites and generally limited to either run habitat (Avon River) or pool habitat at the sediment dam. Avondale Creek had both run and pool habitat, as did the ephemeral creek east of Stratford Main Pit.

Surface sediment was dominated by silt along the downstream reach of Avondale Creek and at the sediment dam; sand along Avon River and Dog Trap Creek; and silt/sand in the upper reaches of Avondale Creek and 3 km upstream of the confluence of Avon River and Avondale Creek. The most downstream point of Avon River surveyed had a high proportion of pebble and gravel. There was a diverse mixture of surface sediments directly downstream of mining operations in Avondale Creek, which had a high proportion of boulders and also in the ephemeral creek east of Stratford Main Pit, which had a high proportion of silt/clay, sand and gravel.

The upstream riparian zones along Dog Trap Creek, along Avondale Creek and surrounding the northern sediment dam were dominated by pasture grasses and shrubs, while the riparian zone along Avon River and the ephemeral creek were more diverse and included several large trees. Land immediately adjacent to the riparian zone along Avondale Creek was predominantly used for mining activities, as was the ephemeral creek and the land to the south of the sediment dam. The land adjacent to the riparian zones of Avon River, Dog Trap Creek, north, east and west of the sediment dam, and stretches of Avondale Creek upstream and downstream of the Stratford Mining Complex was used for grazing or agriculture. Along these areas (where land was used for grazing or agriculture) bank erosion was most extensive due to livestock access and past clearance of vegetation.

Bioassessment scores provide an index of habitat condition, which enables a comparison of habitat quality between sites. Most sites had moderate or good habitat bioassessment scores due to the availability of diverse habitat (e.g. woody debris and vegetation), riparian vegetation, stable banks and channels. However, there was some channel/bank erosion at some of the sites.

The Avon River had a moderate bioassessment score, graduating to a good bioassessment score along the southern stretches of the river. Avondale Creek had a poor bioassessment score upstream of the Stratford Mining Complex, and a moderate bioassessment score downstream of the Stratford Mining Complex. The ephemeral creek, east of the Stratford Main Pit, had a good bioassessment score, while Dog Trap Creek and the sediment dam both had moderate bioassessment scores.

Water quality was generally within the Manning River Catchment guideline values. Differences were present in the following water parameters:

- turbidity was high along the upstream reach of Avondale Creek, along the downstream reach of Avon River (north of the confluence of Avon River and Avondale Creek) and the sediment dam north of BRNOC;
- pH was low in upstream Avon River and the sediment dam; and
- the concentration of dissolved oxygen was below the guideline range upstream and downstream along Avon River; Dog Trap Creek; downstream along Avondale Creek; and the ephemeral creek east of Stratford Main Pit.

Electrical conductivity was within guideline ranges at all sites and alkalinity was lower during the current surveys compared to the surveys conducted by IIA in 2010.

Aquatic Flora

A total of 31 macrophyte species were identified within the survey area. The number of macrophytes ranged from two species recorded within Dog Trap Creek and nine species recorded at the ephemeral creek east of Stratford Main Pit. Mean percent cover of macrophytes (as a percentage of the total substrate) ranged from 6 percent (%) at sites upstream of Avon River and in Dog Trap Creek to 86% at the sediment dam.

Three introduced floral species were recorded during the survey, namely: Common Starwort (*Callitriche stagnalis*), Common Bittercress (*Cardamine hirsuta*) and *Cyperus eragrostis.* All introduced species recorded are widespread in NSW and were found in low abundance at each site. No threatened flora species were recorded during the survey.

Aquatic Macroinvertebrate Communities

Non-biting midge larvae (sub-families Chironominae and Tanypodinae) were the most common and abundant taxa sampled. Water boatman (family Corixidae) and seed shrimp (class Ostracoda) were also found in high numbers at most sites. A site within the upstream reaches of Avondale Creek was not sampled as the water level was too low.

Macroinvertebrate community composition in bed and edge habitat varied between sites. However, there was an overlap (40% similarity) in community structure between most sites within bed habitat except for downstream sites along the Avon River and Avondale Creek. The most closely related sites in bed habitat were those from upstream Avon River. Communities at all sites within edge habitat grouped together at a 40% similarity level, except at the downstream site along Avon River.

Mean abundance was variable between sites. Significant differences in abundance between sites were due to the lower abundance in bed and edge habitat along the downstream reach of the Avon River and in bed habitat along the downstream reach of Avondale Creek.

Taxonomic richness was variable between and within sites and was generally similar at upstream and downstream sites. Total taxonomic richness in bed habitat ranged from nine taxa at the sediment dam to 25 taxa at an upstream site along the Avon River.

Mean taxonomic richness varied between sites and was generally higher in edge habitat compared to bed habitat. The exception to this trend was the downstream sites (north of the confluence of the Avon River and Avondale Creek, and north of the BRNOC along Avondale Creek) and upstream along the Avon River where the reverse was evident. The reach of Avondale Creek adjacent to the Stratford Mining Complex had the lowest mean taxonomic richness in bed habitat, while the furthest reach of upstream Avon River near the town of Stratford had the highest mean taxonomic richness in edge habitat.

Total taxonomic richness in the Australian River Assessment System (AUSRIVAS) samples for edge habitat for downstream sites was generally within the range of the background data at upstream sites. Total taxonomic richness in AUSRIVAS samples was lowest for bed habitat at the sediment dam north of BRNOC and highest in edge habitat in upstream Avon River and in Dog Trap Creek. Low taxonomic richness at the sediment dam was likely due to the poor quality of habitat within the silty bed sediment at this site; high taxonomic richness at the upstream Avon River and Dog Trap creek sites were likely due to the presence of overhanging vegetation and sand/gravel at the stream edges.

Total Plecoptera, Ephemeroptera, and Trichoptera (PET) richness was highest upstream in Avon River and in bed habitats. There were no PET taxa in bed habitat at the sediment dam north of BRNOC and the ephemeral creek in edge habitat. A lack of PET taxa is usually an indication of poor habitat and/or water quality.

Results indicated that most macroinvertebrate communities (at both upstream and downstream sites) were recorded in areas that had high salinity/nutrients or industrial/agricultural pollution. The condition of these communities has remained relatively consistent since the last autumn survey in 2004.

The AUSRIVAS results indicated that the furthest reach of upstream Avon River near the town of Stratford, and the downstream reach north of the confluence of Dog Trap Creek and the Avon River had the lowest overall condition for macroinvertebrate communities. The condition of macroinvertebrate communities at Dog Trap Creek has improved since 2010, while the condition of macroinvertebrate communities downstream of Avon River has declined since 2010.

Macrocrustaceans were caught at all sites with the exception of the sediment dam north of BRNOC. Three species of macrocrustaceans were recorded during the survey. Freshwater prawns were the most dominant species found and accounted for 80 to 100% of the catch at all sites where macrocrustaceans were found.

Survey results show that the ecological condition of the Avon River and its tributaries has improved over the last three years and that the Stratford Mining Complex has had no adverse impacts on the Avon River and Avondale Creek.

Aquatic Vertebrates

Fish surveys were undertaken at all sites except upstream of Avondale Creek, where the water level was too low. Ten species of fish were caught during the survey. The most abundant and widespread species caught were the Eastern Gambusia (*Gambusia holbrooki*) (an exotic and declared noxious species) and the Firetail Gudgeon (*Hypseleotris galii*). The number of fish species found in the community at each site ranged from one (downstream along Avondale Creek) to seven (downstream along Avon River) and fish communities were most diverse along the Avon River. In general, the number of species caught at downstream sites was similar to the number caught at upstream sites.

The fish abundance (total number of fish caught at a site) ranged from four (downstream along Avondale Creek) to 111 (ephemeral creek feeding into Avondale Creek). Exotic Eastern Gambusia was the predominant catch at the ephemeral creek (53% of the catch) and the sediment dam north of BRNOC (87% of the catch).

No live turtles were caught or sighted during the survey. However, a turtle carapace (likely to be the Eastern Snake-necked Turtle [*Chelodina longicollis*]) was found on the bank of the sediment dam north of BRNOC. One platypus was sighted downstream within the Avon River, after the confluence of Avon River and Avondale Creek.

Evaluation of Potential Impacts and Mitigation

Potential impacts of the Project on aquatic ecosystems were evaluated in relation to:

- increased turbidity, input of nutrients or contaminants and loss of habitat for aquatic fauna as a result of vegetation clearing and earthworks;
- loss of catchment area and changes to flow regimes;
- changes to groundwater;
- irrigation runoff;
- obstruction of fish passage due to construction of creek crossings;
- fuel spills and litter/waste entering aquatic habitats as a result of operation and maintenance of vehicles and other equipment; and
- cumulative impacts.

Turbidity in the Project area is variable; as such, small increases in turbidity as a result of the Project would unlikely have a significant impact on aquatic ecology. Where turbid runoff to creeks is minimised via the use of sediment dams and upstream diversions (as planned), the impact to aquatic ecology would be low. Furthermore, where the mine achieves zero discharge of mine water (as planned), the risk of impacts to aquatic habitat due to input of nutrients or other contaminants would also be low.

No measureable changes in flows in the Avon River, Avondale Creek and Dog Trap Creek are expected to result from loss of catchment area or changes to groundwater as a result of the Project. Irrigated water will be drained directly to the mine water storages and no impacts on existing aquatic ecosystems are likely to occur.

Construction of the two new permanent crossings on Avondale Creek and the ephemeral tributary of Avondale Creek may disturb sediment, leading to increases in localised turbidity and sediment deposition. Where construction is carried out in the dry season, the impacts of disturbance to aquatic habitat would be highly localised and are considered acceptable in both a local and regional context, given the ephemeral nature of the creek and the existing disturbed nature of creek crossing locations. The impact to fish passage would be low where crossings are designed and installed following the NSW *Policy and Guidelines for Fish Friendly Waterway Crossings*, and where the crossings are regularly maintained.

Implementation of best practice fuel and waste management systems will effectively address the risk to aquatic ecology from litter and spills.

It is considered unlikely that the Project would result in a significant increase in cumulative adverse impacts on aquatic ecosystems.

Conclusion

The biological values of aquatic ecosystems within the survey area were moderate to good and consistent with those of the wider catchment. The aquatic ecosystems of Dog Trap Creek and Avondale Creek were assessed as having moderate value in regard to aquatic flora and fauna, primarily due to the ephemeral and intermittent nature of the waterways, poor streamside cover, limited depth and some bank erosion. The Avon River was assessed as having greater ecological value to aquatic flora and fauna due to its perennial nature and consistent flow.

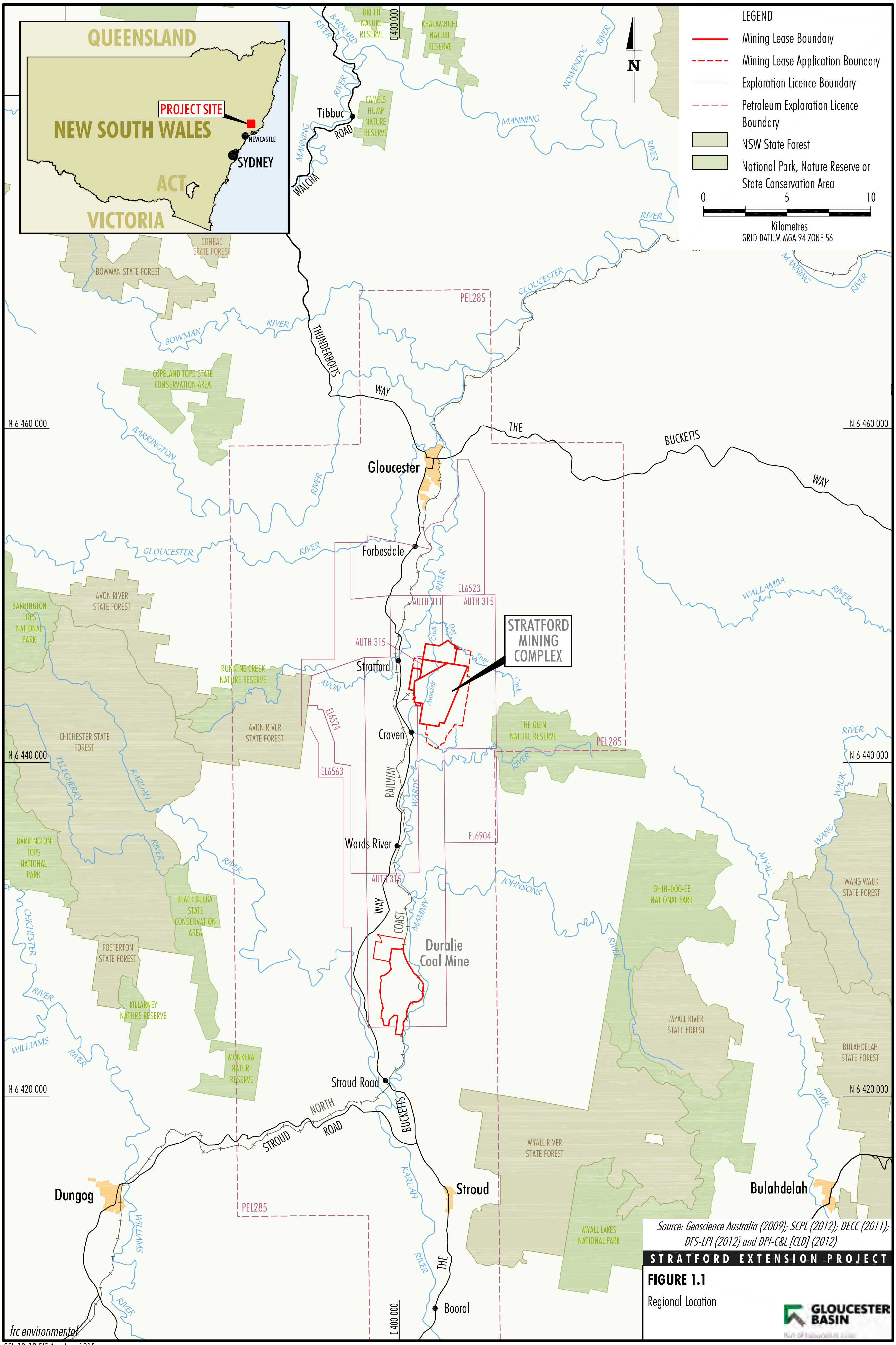
Where the Project achieves the objective of zero discharge of mine water, the risk of impacts to aquatic ecosystems as a result of the Project is considered low. No measureable changes in flows in the Avon River, Avondale Creek and Dog Trap Creek are expected to result from loss of catchment area or changes to groundwater as a result of the Project. Impediment to fish passage as a result of the installation of two new stream crossings on an ephemeral tributary to Avondale Creek and on Avondale Creek would be low, since crossings are designed and installed following the NSW Department of Primary Industries policy and guidelines. The offset strategy for the Project would provide for the conservation and enhancement of a number of watercourses (Avondale Creek, Wards River and drainage lines) and their catchments. The Project would maintain and improve aquatic biodiversity values of the region in the medium to long-term, and continued monitoring of aquatic ecosystems is planned.

1 Introduction

Stratford Coal Pty Ltd, a wholly owned subsidiary of Gloucester Coal Limited, commissioned frc environmental to conduct an aquatic assessment for the Stratford Extension Project (the Project), located approximately 95 kilometres (km) north of Newcastle, New South Wales (NSW) in the Gloucester Basin (Figures 1.1 and 1.2).

The main activities associated with the development of the Project would include:

- run-of-mine (ROM) coal production up to 2.6 million tonnes per annum for an additional 11 years (commencing approximately 1 July 2013 or upon the grant of all required approvals), including mining operations associated with:
  - completion of the Bowens Road North Open Cut (BRNOC);
  - extension of the existing Roseville West Pit; and
  - development of the new Avon North and Stratford East Open Cuts;
- exploration activities;
- progressive backfilling of mine voids with waste rock behind the advancing open cut mining operations;
- continued and expanded placement of waste rock in the Stratford Waste Emplacement and Northern Waste Emplacement;
- progressive development of new haul roads and internal roads;
- coal processing at the existing coal handing and preparation plant (CHPP) including Project ROM coal, sized ROM coal received and unloaded from the Duralie Coal Mine and material recovered periodically from the western co-disposal area;
- stockpiling and loading of product coal to trains for transport on the North Coast Railway to Newcastle;
- disposal of CHPP rejects via pipeline to the existing co-disposal area in the Stratford Main Pit and, later in the Project life, the Avon North Open Cut void;
- realignments of Wheatleys Lane, Bowens Road, and Wenham Cox/Bowens Road;
- realignment of a 132 kilovolt power line for the Stratford East Open Cut;
- continued use of existing contained water storages/dams and progressive development of additional sediment dams, pumps, pipelines, irrigation infrastructure and other water management equipment and structures;
- development of soil stockpiles, laydown areas and gravel/borrow areas, including modifications and alterations to existing infrastructure as required;



STRATFORD EXTENSION PROJECT

FIGURE 1.1

Regional Location

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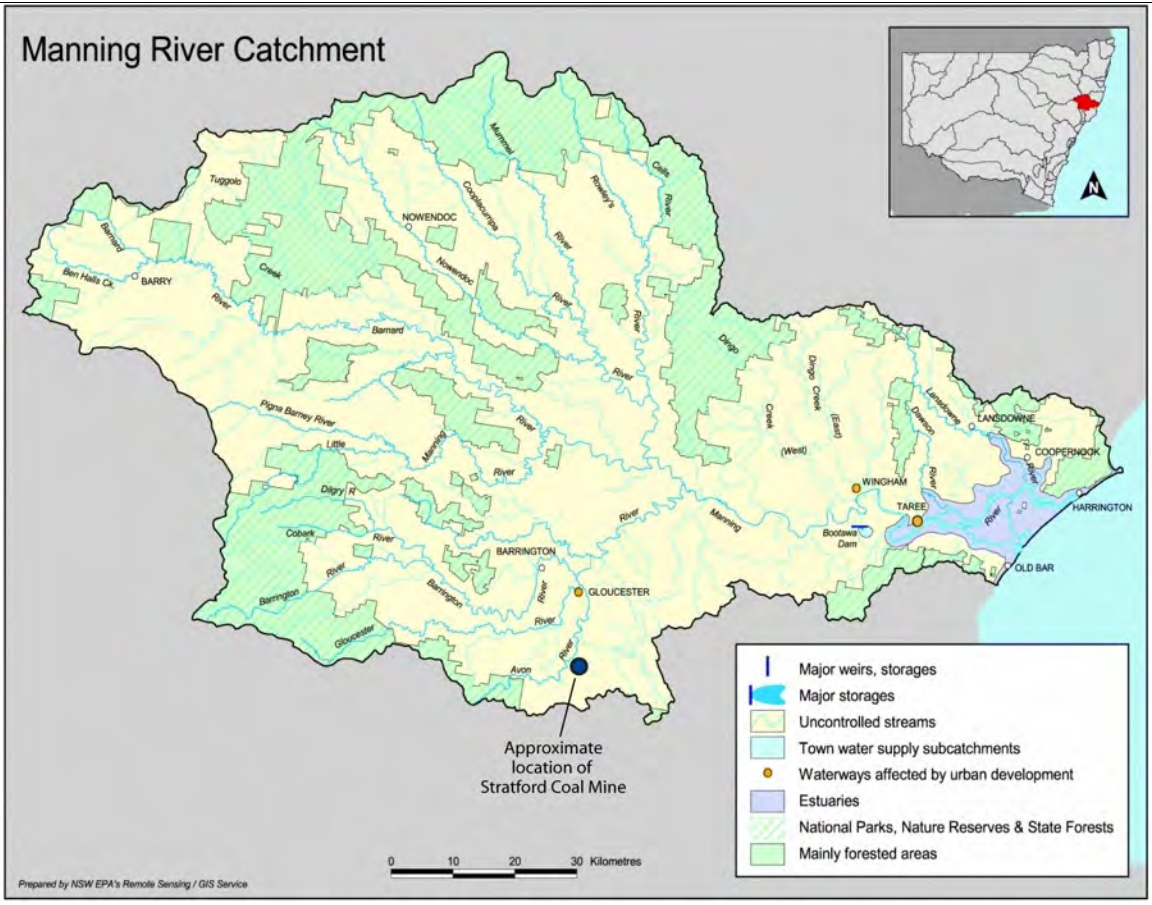

frc environmental AQUATIC ECOLOGISTS deep thinking. science.	Stratford Aquatic Ecology Assessment	
	Figure 1.2 Approximate location of the mine site in the Manning River Catchment.	
	Source: Office of Environment and Heritage (OEH) (2011a)	August 2011

- monitoring and rehabilitation;
- all activities approved under DA 23-98/99 and DA 39-02-01; and
- other associated minor infrastructure, plant, equipment and activities, including minor modifications and alterations to existing infrastructure as required.

The purpose of this report is to:

- Collate the results of previous aquatic surveys undertaken by Invertebrate Identification Australasia (IIA) (2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) (Appendix A).
- Collate the results of more recent surveys undertaken by frc environmental.
- Describe the aquatic habitat, flora and fauna occurring and likely to occur in the waterways near the Project (including wetlands and downstream waters).
- Discuss potential direct and indirect effects of the Project on aquatic flora and fauna (including aquatic species or communities listed in the NSW *Fisheries Management Act 1994* [FM Act], NSW *Threatened Species Conservation Act 1995* [TSC Act] and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* [EPBC Act]).
- Propose measures to avoid, manage, mitigate and offset potential impacts.

A description of the survey area is provided in Section 1.1, while the methodologies employed during previous and current surveys are provided in Section 1.2.

1.1 Description of Survey Area

The SCM is an open cut coal mine located approximately 95 km north of Newcastle and approximately 10 km north of the southern boundary of the Manning River Catchment, on the mid-north coast of NSW (Figures 1.1 and 1.2). The Project area (Figure 1.3) is situated in the Gloucester Valley and lies on Avondale Creek, an ephemeral tributary of Dog Trap Creek, which flows approximately 900 metres (m) to the junction with the Avon River and then into the Gloucester River. The Gloucester River eventually meets the Manning River to the north, which flows to the sea near Taree.

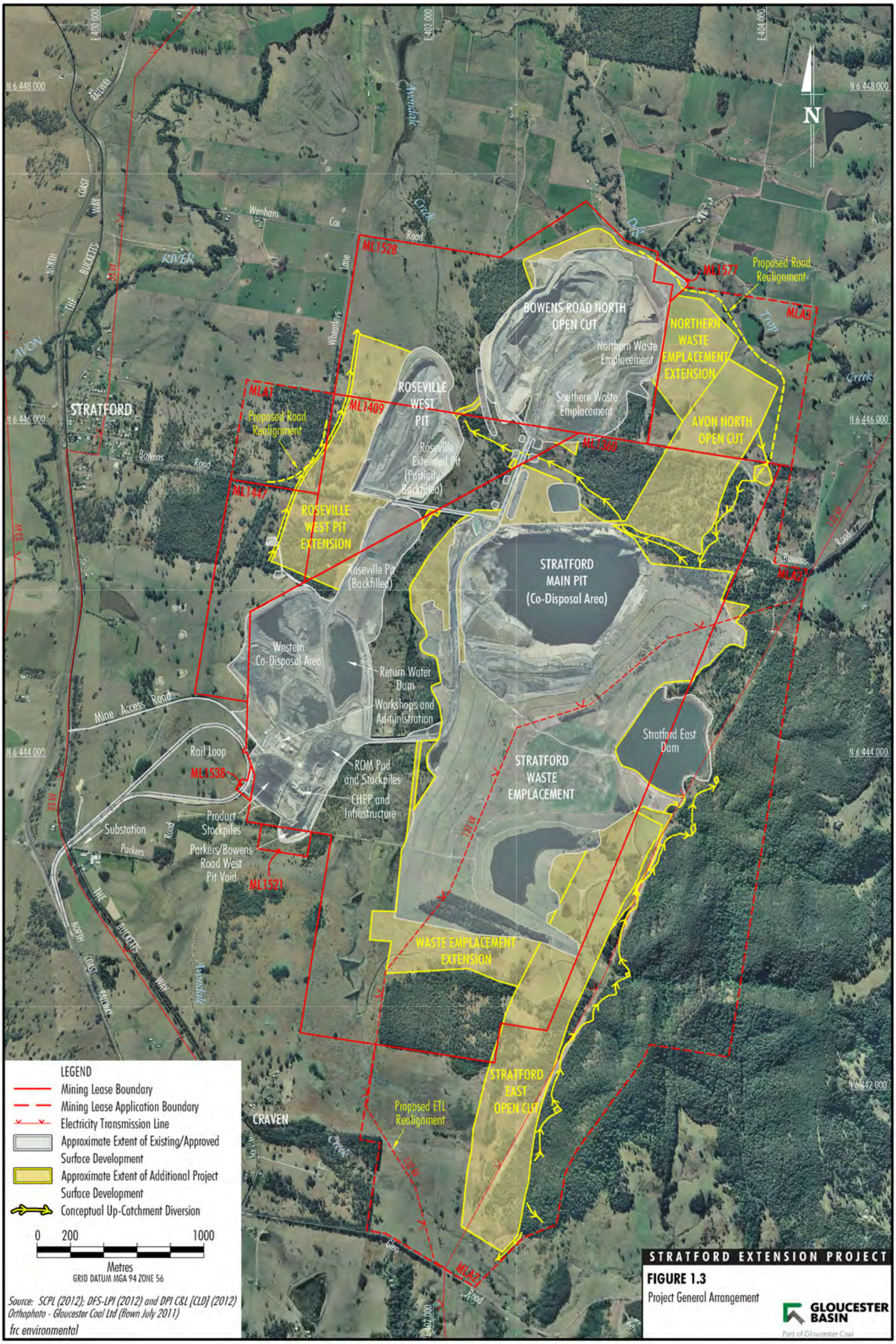

FIGURE 1.3
Project General Arrangement

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1.1.1 Avondale Creek

Avondale Creek is a small meandering stream that passes through a mixture of heavily wooded native forest in the surrounding escarpment and cleared, grazing country in the lower sections (IIA 2010). The lower sections of the stream have very high natural salinity levels as a result of saline groundwater discharges (IIA 2010). The salinity levels are inversely proportional to stream flow levels and the riverbed is characterised by a hard clay or bedrock base overlain by fine gravels (IIA 2010).

Some parts of Avondale Creek currently support permanent wetlands in the area between Bowens Road and Parkers Road, and immediately south of Parkers Road. These wetlands are considered unlikely to be natural. Rather, they are the result of low level damming by elevated earthworks associated with road construction across the swampy ground. Traditionally, this area has been used for dairying and beef production, and remnants of former dairy infrastructure are present along Avondale Creek. Areas along the creek could be considered degraded where significant incision of the stream has occurred.

1.1.2 Avon River

The Avon River is a generally slow flowing river that flows along the western side of the Project area (IIA 2010), although there are high flows at times. The riverbanks have a narrow riparian zone consisting of a mixture of native and introduced tree and shrub species, and the surrounding catchment has largely been cleared, with cattle grazing being the main agricultural activity (IIA 2010). The riffle zone of the riverbed is characterised by coarse gravel and cobble riffles on a hard clay base, while the pool substrate is fine sand to silt (IIA 2010).

1.1.3 Dog Trap Creek

Dog Trap Creek drains the forested escarpment area north-east of the Project area and flows westward (IIA 2010). During normal flow conditions the stream is fast flowing with a coarse sand and gravel substrate on a clay base (IIA 2010). The downstream area is heavily impacted by cattle grazing and has a minimal riparian zone consisting mainly of Eucalyptus and Casuarina species (IIA 2010). The stream banks and bed are impacted by cattle activity, with areas of bank erosion (IIA 2010).

1.1.4 Ephemeral Creek

An ephemeral creek occurs within the Project area in the northern arm of the eastern clean water diversion drain, approximately 800 m below the discharge point (IIA 2010). This creek feeds into Avondale Creek and is relatively undisturbed. This creek is characterised by a dense native riparian zone, undisturbed stream banks, some macrophytes, substrate consisting of gravel and sand on a hard clay base (IIA 2010). This section of the stream generally has elevated saline levels (IIA 2010).

1.2 Survey Details

1.2.1 Previous Surveys

IIA has undertaken biological monitoring from 2000 to 2010 at the Project (IIA 2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010). Biological monitoring has included physicochemical water quality sampling and the sampling of macroinvertebrates.

Surveys were undertaken at six sites on the main tributaries and ephemeral creeks within the survey area

- sites W8 and W5 (Avondale Creek);
- sites W1 and W2 (Avon River);
- Site W3 (Dog Trap Creek); and
- Site S3 (ephemeral creek feeding into Avondale Creek).

These sites were also surveyed during the recent surveys (described below). A detailed description of sites (including photographs of each site) and the surveys conducted at each site is provided in Appendix B. The location of these surveys sites is shown on Figure 1.4 and provided in Table 1.1.

1.2.2 frc environmental Surveys

Aquatic habitat condition (including water quality parameters), aquatic flora, aquatic macroinvertebrates, fish (including targeted surveys for listed threatened species and ecological communities) and other vertebrates (e.g. turtle and platypus) were surveyed from 6 to 12 June 2011. Targeted surveys were undertaken in accordance with the *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities – Working Draft* (Department of Environment and Conservation 2004 and OEH 2011b).

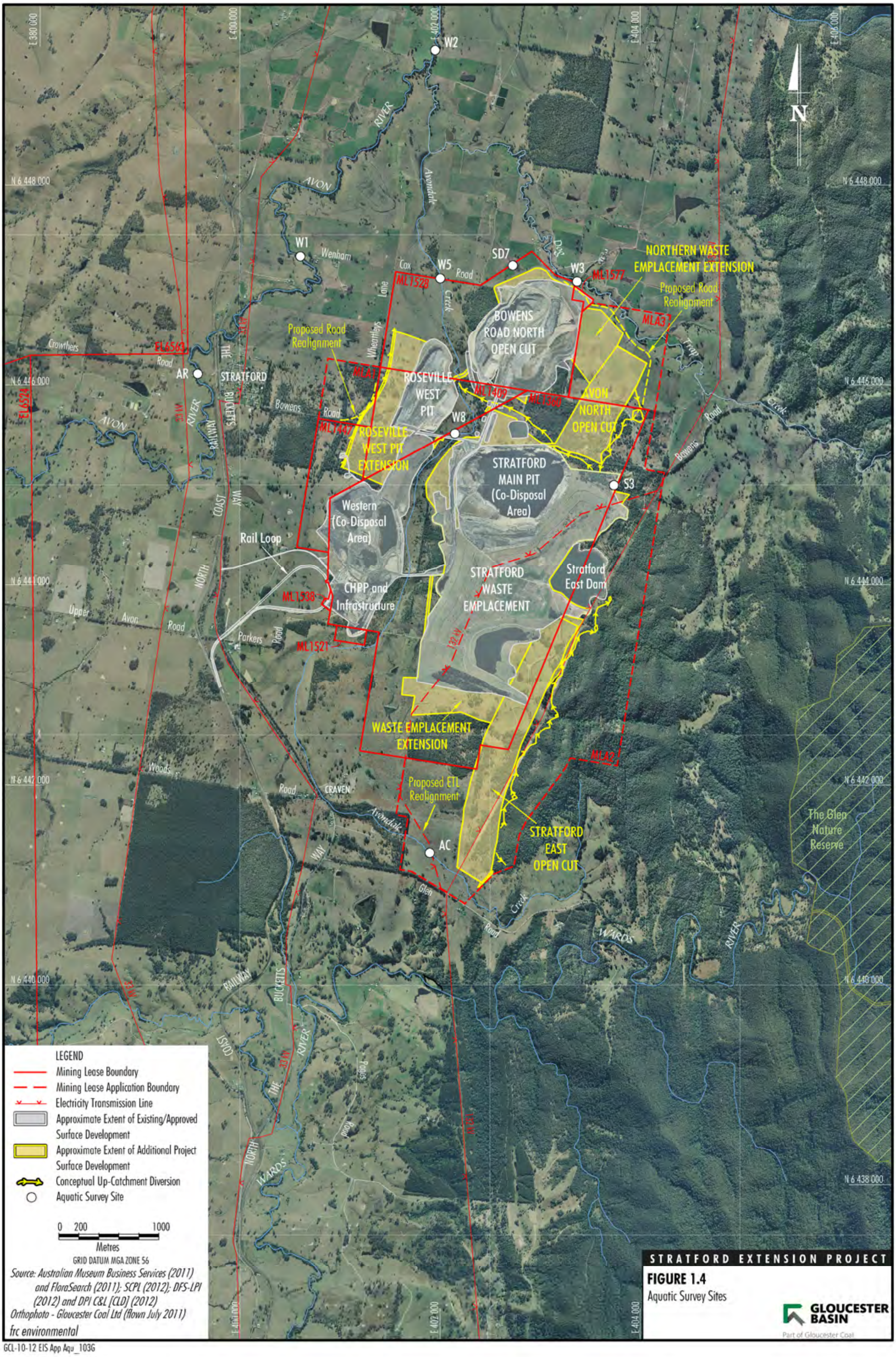

FIGURE 1.4
Aquatic Survey Sites

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Table 1.1 Location of sites surveyed during the current surveys undertaken by frc environmental and previous surveys undertaken by IIA.

Site	Location	Latitude	Longitude
Upstream Sites			
AR	Avon River, upstream of Growthers Road bridge	-32.11	151.93
AC	Avondale Creek, north of Glen Road	-32.16	151.95
*W1	Avon River, upstream of confluence of Avon River and Avondale Creek	-32.10	151.94
*W3	Dog Trap Creek, north-east of Wenhams Cox Road	-32.10	151.97
Downstream Sites			
*W2	Avon River, downstream of confluence of Avon River and Avondale Creek	-32.08	151.96
*W5	Avondale Creek, downstream of Site W8	-32.10	151.96
*W8	Avondale Creek, within mining lease and directly downstream of mining operations	-32.12	151.96
*S3	East of Stratford Main Pit, an ephemeral creek feeding into Avondale Creek	-32.12	151.97
SD7	North of mine water storage area and waste rock emplacement	-32.10	151.96

*previously surveyed by IIA.

Note: Co-ordinates are presented in WGS 84 datum, decimal degrees.

There was significant rainfall in the survey area in the weeks preceding the survey, and light showers on 11 and 12 June 2011. The weather was fine to overcast throughout the survey. Maximum and minimum temperatures, as well as rainfall for this period are shown in Table 1.2.

Table 1.2 Weather and other environmental conditions during the survey period.

Date	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Rainfall (mm)
6 June 2011	17.2	17.2	0
7 June 2011	16.5	4.3	0
8 June 2011	13.5	4.5	0
9 June 2011	14.0	6.5	0
10 June 2011	–	7.4	0
11 June 2011	–	–	3.2
12 June 2011	16.5	–	4.8

Source: Bureau of Meteorology (2011).

Note: Climate data recorded from the Craven (Longview) and Lostock Metrological Stations.

mm = millimetres.

Surveys were undertaken at nine sites on the main creeks and rivers, an ephemeral creek and a sediment dam within the survey area (Figure 1.4):

- Sites AC, W8 and W5 (Avondale Creek);
- Sites AR, W1 and W2 (Avon River);
- Site W3 (Dog Trap Creek);
- Site S3 (ephemeral creek feeding into Avondale Creek); and
- Site SD7 (sediment dam north of BRNOC).

Comparative sites (upstream of potential influences from the Stratford Coal Mine) were chosen to represent the range of aquatic habitats in the area, and to match the downstream sites':

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

Results at the downstream sites were compared to upstream sites in the survey, and results were compared to previous surveys undertaken by IIA (2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) (Appendix A).

A detailed description of sites (including photographs of each site) and the surveys conducted at each site is provided in Appendix B.

The location of where each site was surveyed is provided in Table 1.1 and shown on Figure 1.4.

1.2.3 Survey Team

The frc environmental survey team is shown in Table 1.3.

Table 1.3 Members of the frc environmental survey team.

Team Member	Role	Qualifications	Years in Industry
Lauren Thorburn Associate Ecologist	Field Planning	Bachelor of Science, 2001 Bachelor of Science, Hons. Class I, 2003 National AUSRIVAS Accreditation, 2004	9
Nirvana Searle Senior Ecologist	Site Visit and Field Planning	Bachelor of Applied Science, Hons. 1997 Master of Geographic Information System and Remote Sensing, current National AUSRIVAS Accreditation, 2004	13
Melissa Langridge Ecologist	Survey Leader	Bachelor of Science, 2006 Bachelor of Science, Hons. Class I, 2007	4
Drew Holzheimer Ecologist	Survey Team Member	Bachelor of Science, 2008 Bachelor of Science, Hons. 2009 National AUSRIVAS Accreditation, 2011	3

AUSRIVAS = Australian River Assessment System.

2 Threatened Species and Communities

Threatened aquatic species and ecological communities relevant to the Karuah Manning sub-region are listed in Table 2.1. The list was determined in accordance with the *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities – Working Draft* (Department of Environment and Conservation 2004). These were based on database search results of:

- NSW Department of Primary Industries (DPI) (Fishing and Aquaculture) *Threatened and Protected Species Records Viewer* (DPI [Fishing and Aquaculture] 2011a);
- threatened species, populations and ecological communities website (OEH 2011c);
- OEH (2011d) Atlas of NSW Wildlife database records database records for a 10 x 10 km search area surrounding the survey area;
- EPBC Act Protected Matters Search within a 10 km radius of the survey area (Commonwealth Department of Sustainability, Environment, Water, Population and Communities 2011); and
- previous surveys (IIA 2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010).

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

Table 2.1 Threatened species and communities potentially occurring in the Karuah Manning sub-region.

Species or Community	Common Name	Conservation Status[1]		
		FM Act	**TSC Act**	**EPBC Act**
Fauna				
Archaeophya adamsi	Adam's Emerald Dragonfly	E	–	–
Macquaria australasica	Macquarie Perch	E	–	E
Aquatic Flora				
Maundia triglochinoides	Maundia	–	V	–
Persicaria elatior	Tall Knotweed	–	V	V
Zannichellia palustris	Zanichellia	–	E	–
Ecological Community				
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Freshwater wetlands on coastal floodplains	–	E	–
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Swamp oak floodplain forest	–	E	–
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Swamp sclerophyll forest on coastal floodplains	–	E	–

Note: Threatened species exclude non-aquatic flora, and avian and amphibious fauna.

[1] Threatened species status under the FM Act, TSC Act and EPBC Act (current as of 30 January 2012). E: Endangered species, V: Vulnerable species.

2.1 NSW *Fisheries Management Act 1994*

The FM Act[1] sets out the regulatory framework for managing NSW fishing resources, in particular threatened fish and marine vegetation, and is administered by the DPI, except for Part 7 (Division 2) which is administered jointly by the NSW Department of Climate Change, Environment and Water. Part 7A of the FM Act enables the listing of:

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

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

2.1.1 Threatened Species

There are two species listed as endangered under the FM Act that may occur in aquatic communities in the vicinity of the survey area (i.e. the Karuah Manning sub-region) (Table 2.1). These species are described below.

The Adam's Emerald Dragonfly (*Archaeophya adamsi*) is listed as Endangered under the FM Act and is extremely rare, found only in small streams and creeks with gravel or sandy bottoms, specifically in narrow, shaded riffle zones with moss and rich riparian vegetation (DPI [Fishing and Aquaculture] 2011b). They are only found in four areas in NSW; Somersby Falls and Floods Creek near Gosford; Bedford Creek in the Lower Blue Mountains and Hungry Way Creek in Wollemi National Park (Fisheries Scientific Committee 2008a).

[1] Reprint No. 38. Current version for 5 August 2011 compiled and maintained by the Parliamentary Counsel's Office.

The Macquarie Perch (*Macquaria australasica*) is listed as Endangered under the FM Act (and also listed as Endangered under the EPBC Act). The Macquarie Perch is a native Australian fish that spends its entire life in freshwater streams, migrating between deep pools and fast flowing riffle habitats during different stages of its life history (McDowall 1996). It is endemic to the southern tributaries of the Murray-Darling River System (Fisheries Scientific Committee 2008b).

2.1.2 Ecological Communities

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

2.1.3 Key Threatening Processes

Key threatening processes are those that may adversely affect threatened species populations or ecological communities, or could cause species, populations or ecological communities that are not threatened to become threatened. There are currently eight key threatening processes listed in the FM Act (current as of 30 January 2012). Two key threatening processes may apply to the Project:

- degradation of native riparian vegetation along NSW water courses; and
- installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams.

Riparian vegetation is degraded by the complete removal or modification of native plants by processes such as clearing, gravel extraction, cropping, livestock grazing, trampling and introduction of non-native species (DPI 2005a).

Alteration to natural flow regimes can occur by:

- reducing or increasing flows;
- altering the seasonality of flows;
- changing the frequency, duration, magnitude, timing, predictability and variability of flow events;
- altering surface and subsurface water levels;
- changing the rate of rise or fall of water levels; and
- by altering water temperatures.

In-stream structures that modify natural flow include dams, weirs, canals, navigation locks, floodgates, culverts, flow regulators, levee banks, erosion control structures and causeways. Other mechanisms that may alter flow include water extraction, pumping and diversion, and sand and gravel extraction (DPI 2005b).

2.2 NSW *Threatened Species Conservation Act 1995*

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

Species, populations and ecological communities listed as endangered, critically endangered and vulnerable in NSW are listed in Schedules 1, 1A and 2 of the TSC Act. Key threatening processes are listed under Schedule 3.

2.2.1 Threatened Species

There are three aquatic floral species listed as threatened for the Karuah Manning sub-region under the TSC Act (Table 2.1) and are described below.

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

The Tall Knotweed (*Persicaria elatior*) is listed as Vulnerable under the TSC Act (also listed as Vulnerable under the EPBC Act). This herb grows in damp places, especially beside streams and lakes or in swamp forest. In the Karuah Manning sub-region it is associated with forested wetlands, freshwater wetlands, heathlands, rivers, lakes and streams. Tall Knotweed is threatened by the clearing of, and hydrological changes to, wetland vegetation (OEH 2011f). Flowers are produced in autumn and summer, and are required to identify the species.

[2] Reprint No. 101. Current version for 6 January 2012 compiled and maintained by the Parliamentary Counsel's Office.

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

2.2.2 Ecological Communities

There are three threatened ecological communities listed as Endangered under the TSC Act for the Karuah Manning sub-region (Table 2.1).

Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions are dominated by herbaceous plants and have very few woody species. They are associated with coastal areas subject to periodic flooding, where standing fresh water persists for at least part of the year.

Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions has a dense to sparse tree layer dominated by Swamp Oak (*Casuarina glauca*). Less than 3,200 hectares (ha) of Swamp Oak floodplain forests remain in the Hunter and Hunter-Central Rivers Catchments.

Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions comprise Eucalypts (*Eucalyptus* spp.) and Paperbarks (*Melaleuca* spp.). Where trees are sparse or absent, the community also includes ferns, reeds and/or sedges.

2.2.3 Key Threatening Processes

There are currently 37 key threatening processes listed under the TSC Act (current as of 30 January 2012). The following two key threatening processes relative to aquatic habitats may apply to the Project:

- alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands; and
- clearing of native vegetation.

The alteration of natural flows contributes to the loss of biological diversity and ecological function in aquatic ecosystems. Alterations may cause a number of species, populations or ecological communities that rely on river flows for their short-term and long-term survival, to become threatened (OEH 2011h).

Clearing refers to the destruction of one or more strata (layers) within a stand or stands of native vegetation. Clearing may cause riparian zone degradation, such as bank erosion leading to sedimentation that affects aquatic communities (OEH 2011i).

Predation by Eastern Gambusia (*Gambusia holbrooki*) is also listed as a key threatening process under the TSC Act. The Eastern Gambusia (*Gambusia holbrooki*) is a small freshwater fish originally introduced into Australia in the 1920s. The fish was originally imported as an aquarium fish but some were released into creeks around Sydney, Melbourne and Brisbane. Eastern Gambusia are now widespread in NSW and are aggressive predators of native fauna, such as threatened frog species, freshwater fishes and macroinvertebrates (NSW National Parks and Wildlife Service 2003). Eastern Gambusia were prevalent at several sites in the current survey, however it is unlikely that the Project will cause Eastern Gambusia to spread to further waterways.

2.3 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

Matters of National Environmental Significance under the EPBC Act[3] include:

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

The EPBC Act also provides for the identification and listing of key threatening processes.

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

2.3.1 Threatened Species

The Macquarie Perch (*Macquaria australasica*) is listed as Endangered under the EPBC Act (Table 2.1) but is endemic to the Murray-Darling River System and as such does not occur in the study area. The Tall Knotweed (*Persicaria elatior*) is listed as Vulnerable under the EPBC Act (Table 2.1) and is known from the region (Section 2.1). It has not previously been recorded within the study area and was not recorded during the current survey.

2.3.2 National Heritage Places

Barrington Tops (part of the Gondwana Rainforests of Australia) is situated approximately 45 km west of the Project and, therefore, a considerable distance from the area of any potential direct or indirect effect of the Project.

2.3.3 Key Threatening Processes

There are 19 key threatening processes currently listed under the EPBC Act (current as of 30 January 2012). The only key threatening process relative to aquatic habitats that may apply to the Project is 'land clearance'. Land clearing includes clearance of native vegetation for crops, improved, pasture, plantations, gardens, houses, mines, buildings and roads. It also includes infilling of wetlands or dumping material on dry land with native vegetation, and the drowning of vegetation through the construction of impoundments.

3 Aquatic Fauna Habitat

3.1 Methods

The aquatic habitat of the survey area was assessed at nine sites in a survey from 6 to 12 June 2011. Details of the sites surveyed are described in Section 1.2 and Appendix B.

3.1.1 Habitat Assessment

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

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

3.1.2 Habitat Bioassessment Scores

To enable a comparison of habitat quality between sites using an index of habitat condition, habitat bioassessment score datasheets in the *Australia-Wide Assessment of River Health: Queensland AUSRIVAS Sampling and Processing Manual* (Queensland Department of Natural Resources and Mines 2001) were used to numerically score nine criteria, which were then allocated to one of four categories (excellent, good, moderate and poor) (Table 3.1):

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

Table 3.1 Habitat bioassessment scores used to derive overall condition categories.

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

Source: Queensland Department of Natural Resources and Mines (2001).

3.1.3 Water Quality

Water quality was assessed at the nine sites from 6 to 12 June 2011 (Appendix C). Physical water quality measurements were sampled *in situ* at each site. A Hydrolab QUANTA multi-parameter water quality probe was used to measure:

- water temperature;
- turbidity;
- pH;
- electrical conductivity; and
- dissolved oxygen.

The water quality meter was calibrated daily for all parameters. Water samples were analysed by Advanced Analytical (a National Association of Testing Authorities-accredited laboratory) for alkalinity.

3.1.4 Data Analysis

Water quality data at the downstream sites (sites W2, W5, W8, S3 and SD7) was compared to:

- data from upstream sites (sites W1, AR, AC and W3) (Figure 1.4);
- historical data collected by IIA (2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) at each site from 2001 to 2010 (Appendix A); and
- the relevant NSW Water Quality Objectives (NSW Department of Environment, Climate Change and Water [DECCW] 2006) for uncontrolled streams and water bodies in the Manning River Catchment[4] for:
    - lowland[5] rivers (all sites except Site SD7); and
    - lakes and reservoirs (the sediment dam at Site SD7).

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

Water quality guidelines for physicochemical water quality parameters in freshwater systems for lowland rivers and lakes and reservoirs are summarised in Table 3.2.

[4] The Manning River Water Quality Objectives are drawn from the national ANZECC & ARMCANZ (2000) Guidelines.

[5] The DECCW (2006) guidelines define lowland streams as those below 150 m altitude. The altitude of the Stratford township is 130 m above sea level.

Table 3.2 Water quality guidelines for physicochemical water quality parameters in freshwater systems recorded in the current survey.

Parameter	Units	Water Quality Guidelines	
		Lowland Rivers	Lakes and Reservoirs
Temperature	°C	–	–
Turbidity	NTU	6–50	1–20
Ph	pH units	6.5–8.5	6.5–8.0
Electrical conductivity	µS/cm	125–2 200	–
Dissolved oxygen [a]	% saturation	85–110	90–110
Alkalinity	mg $CaCO_3$/L	–	–

Source DECCW (2006).

[a] Dissolved oxygen values derived from daytime measurements, and may vary overnight and with depth.

– not available.

°C = degrees Celsius.

NTU = nephelometric turbidity unit.

µS/cm = microSiemens per centimetre.

mg $CaCO_3$/L = milligrams calcium carbonate per litre.

3.2 Results

3.2.1 Habitat Assessment

In-stream Habitat

In-stream habitat (i.e. structural elements) provides refuge and food for aquatic fauna such as fish, turtles and macrocrustaceans. In-stream habitat was dominated by aquatic vegetation (i.e. macrophytes), woody debris and overhanging/trailing bank vegetation. Boulders provided additional habitat at Site W8 (downstream site on Avondale Creek) (Plate 1.1 in Appendix C). In-stream habitat at Site SD7 (sediment dam north of the BRNOC) is shown on Plate 3.1.

Plate 3.1: In-stream vegetation at the sediment dam at Site SD7.

Channel Diversity

Channel diversity was low at all sites and generally limited to either run habitat (flowing water at sites) upstream and downstream along Avon River (sites AR and W2, respectively) and downstream Avondale Creek (Site W5) or pool habitat, such as that in the sediment dam (Site SD7). Both run and pool habitats were present at upstream and downstream sections of Avondale Creek (sites AC and W8, respectively) and at the ephemeral creek east of the Stratford Main Pit (Site S3). There were short reaches of riffle habitat at sites W1 (upstream site along Avon River) (5% of habitat) and W3 (site along Dog Trap Creek) (20% of habitat). There was a small cascade along upstream Avon River (Site W1) (Plate 1.2 in Appendix C). Bends and changes in water depth are likely to provide some channel diversity during periods of higher flow.

Substrate Composition

Surface sediment was dominated by (Figure 3.1):

- silt at sites W5 (downstream site along Avondale Creek) and SD7 (sediment dam);
- sand at sites AR (upstream site along Avon River) and W3 (upstream site along Dog Trap Creek); and
- silt/sand at sites AC and W1, upstream sites along Avondale Creek and Avon River, respectively.

There was a diverse mixture of surface sediments at sites W2, W8 and S3, downstream sites along Avon River and Avondale Creek, and upstream along Dog Trap Creek, respectively, as Site W2 had a high proportion of pebble and gravel, Site W8 had a relatively high proportion of boulders and Site S3 had a high proportion of silt/clay, sand and gravel (Figure 3.1).

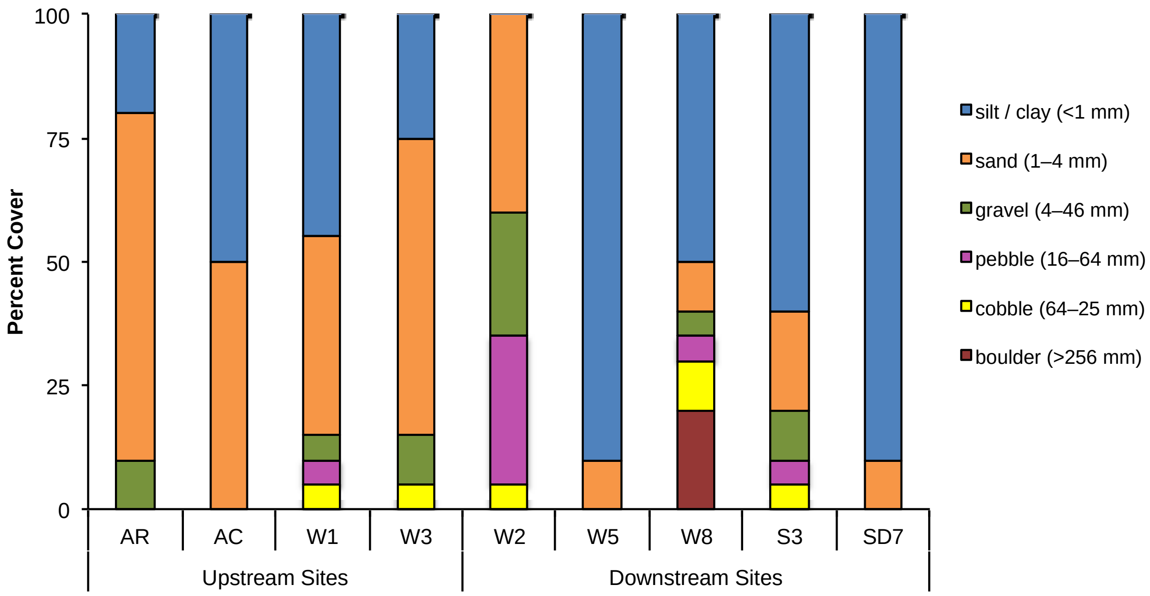

Figure 3.1 Percent cover of substrate types at each site.

Riparian Vegetation and Adjacent Land Use

The riparian zone at upstream sites AC (Avondale Creek) and W3 (Dog Trap Creek) and downstream sites W5 and W8 along Avondale Creek and SD7 (sediment dam) was dominated by pasture grasses and shrubs (Plate 1.3 of Appendix C). The riparian zone at upstream sites AR and W1 (along Avondale Creek) and downstream sites W2 (Avon River) and S3 (ephemeral creek) was more diverse and included several large trees (Plate 1.4 of Appendix C).

At sites W8 (Avondale Creek) and S3 (ephemeral creek) the land immediately adjacent to the riparian zone was predominantly used for mining activities, and at sites AR, W1 W2 along Avon River; sites AC and W5 along Avondale Creek; and Site W3 along Dog Trap Creek the land was used for grazing/agriculture (Plate 3.2). Mining activities were also underway immediately to the south of the sediment dam (Site SD7), however the land to the north, east and west was used for grazing/agriculture.

Plates 1.3 to 1.5 of Appendix C provide additional photographs showing riparian vegetation and adjacent land use within the survey area.

Plate 3.2: The land next to Dog Trap Creek (Site W3) was used for grazing by cattle.

Bank Stability

Bank erosion was most extensive at sites accessed by livestock and at sites that had been cleared of vegetation for grazing/agriculture (i.e. sites AC and W5 along Avondale Creek and Site W3 along Dog Trap Creek) (Plate 3.2 and Plate 3.3). Although channel diversity was generally low, in-stream habitat such as aquatic vegetation (i.e. macrophytes), woody debris and overhanging/trailing bank vegetation providing refuge and food for aquatic fauna was present at most sites. Plates 1.6 to 1.7 of Appendix C provide additional photographs of bank erosion within the survey area.

Plate 3.3: Bank erosion along Avondale Creek (Site AC) due to clearance of vegetation.

3.2.2 Habitat Bioassessment Scores

Most sites had either a moderate or good habitat bioassessment score, however, upstream Site AC along Avondale Creek had a poor score. Downstream sites had habitat scores equal (moderate) or above (good) the range of the upstream sites (Figure 3.2).

The poor habitat score at upstream Site AC along Avondale Creek was due to channel/bank erosion, limited in-stream habitat diversity and poor streamside cover that was dominated by pasture grasses and/or shrubs. Despite a moderate bioassessment score, downstream Site W5 (Avondale Creek) had low bank/vegetative stability and poor streamside cover and Site SD7 (sediment dam) had low streamside cover, limited depth and high deposition of silty sediments.

Moderate to good scores were generally due to more diverse habitat (e.g. woody debris and vegetation) and riparian vegetation, together with more stable banks and channels.

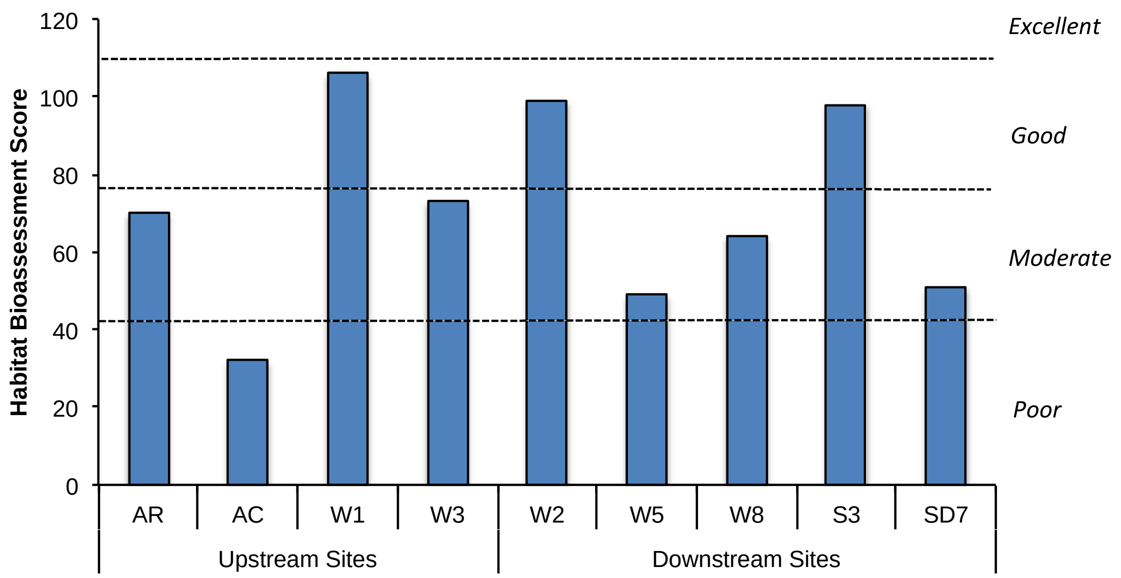

Figure 3.2 Habitat bioassessment scores at each site and the thresholds for poor, moderate and good habitats.

Wetland Habitat

The sediment dam (Site SD7) located within the survey area does not provide high value wetland habitat due to the low streamside cover, limited depth and high deposition of silty sediments.

None of the known threatened ecological communities in the region (Section 2) were identified within or surrounding the Project area.

3.2.3 Water Quality

Water Temperature

There are no Manning River Water Quality Guidelines for water temperature (DECCW 2006). The range in water temperature was 9.4°C to 12.9°C during the surveys (Figure 3.3).

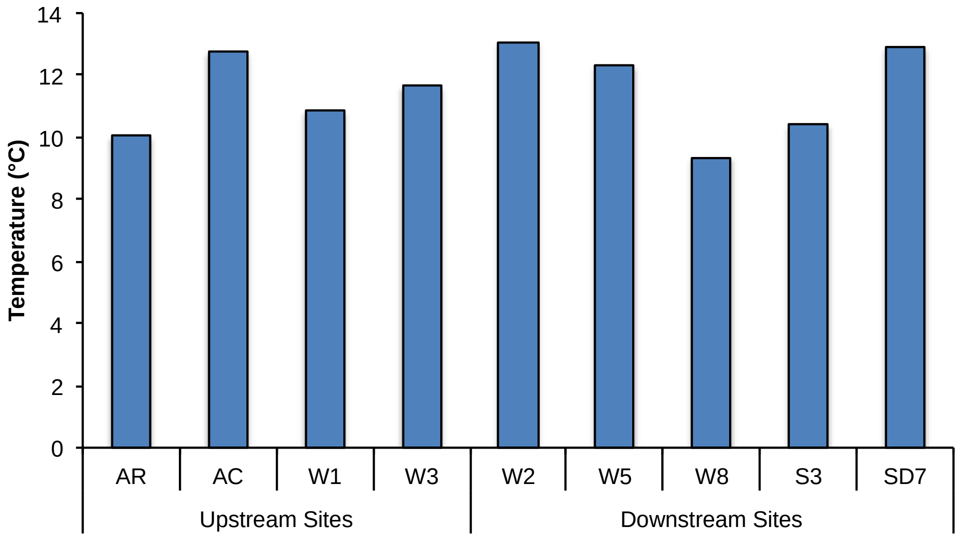

Figure 3.3 Water temperature at each site.

Temperature varied between sites, but the range of water temperatures was similar at upstream and downstream sites. Water temperature at any given site is likely to reflect a number of factors including the season, time of day, size of the waterbody, prevailing weather conditions, flow, and riparian cover.

Temperatures recorded during the current survey were slightly lower than those recorded during previous surveys undertaken by IIA (11.8 to 28.2°C) (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007; 2008, 2009, 2010) (Appendices A and C).

Turbidity

Turbidity exceeded the Manning River Catchment upper limit at sites AC (Avondale Creek), W2 (Avon River) and SD7 (sediment dam) (Figure 3.4). The range in turbidity was 14.1 NTU (Site W8 – Avondale Creek) to 56.6 NTU (sites AC – Avondale Creek and W2 – Avon River) (Figure 3.4).

Turbidity is a potential indicator of sedimentation and erosion. Turbidity was variable between sites, but the range recorded was similar at upstream and downstream sites. The high turbidity at Site SD7 (sediment dam) is likely to be related to its historical function as a sediment dam (Figure 3.4).

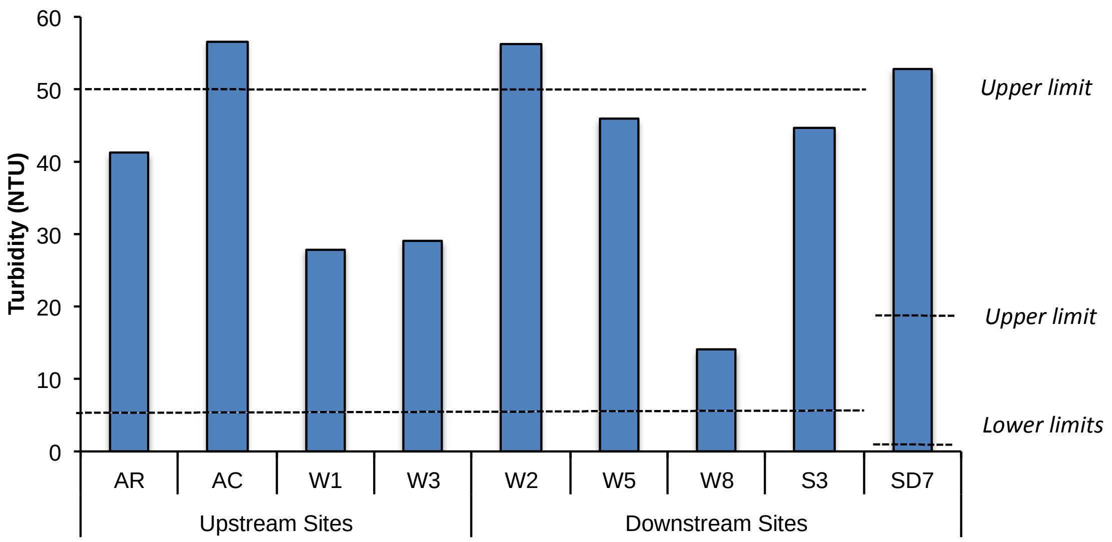

Figure 3.4 Turbidity at each site and the Manning River Catchment Water Quality Guideline ranges.

Turbidity was higher at all sites in 2011 than in 2010, most likely due to recent high flows (Appendix C).

pH

The pH was below the Manning River Catchment guideline range at sites AR and W1 along the Avon River, and the sediment dam at Site SD7 (Figure 3.5). The range in pH was 5.9 to 6.9 (Figure 3.5).

Figure 3.5 The pH at each site and the Manning River Catchment Water Quality Guideline ranges.

The pH was slightly lower than in previous surveys conducted by IIA (pH 6.3 to 8.75) (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007; 2008, 2009, 2010), particularly at Site W1 (Avon River) (Appendix C).

Electrical Conductivity

Electrical conductivity was within the Manning River Catchment guideline range for lowland streams at all sites (guideline range: 125 to 2,200 µS/cm). There is no guideline range for electrical conductivity within lakes and reservoirs; however, electrical conductivity at the sediment dam (Site SD7) was within the guideline range for lowland streams and within the range of other sites. The range in electrical conductivity was 171 to 400 µS/cm (Figure 3.6).

Electrical conductivity was higher at all downstream sites compared to upstream sites (Figure 3.6). Electrical conductivity depends on a number of factors including catchment runoff and local geology.

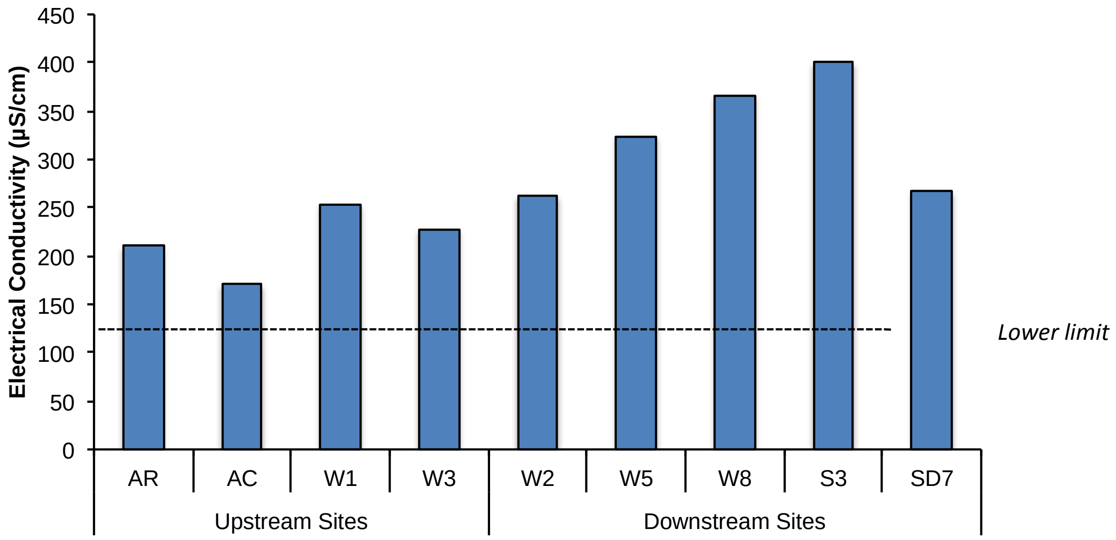

Figure 3.6 Electrical conductivity at each site and the Manning River Catchment Water Quality Guideline lower limit.

The range in electrical conductivity in 2011 was much less than in previous surveys conducted by IIA (134.5 to 5460 mg/L) (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007; 2008, 2009, 2010) (Appendix C).

Dissolved Oxygen

The percent saturation of dissolved oxygen was within the Manning River Catchment guideline range at site AR along Avon River; sites AC and W5 along Avondale Creek; and the sediment dam (Site SD7) and below the guideline range at sites W1 and W2 along Avon River; Site W8 along Avondale Creek; Site W3 along Dog Trap Creek; and Site S3 along the ephemeral creek (Figure 3.7). The range in dissolved oxygen was 74.1 to 94.6% (Figure 3.7).

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

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

Note: % = percent

Figure 3.7 Dissolved oxygen at each site and the Manning River Catchment Water Quality Guideline ranges.

Dissolved oxygen was much higher at all sites in 2011 than in 2010, most likely due to recent high flows, site-specific levels of solar exposure and the production of algae (Appendix C).

Alkalinity

Alkalinity is the ability of a solution to neutralise acids. Fluctuations in alkalinity are related to the proportions of surface water and rainfall, and therefore show an inverse relationship to rainfall.

There are no Manning River Water Quality Guidelines for alkalinity (DECCW 2006). The range in alkalinity was 38 to 92 mg $CaCO_3$/L (Figure 3.8).

Alkalinity varied between sites (Figure 3.8).

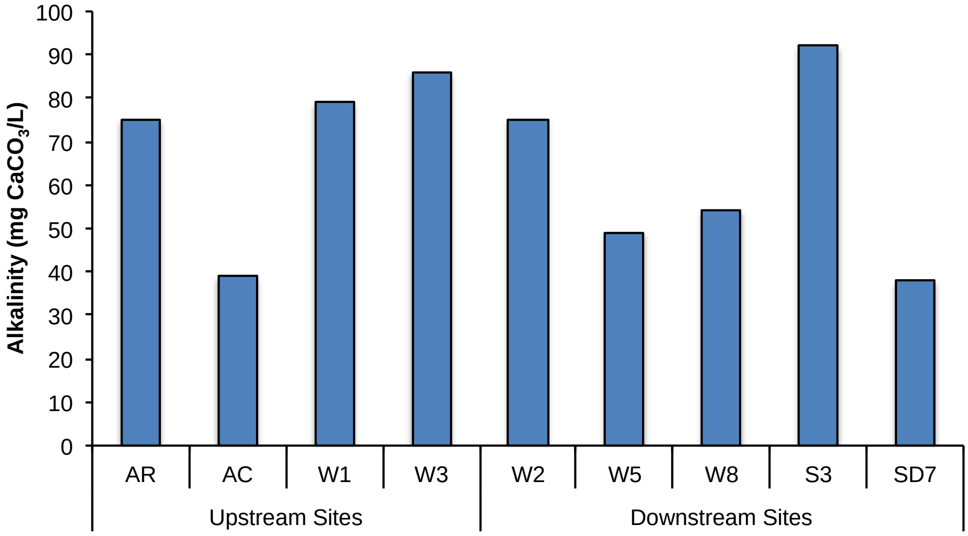

Figure 3.8 Alkalinity at each site.

Generally, alkalinity was lower in 2011 than in June 2010 most likely due to the high rainfall in the months before the 2011 survey (Appendix C). The lower alkalinity may explain the lower pH in 2011.

4 Aquatic Flora

4.1 Methods

The aquatic flora of the survey area was assessed at nine sites in a survey from 7 to 12 June 2011. Details of the sites surveyed are described in Section 1.2 and Appendix B.

The macrophyte community at each site was assessed along a 100 m reach within the stream or dam. Plants were identified and the following recorded:

- taxonomic richness;
- mean percent cover (% of substrate [bed/bank] covered by aquatic vegetation);
- total percent cover (% of substrate [bed/bank] covered by each aquatic species);
- growth form of each species (submerged, floating [free-floating or rooted] and emergent) (Table 4.1);
- whether the plant was native or introduced to Australia; and
- whether the plant was listed under state or commonwealth legislation.

Results at downstream sites were compared to the data from comparative upstream sites.

Table 4.1 Macrophyte growth forms.

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

Source: Sainty and Jacobs (2003).

Total percent cover of each species was assessed visually and macrophyte species were identified in the field, where practical. Representative specimens were collected for identification by the National Herbarium of NSW. Species were identified as native or exotic according to *New South Wales Flora Online* (National Herbarium of NSW 2011).

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

4.2 Results

4.2.1 Taxonomic Richness

A total of 31 macrophytes were identified within the survey area. The number of macrophytes found in the 100 m reach at each site ranged from two species at Site W3 (upstream site along Dog Trap Creek) to nine species at Sites S3 (the ephemeral creek east of Stratford Main Pit). The number of species at all downstream sites was similar to, or higher than, the number of species recorded at the upstream sites (Figure 4.1). A table listing macrophytes recorded during the survey and photographs of recorded macrophytes are presented in Appendix D.

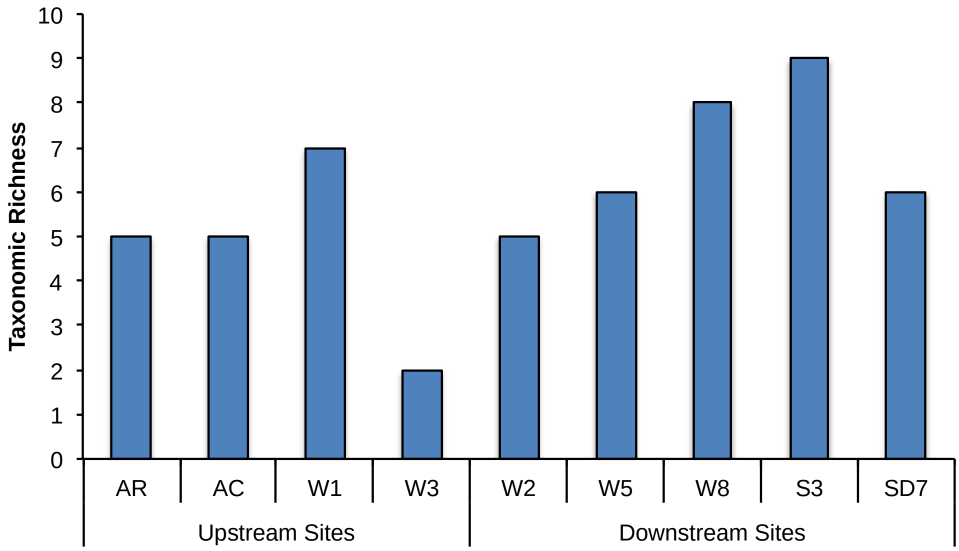

Figure 4.1 Taxonomic richness at each site.

Mean percent cover of macrophytes (as a percentage of the total substrate) ranged from 6% at sites AR (upstream Avon River) and W3 (upstream Dog Trap Creek) to 86% at Site SD7 (sediment dam). The macrophyte cover at all downstream sites was higher than the range recorded at the upstream sites (Figure 4.2). The mean percent cover of macrophyte species at each site is detailed in Appendix D.

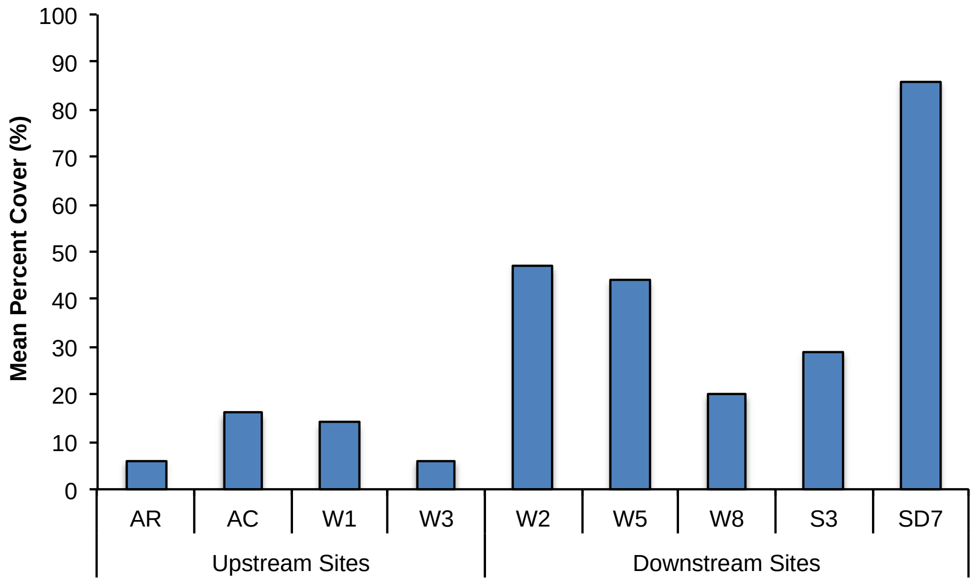

Figure 4.2 Mean percent cover of macrophytes at each site.

The high macrophyte cover at sites W5 (Avondale Creek) and SD7 (sediment dam) was due to a high abundance of the following in-stream flora: *Schoenoplectus mucronatus* (a sedge) dominated the substrate at Site W5 (Avondale Creek); and Tall Spike Rush (*Eleocharis sphacelata*) dominated substrate at Site SD7 (sediment dam). A high abundance of Honey Reed (*Lomandra longifolia*) and Australian Basket Grass (*Oplismenus aemulus*) was recorded at Site W2 (Avon River) (Appendix D).

Slender Knotweed (*Persicaria decipiens*) (Plate 1 in Appendix D) and *Persicaria* sp.[6] were the most common species, found at eight of the nine sites. *Juncus usitatus* (a Common Rush) (Plate 3 in Appendix D) was also common, found at five sites (Appendix D).

[6] Specimens were unable to be identified to the species taxonomic level by the National Herbarium of NSW.

Emergent macrophytes were the most common growth form recorded at both upstream and downstream sites. Submerged macrophytes were recorded at Site W8 along Avondale Creek; Site W2 along Avon River; and along the ephemeral creek at Site S3. Two unidentifiable species of free-floating rooted macrophyte was recorded at Site W1 (Avon River) (Appendix D).

The lack of submerged and floating macrophytes at most sites (Appendix D) suggests that water levels fluctuate considerably and/or that the water column is likely to be highly turbid. Submerged macrophytes cannot survive dry periods and high turbidity (high turbidity reduces light levels in the water column and inhibits photosynthesis) and emergent forms are most tolerant to dry conditions.

Three introduced species were recorded during the survey, namely the: Common Starwort (*Callitriche stagnalis*), Common Bittercress (*Cardamine hirsuta*) and Umbrella Sedge (*Cyperus eragrostis*) (Appendix D). All introduced species are widespread in NSW and were found in low abundance at each site.

Common Starwort was recorded at Site W1 (Avon River) (Appendix D). It is found in still or slow-moving waterbodies and on surrounding muddy edges (Sainty and Jacobs 2003) (Plate 4 in Appendix D). Common Bittercress was recorded at Site AR (Avon River) (Appendix D). It is a widespread weed, often found in moist gardens (National Herbarium of New South Wales 2011) (Plate 5 in Appendix D). Umbrella Sedge was recorded at Site W5 (Avondale Creek) (Appendix D). Umbrella sedge is a weed of shallow permanent or ephemeral creeks, drains and channels, or damp margins of larger water bodies (Sainty and Jacobs 2003; National Herbarium of NSW 2011) (Plate 6 in Appendix D).

No macrophytes listed under the EPBC Act or TSC Act were recorded during the survey. Several specimens of *Persicaria* sp. were unable to be identified by the National Herbarium of NSW. However, based on analysis of photos and specimens, it is unlikely that these specimens are *P. elatior*, which is listed as Vulnerable under the TSC Act and EPBC Act.

5 Aquatic Macroinvertebrate Communities

Aquatic macroinvertebrate communities were assessed at eight sites from 7 to 12 June 2011. Site AC (Avondale Creek) was not sampled as the water level was too low. Details of the sites surveyed are described in Section 1.2 and Appendix B.

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

5.1 Methods

5.1.1 Quantitative Samples

At each site, five macroinvertebrate samples were collected from bed habitat and five samples were collected from edge habitat. Sediment was disturbed within a 30 x 30 centimetre (cm) area for five seconds, and each sample was then collected by sweeping a standard triangular-framed, macroinvertebrate sampling net, with a 250 micrometre (µm) mesh, through the disturbed area five times. More detail on the qualitative methods employed during the survey is provided in Appendix E.

5.1.2 AUSRIVAS Samples

At each site, one sample from the bed habitat and one sample from the edge habitat were collected, to enable comparison to other AUSRIVAS data sets from the region. This sampling followed the methods in the AUSRIVAS sampling manual (Turak and Waddell 2002). A standard triangular-framed, macroinvertebrate sampling net with 250 µm mesh was used to collect the samples. More detail on the AUSRIVAS sampling technique employed during the survey is provided in Appendix E.

5.1.3 Macrocrustacean Samples

Macrocrustaceans (e.g. shrimps, yabbies and prawns) were caught during fish surveys, using a combination of bait trapping and electrofishing in accordance with the *Australian Code of Electrofishing Practice 1997*. This method is further described in Section 6.1.

5.2 Sample Processing

All samples were frozen and returned to frc environmental's Brisbane laboratory, where they were sorted, counted and identified to the lowest practical taxonomic level (in most instances family), to comply with AUSRIVAS standards and those described by Chessman (2003). Dragonfly larvae were examined for the presence of the Adam's emerald dragonfly (*Archaeophya adamsi*) (listed as Endangered under the FM Act).

5.3 Data Analysis

Several methods were used to analysis the data collected during the surveys. These methods are summarised below and are detailed in Appendix E.

5.3.1 Quantitative Samples

Calculation of Indices

The following macroinvertebrate indices were calculated for each quantitative sample: abundance, taxonomic richness, Plecoptera, Ephemeroptera, and Trichoptera (PET) richness and Stream Invertebrate Grade Number-Average Level (SIGNAL) 2.

Univariate Statistical Analyses

A one-way Analysis of Variance (ANOVA) test was conducted on quantitative samples to determine differences in the macroinvertebrate indices among sites. Where an ANOVA test indicated significant differences among sites, a Tukey's Honestly Significant Difference (HSD) test was used to determine which pairs of sites differed.

Multivariate Analyses

Multivariate analysis was conducted on quantitative samples using a one-way analysis of similarity (ANOSIM). Community differences between sites were displayed visually, using the averaged data for each habitat at each site, using non-metric multi-dimensional scaling (MDS) ordinations. Where sites were closely grouped, these were overlaid by lines indicating 40% and/or 60% similarity between sites, as determined using Cluster analysis (Clarke 1993). Individual taxa, that contributed to the differences between sites, were identified using the similarity percentages (SIMPER) species contributions routine (Clarke 1993).

5.3.2 AUSRIVAS Samples

The following were calculated for the AUSRIVAS samples: taxonomic richness, PET richness and SIGNAL 2/family bi-plots. Data were compared to the results of previous surveys undertaken in autumn by IIA from 2000 to 2010 where relevant.

More information on the data analysis used during the surveys is presented in Appendix E.

5.4 Results

Results are summarised below and are described in detail in Appendix E.

5.4.1 Quantitative Samples

Community Composition

Non-biting midge larvae (sub-families Chironominae and Tanypodinae) were the most common and abundant taxa sampled. Water boatman (family Corixidae) were also found in high numbers at most sites. Typically, these families are tolerant of a wide range of environmental conditions and are often found in moderately disturbed ecosystems (Chessman 2003).

Bed Habitat

Macroinvertebrate community composition in bed habitat varied between sites (result determined using ANOSIM Global R statistic = 0.302, $p < 0.001$; Figure 5.1). However, there was an overlap (40% similarity) in community structure between most sites except for Sites W2 (Avon River) and sites W5 and W8 (Avondale Creek) (result determined using cluster analysis). The most closely related sites were those from Avon River at upstream sites W1 and AR (result determined using ANOSIM Pairwise test: R statistic = 0.11, $p = 0.21$). These sites were most likely related due to their close proximity and similarities in flow conditions.

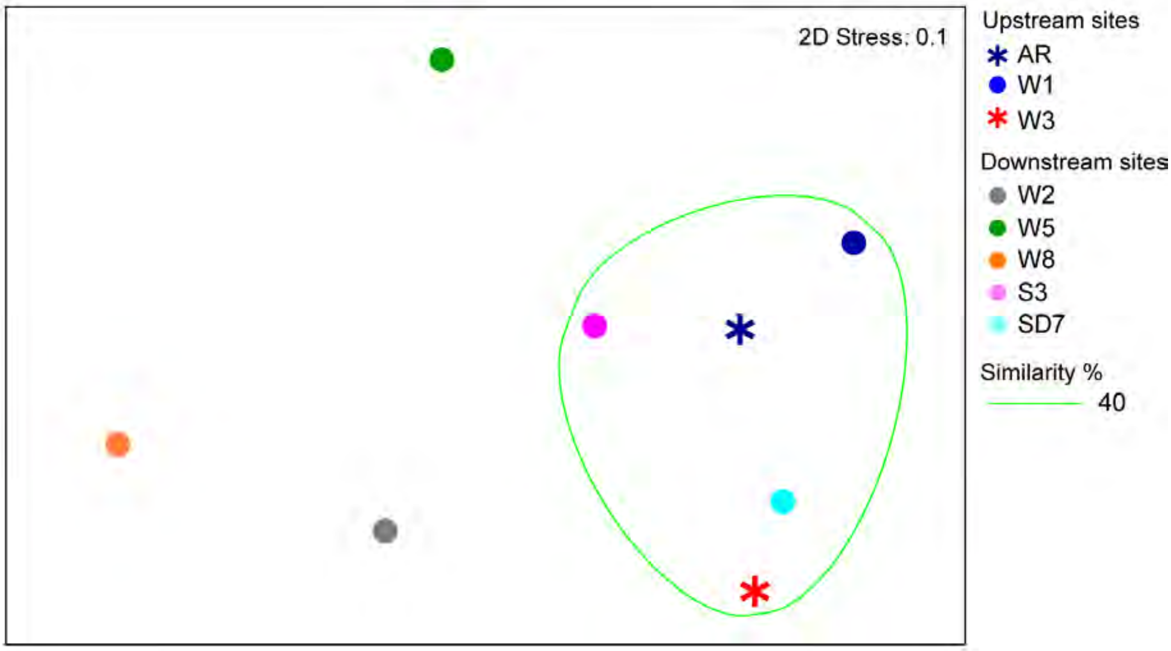

Figure 5.1 Multidimensional Scaling ordination in bed habitat, showing similarities in community composition between sites using CLUSTER analysis.

Edge Habitat

Macroinvertebrate community composition in edge habitat varied significantly between sites (result determined using ANOSIM Global R statistic = 0.371, p< 0.001; Figure 5.2). However, communities at all sites grouped together at a 40% similarity level, except at Site W2 (Avon River) (Figure 5.2).

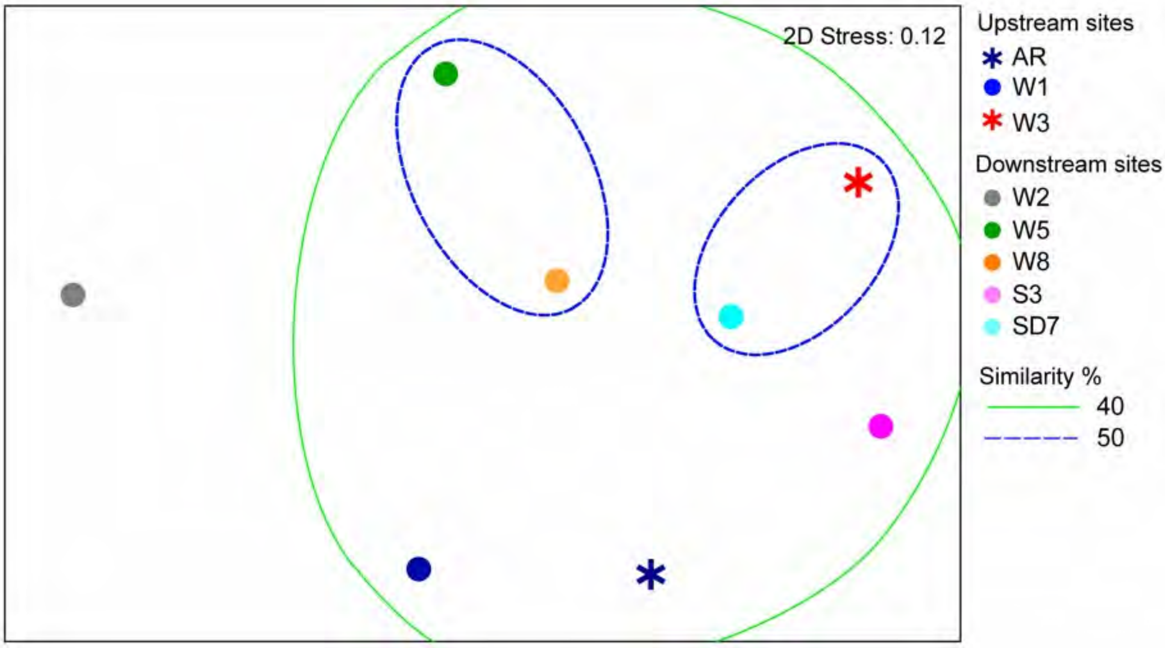

Figure 5.2 Multidimensional Scaling ordination in edge habitat showing differences in macroinvertebrate community composition between sites.

Mean Abundance

Mean abundance (i.e. the average number of individuals of the five samples from each site) was variable between sites (Figure 5.3). Significant differences in abundance between sites were due to the lower abundance in edge habitat at Site W2 (Avon River), and in bed habitat at sites W2 (Avon River) and W8 (Avondale Creek) (Figure 5.3; Appendix E) (result determined using ANOVA and Tukey's HSD test).

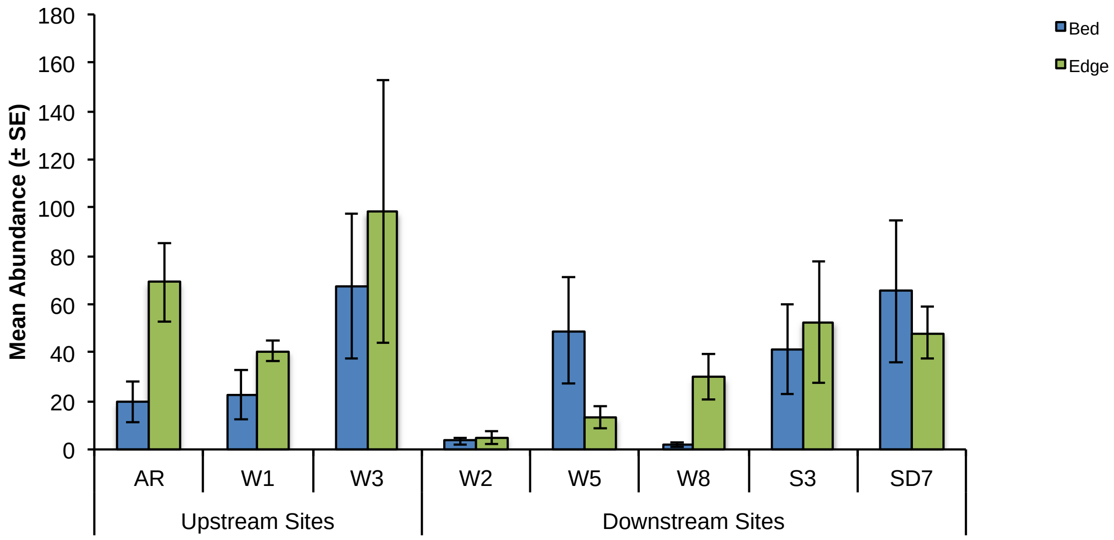

Figure 5.3 Mean abundance (± SE) in bed and edge habitat at each site.

Total Taxonomic Richness

Total taxonomic richness from the quantitative samples (i.e. the total number of taxa in the five samples from each site) was variable between and within sites (i.e. between bed and edge habitat). Total taxonomic richness in bed habitat ranged from nine taxa at the sediment dam at Site SD7 to 25 taxa at Site W1 along Avon River, and was lowest in bed habitat at downstream sites W8 (Avondale Creek) and SD7 (sediment dam). Total taxonomic richness was higher in edge habitat compared with bed habitat, and ranged from 12 taxa at downstream Site W2 to 28 taxa at upstream Site AR, both along the Avon River (Figure 5.4).

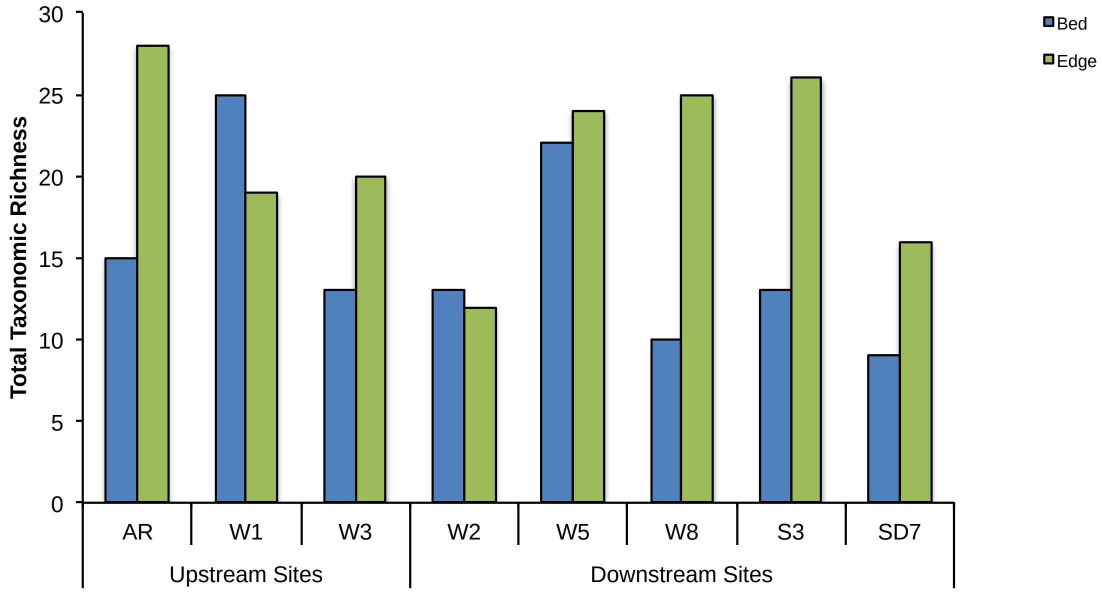

Figure 5.4 Total taxonomic richness in bed and edge habitats at each site from quantitative samples.

Mean Taxonomic Richness

Mean taxonomic richness (i.e. the average number of taxa in the five samples from each site) varied between sites and was generally higher in edge habitat compared to bed habitat. Taxonomic richness was lower in edge habitat compared to bed habitat at sites W1 and W2 along the Avon River. Downstream Site W8 (Avondale Creek) had the lowest mean taxonomic richness in bed habitat, and upstream Site AR (Avon River) had the highest in edge habitat. Significant differences in mean taxonomic richness between sites were due to the lower richness in edge habitat at Site W2 (Avon River), and in bed habitat at Site W8 (Avondale Creek), compared to the majority of other sites (result determined using ANOVA and Tukey's HSD test) (Figure 5.5).

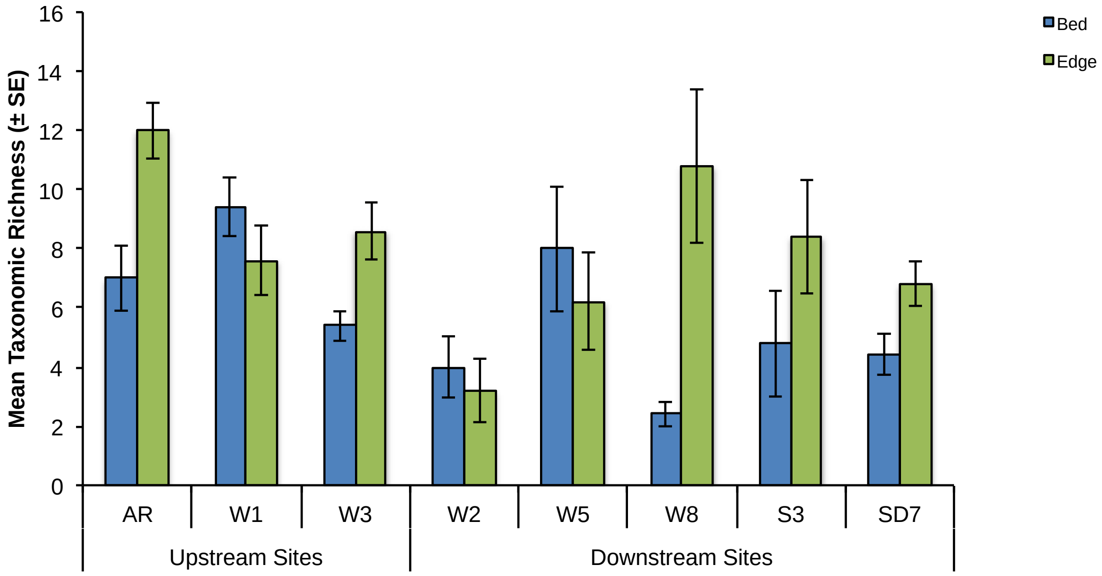

Figure 5.5 Mean taxonomic richness (± standard error) in bed and edge habitats at each site from quantitative samples.

5.4.2 AUSRIVAS Samples

Total Taxonomic Richness

Total taxonomic richness in the AUSRIVAS samples for edge habitat for downstream sites was generally within the range of the background data at upstream sites. Total taxonomic richness in AUSRIVAS samples was lowest for bed habitat at downstream sediment dam at Site SD7 and highest in edge habitat at upstream sites AR (Avon River) and W3 (Dog Trap Creek) (Figure 5.6).

Taxonomic richness in edge habitat was compared to surveys conducted by IIA (2000, 2001c, 2002, 2003b, 2004a). Results indicated that taxonomic richness has increased at sites W3 (Dog Trap Creek) and W5 (Avondale Creek) since autumn 2004 (Appendix E).

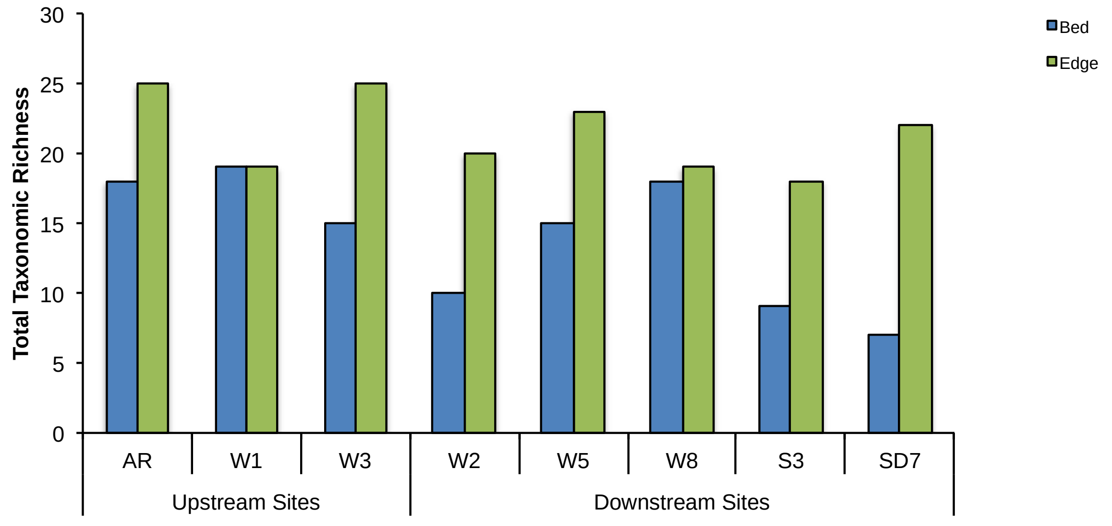

Figure 5.6 Total taxonomic richness in bed and edge habitats at each site from AUSRIVAS samples.

Total PET Richness

PET taxa are sensitive to pollutants and changes in water quality and/or environmental degradation. Total PET richness was highest in bed habitat along the Avon River at Site AR. There were no PET taxa in bed habitat along the ephemeral creek (Site S3) and sediment dam (Site SD7) or in edge habitat along the Avon River at Site W2 (Figure 5.7).

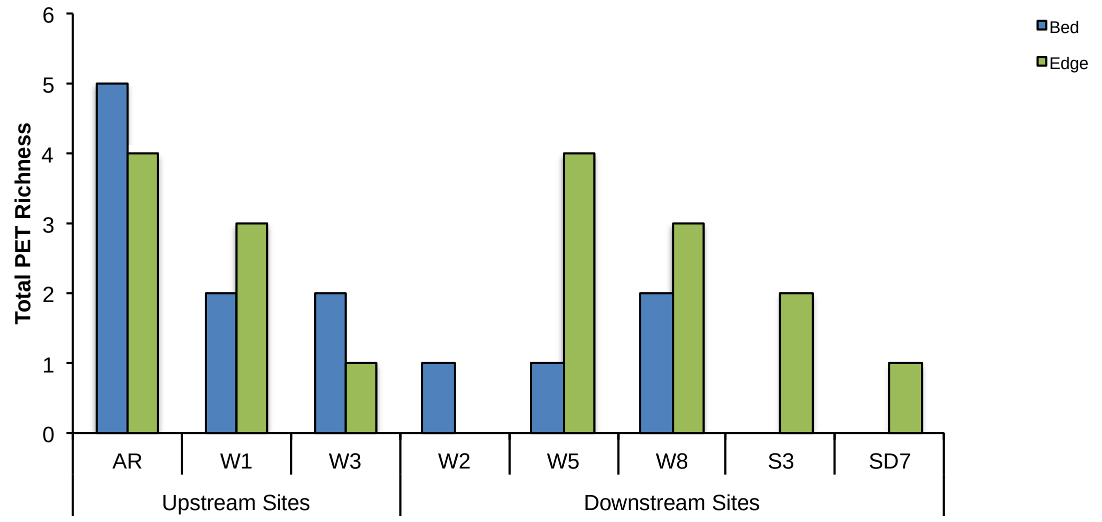

Figure 5.7 Total PET richness in bed and edge habitats at each site from AUSRIVAS samples.

Total PET richness was compared to surveys conducted by IIA (2000, 2001c, 2002, 2003b, 2004a). Total PET richness was generally lower in 2011 than in autumn 2000 to 2002, but higher than or similar to total PET richness in autumn 2003 and 2004 (Appendix E).

SIGNAL 2/Family Bi-plot

The SIGNAL 2/Family bi-plot communities at upstream and downstream sites were generally within quadrant 2 (which indicates high salinity or nutrient levels that may be natural) and quadrant 4 (which indicates industrial or agricultural pollution) (Figure 5.8). Macroinvertebrate communities in the current survey, which was undertaken in the NSW AUSRIVAS autumn sampling season, were compared to communities sampled in the most recent autumn survey by IIA (2004a) (all other surveys by IIA after 2004 were undertaken during spring or summer). Sites surveyed by IIA in 2004 were also within quadrants 2 and 4.

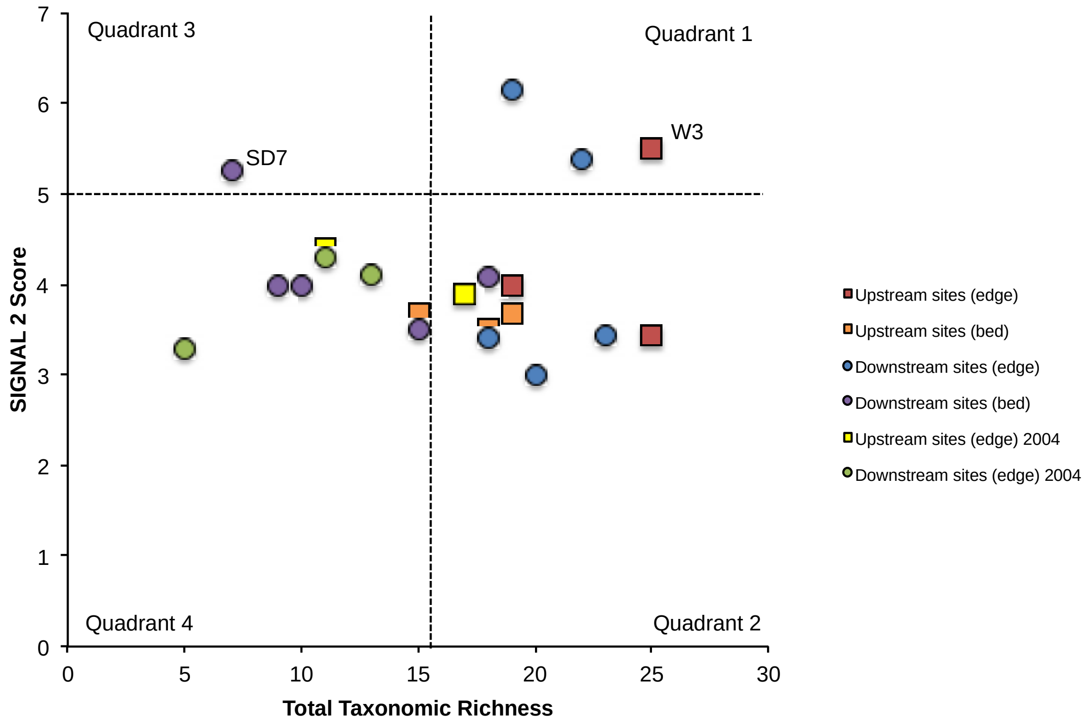

Figure 5.8 SIGNAL 2/family bi-plot for bed and edge habitat at each site and edge habitat for sites sampled by IIA in autumn 2004.

AUSRIVAS Bandings

The AUSRIVAS results indicate that sites AR and W2 on the Avon River had the lowest overall condition for macroinvertebrate communities (i.e. there were less taxa than were expected at these sites). The condition of the aquatic macroinvertebrate community at upstream Site W3 along Dog Trap Creek had improved compared to the previous year, while the condition of the community at Site W2 along the Avon River had declined. Since 2010, the condition at all other sites remained consistent.

Macrocrustaceans

Macrocrustaceans were caught at all sites with the exception of the sediment dam at Site SD7 and are described in detail in Appendix E. Three species of macrocrustaceans were caught during the survey:

- freshwater prawn (family Atyidae);
- freshwater shrimp (*Macrobrachium* sp.); and
- common yabby (*Cherax destructor*).

Freshwater prawns dominated the catch of macrocrustaceans, accounting for 80 to 100% of the catch at all sites where macrocrustaceans were found.

6 Aquatic Vertebrates

Fish communities were assessed at eight sites from 7 to 12 June 2011. The sites surveyed are detailed in Section 1.2 and in Appendix B.

6.1 Methods

6.1.1 Fish

Fish communities were surveyed using a combination of electrofishing (backpack or boat unit) and baited traps (Table 6.1). Fish surveys were undertaken at all sites except Site AC along Avondale Creek, where the water level was too low.

Table 6.1 The electrofishing and net efforts for fish surveys at each site.

Site	Method	Habitat	Date	Time In	Time Out	Settings	Effort
Upstream Sites							
AR	small bait traps (5)	run	06/06/11	0720	0900	–	6.6 hours
	backpack electrofishing			0730	0815	350 V, 30 Hz, 12 ms	552 seconds
W1	small bait traps (5)	run	12/06/11	0950	1200	–	10.8 hours
	backpack electrofishing			1130	1215	340 V, 30 Hz, 12 ms	531 seconds
W3	small bait traps (5) opera traps (2)	run/ riffle	07/06/11	0915	1100	–	12.25 hours
	backpack electrofishing			0925	1000	350 V, 30 Hz, 12 ms	515 seconds
Downstream Sites							
W2	small bait traps (5) opera traps (2)	pool/ run	06/06/11	1625	1625	–	10.0 hours
	boat electrofishing			1510	1600	500 – 1000 V, 60 DC, 80%	1000 seconds

Site	Method	Habitat	Date	Time In	Time Out	Settings	Effort
W5	backpack electrofishing	pool	07/06/11	1400	1430	350 V, 30 Hz, 12 ms	492 seconds
W8	small bait traps (4) opera traps (2)	run	08/06/11	1500	1700	–	12.0 hours
	backpack electrofishing			1615	1640	250 V, 30 Hz, 12 ms	500 seconds
S3	small bait traps (5)	pool/ run	08/06/11	1020	1350	–	17.5 hours
	backpack electrofishing			1245	1320	230 V, 30 Hz, 12 ms	497 seconds
SD7	small bait traps (5) opera traps (2)	pool	12/06/11	1245	1430	–	12.3 hours
	backpack electrofishing			1255	1335	400 V, 30 Hz, 12 ms	516 seconds

V = volts

Hz = hertz

ms = millisecond.

All available habitats (e.g. pool, riffle, run and bend) were fished at each site. Electrofishing was conducted in accordance with the *Australian Code of Electrofishing Practice 1997*, using a Smith-Root LR-24 backpack electrofisher. A Smith-Root boat 2.5 GPP electrofishing system was used in deep waters at site W2.

Fish communities were also surveyed with five small (2 millimetre [mm] mesh size) baited traps and two opera traps, which were set at each site for approximately two hours. Opera traps were not set at sites where platypus were likely to be present as these traps may be a drowning hazard to platypus.

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

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

Fish communities at each site were assessed for the:

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

Results at downstream sites were compared to data at upstream sites.

6.1.2 Other Vertebrates

At sites W2 and AR (Avon River) and SD7 (sediment dam) (where the water depth allowed), three large cathedral traps were baited and set along the bank and next to cover (e.g. vegetation and snags) for turtles and other vertebrates (Table 6.2). The design of the traps was similar to traps used by the Queensland Department of Environment and Resource Management's turtle research group. The traps had a series of collapsible chambers (approximately 3.5 m in height and 0.7 m in diameter) and two, one-way entrances in the lower baited chamber. Traps were set so that the top of the chamber allowed turtles access to the surface to breathe. Traps were closely monitored to ensure that no turtles or other air-breathing species were entangled or trapped below the surface.

Table 6.2 Trap efforts for turtle surveys at each site.

Site	Habitat	Date	Time In	Time Out	Effort
W1	run	12/06/11	0950	1200	6.5 h
W2	pool	07/06/11	0720	0900	4 h
SD7	pool	21/06/11	1245	1430	5.3 h

The sampling of turtles was conducted under Animal Research Authority Trim File No.10/2604 and NSW Scientific Licence SL100158 issued to frc environmental.

Platypuses were surveyed at sunrise, for half an hour, at sites AR and W2 (Avon River), where suitable nesting habitat was observed. At Site AR (Avon River), platypuses were surveyed from the riverbank by two observers. At Site W2 (Avon River), a boat was launched upstream of the site and platypuses were surveyed by two observers while the boat drifted downstream. The Platypus was recorded using these methods.

6.2 Results

6.2.1 Fish

Ten species of fish were caught during the survey, out of 20 known in the Manning River Catchment (Table 6.3).

Table 6.3 Fish species recorded during the current survey and previously recorded in the Manning River Catchment.

Family *Species*	**Common Name**	**Survey Area**	**Manning River Catchment**	
		Current Survey	**Howell and Creese (2010)**	**NSW Rivers Survey[1]**
Anguillidae				
Anguilla australis	Short-fin Eel	•	•	–
Anguilla reinhardtii	Marbled Eel	•	•	•
Clupeidae				
Potamalosa richmondia	Freshwater Herring	–	•	•
Cyprinidae				
Carassius auratus	Common Goldfish[2]	•	•	•
Eleotridae				
Gobiomorphus australis	Striped Gudgeon	•	•	•
Gobiomorphus coxii	Cox's Gudgeon	–	•	•
Hypseleotris compressa	Empire Gudgeon	–	•	•
Hypseleotris galii	Firetail Gudgeon	•	•	–
Philypnodon grandiceps	Flathead Gudgeon	•	•	
Philypnodon macrostomus	Dwarf Flathead Gudgeon	•	•	–
Philypnodon sp. 1	Gudgeon sp.	–	–	•
Mugilidae				
Mugil cephalus	Flathead Mullet	–	•	•
Myxus petardi	Freshwater Mullet	•	•	•

Table 6.3 Fish species recorded during the current survey and previously recorded in the Manning River Catchment (continued).

Family *Species*	Common Name	Survey Area	Manning River Catchment	
		Current Survey	Howell and Creese (2010)	NSW Rivers Survey[1]
Percichthyidae				
Macquaria novemaculeata	Australian Bass	–	•	•
Plotosidae				
Tandanus tandanus	Freshwater Catfish	–	•	•
Poecilidae				
Gambusia holbrooki	Eastern Gambusia[3]	•	–	•
Pseudomugilidae				
Pseudomugil signifer	Pacific Blue eye	–	•	•
Retropinnidae				
Retropinna semoni	Australian Smelt	•	•	•
Salmonidae				
Oncorhynchus mykiss	Rainbow Trout[2]	–	•	•
Tetrarogidae				
Notesthes robusta	Bullrout	–	•	•

• Species caught.

– species not caught.

1 NSW Fisheries and the Co-operative Research for Freshwater Ecology (1997).

2 Exotic non-indigenous species.

3 Exotic non-indigenous species, declared *noxious* under the NSW *Fisheries Regulation 2008.*

Taxonomic Richness

The most abundant and widespread species caught were the Eastern Gambusia (*Gambusia holbrooki*) and the Firetail Gudgeon (*Hypseleotris galii*). These fish were also the most widespread as the Eastern Gambusia was caught at all sites, and Firetail Gudgeons were caught at sites AR and W2 (Avon River), Site W3 (Dog Trap Creek), Site S3 (ephemeral creek) and SD7 (sediment dam) (Appendix F). The Eastern Gambusia is declared as noxious under the FM Act, and is considered a pest by DPI (Fishing and Aquaculture).

The number of fish species found in the community at each site ranged from one (Site W8 – Avondale Creek) to seven (Site W2 – Avon River). Fish species were the most diverse at sites AR and W2 along the Avon River. Two or three species of fish were caught at most other sites (Figure 6.1). The lower number of species may indicate the ephemeral nature of the waterbodies, or may be due to disturbances caused by adjacent land use (e.g. mining and mining-associated activities or agriculture).

In general, the number of species caught at downstream sites was similar to the number caught at upstream sites. Taxonomic richness was highest downstream along the Avon River, while downstream at Avondale Creek had the lowest taxonomic richness (Figure 6.1).

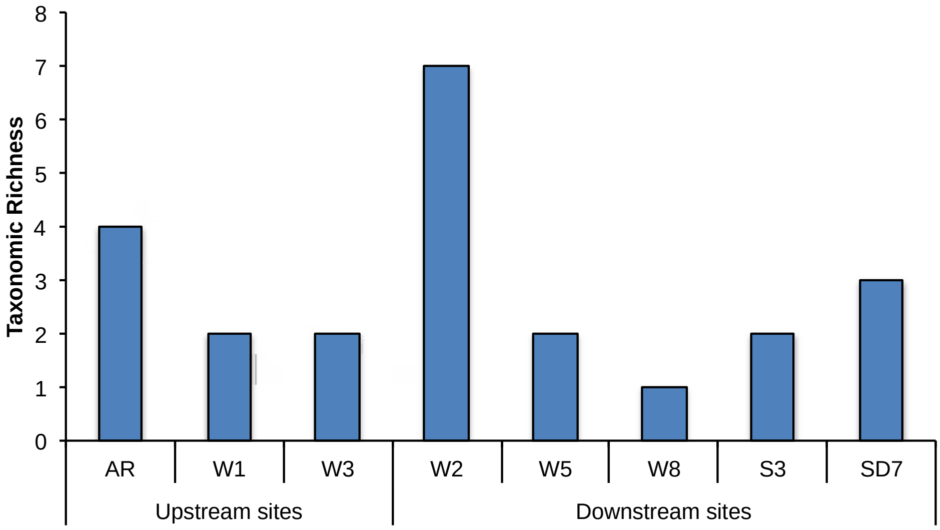

Figure 6.1 Taxonomic richness of fish caught at each site.

Abundance

The abundance of fish (total number of fish caught at a site) varied between sites from four (Site W5 – Avondale Creek) to 111 (Site S3 – ephemeral creek) (Figure 6.2). This range is typical of ephemeral waterways. A high number of fish was also caught at Site SD7 (sediment dam) (93 individuals). However, exotic Eastern Gambusia was the predominant catch at these sites:

- Site S3 (ephemeral creek) – 53%; and
- Site SD7 (sediment dam) – 87%.

The abundance of each fish species recorded at each site during the current survey is described in detail in Appendix F.

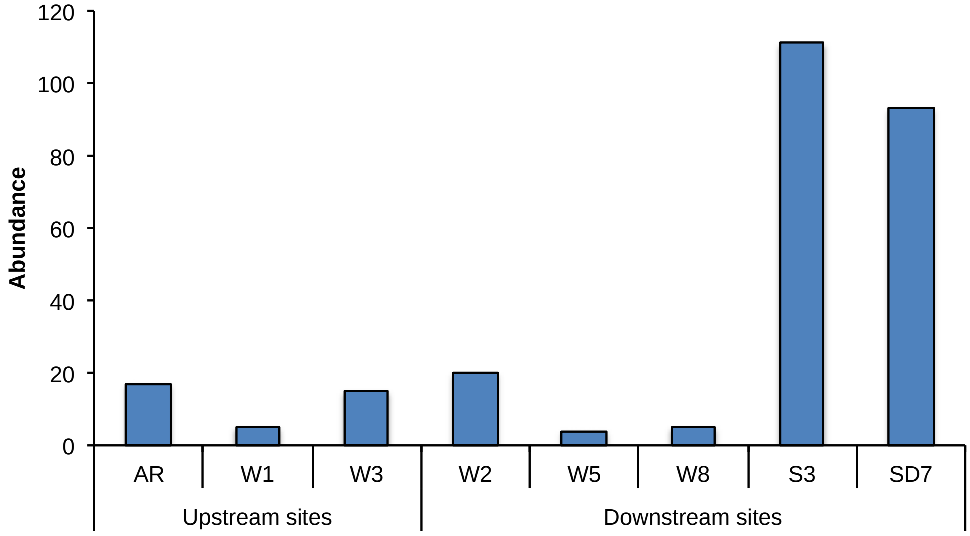

Figure 6.2 Abundance of fish at each site.

6.2.2 Exotic Species

Exotic Eastern Gambusia (*Gambusia holbrooki*) was caught at all sites. Eastern Gambusia is declared as noxious under the *Fisheries Management Act 1994*, and is considered a pest by the DPI.

Eastern Gambusia accounted for 100% of the catch at Site W8 (Avondale Creek), and 76 to 93% of the catch at sites AR and W1 (Avon River), Site W3 (Dog Trap Creek), Site W5 (Avondale Creek) and SD7 (sediment dam) (Appendix F).

6.2.3 Threatened Species

No threatened species were caught during the current survey.

6.2.4 Other Vertebrates

No live turtles were caught or sighted during the survey. However, a turtle carapace was found on the bank of the sediment dam at Site SD7 (Plate 1.10 Appendix F). Based on the morphology of the carapace, it was most likely that of an Eastern Snake-necked Turtle (*Chelodina longicollis*), or a hybrid of the species.

Two species of turtles (which are not listed threatened species but are protected under the *National Parks and Wildlife Act 1974*) have been recorded in the Manning River Catchment:

- Manning River Snapping Turtle (*Myuchelys purvisi*, previously *Wollumbinia purvisi/Elseya purvisi*); and
- Eastern Snake-necked Turtle (*Chelodina longicollis*).

The Eastern Snake-necked Turtle is common in most of NSW where it inhabits freshwater ponds, lakes and streams. The Manning River Snapping Turtle is found only in the Manning River Catchment. There is insufficient information available regarding this species to determine whether it is likely to occur in the survey area or not.

One platypus was sighted along the Avon River at Site W2. Site W2 provided highly suitable habitat for platypus; earthy riverbanks, consolidated by the roots of native vegetation, provided overhanging shady vegetation. The substrate comprised cobble and gravel stones. Although suitable riverbank habitat was available, no platypuses were observed at Site AR along Avon River. This may be due to the lack of suitable substrate (e.g. gravel and cobbles) at this site.

Platypuses are found throughout the freshwater reaches of the Manning River and are common in the local area. The platypus is not listed under the TSC Act or EPBC Act. However, they are protected under the NSW *National Parks and Wildlife Act 1974* (as is the case with all native species).

7 Assessment of Potential Impacts

Some marginal aquatic habitat (represented by ephemeral creek lines) occurs within the Project area and would be removed as a result of the Project (Figure 1.3). These creek lines are ephemeral streams that flow (when there is sufficient rainfall) from the hills to the east of the Project area. The surface water then drains to Avondale Creek and Dog Trap Creek.

This report includes an assessment of the potential aquatic ecology impacts on, not only these ephemeral creek lines that would be directly impacted, but also the downstream watercourses, namely Avondale Creek, Dog Trap Creek and the Avon River.

The impacts on aquatic ecology are evaluated below under the following headings:

- Vegetation Clearing and Earthworks
  - Increased Turbidity
  - Input of Nutrients or Other Contaminants
  - Decreased Habitat for Aquatic Fauna
- Loss of Catchment Area and Changes to Flow Regimes
- Creek Crossings
  - Construction of Creek Crossings
  - Obstruction of Fish Passage
- Groundwater
- Irrigation
- Operation and Maintenance of Vehicles and Other Equipment
  - Fuel Spills
  - Litter and Waste

7.1 Vegetation Clearing and Earthworks

Following vegetation clearing and earthworks, there is a potential for soil erosion and sedimentation during rainfall. This could lead to impacts on aquatic ecology (i.e. increased turbidity and nutrients) in downstream waterways, as well as alteration of aquatic habitats. Degradation of riparian vegetation is listed as a key threatening process under the FM Act, clearing of native vegetation is listed as a key threatening process under the TSC Act and land clearance is listed as a key threatening process under the EPBC Act.

The following subsections evaluate the effect of vegetation clearing and earthworks on increased turbidity, input of nutrients or other contaminants, and decreased habitat for aquatic fauna.

7.1.1 Increased Turbidity

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

Turbidity in the Project area is variable but was generally high in the Avon River, Avondale Creek and Dog Trap Creek, with the exception of Avondale Creek within the current mining lease (Section 3.2.3). Based on the published tolerances of the caught macroinvertebrate and fish species, most of the faunal communities of the survey area are capable of living in turbid waters. No submerged macrophytes were found in the Project area, though one species was found in the Avon River downstream of the Project area and submerged species are known in larger waterways downstream.

Given these background conditions, small increases in turbidity as a result of the Project would unlikely have a significant impact on aquatic ecology. However, significant increases in turbidity could adversely impact the health, feeding and breeding ecology of some species of both macroinvertebrates and fishes, and submerged macrophyte growth downstream of the Project area. The turbid runoff to creeks would be minimised via the use of sediment dams and upstream diversions (as planned), so the impact to aquatic ecology of the Avon River, Avondale Creek and Dog Trap Creek would be expected to be very low.

7.1.2 Input of Nutrients or Other Contaminants

Aquatic biota could also be impacted by nutrients or other contaminants washed into waterways with the sediment (e.g. if excessive nutrients/fertilisers are used on agricultural land during rehabilitation). Nutrient inputs can lead to algal or macrophyte blooms. During the day, as the algae photosynthesise blooms can produce high levels of dissolved oxygen. However, at night, there is a net consumption of oxygen as the algae continue to respire. This can cause dissolved oxygen to be reduced to very low levels during the night and early morning, and this is harmful to fish and biota.

Input of nutrients or other contaminants into the waterways greater than threshold levels would likely impact on aquatic flora and fauna. Where the spill is a one-off occurrence, communities may be impacted but would be expected to recover over time. Communities would be likely to fully recover by the next wet season. Chronic inputs of nutrients or contaminants to the waterways would be expected to have longer-term impacts on floral and faunal communities. Impacts would be expected to be highest near the source of the spill (i.e. in waterways close to the Project area such as Avondale Creek and Dog Trap Creek. In particular, turbidity was lower in Avondale Creek immediately downstream of the current mining activities; as such this creek may be more susceptible to algae or macrophyte growth as a result of nutrient inputs. Due to dilution and dispersion and the effects of surrounding land uses, the impacts of nutrients and contaminants as a result of runoff from the Project area would likely be negligible. However, given the site would operate to achieve ‘zero discharge’ of mine water, the risk of chronic or lesser inputs to the waterways is likely to be very low to non-existent.

7.1.3 Decreased Habitat for Aquatic Fauna

Vegetation clearing and earthworks near and within the waterways of the Project area (e.g. clearance associated with the construction of creek crossings described in Section 7.3 and shown on Figure 1.3) may decrease the amount of in-stream habitat for aquatic fauna via the deposition of sediment-laden runoff from cleared areas.

Aquatic fauna use a variety of in-stream and off-stream structures for habitat including large and small woody debris, bed and banks, detritus, tree roots, boulders, undercut banks, and in-stream, overhanging and trailing bank vegetation, which were all found in the survey area. In-stream habitat is an important habitat component and territory marker for many fish and macroinvertebrates. Many species live on or around in-stream habitat as it provides shelter from direct sunlight, higher temperatures, current and predators, contributes organic matter to the system and is important for successful reproduction. Australian fish species typically spawn either on in-stream vegetation or on hard surfaces like cobbles, boulders, and woody debris.

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

A decrease in available habitat for aquatic fauna would lead to a decline in the abundance and diversity of both macroinvertebrate and fish communities in the creeks.

Where the mine achieves zero discharge of mine water (as planned), the risk of impacts to aquatic faunal habitat in the Avon River, Avondale Creek and Dog Trap Creek is considered likely to be very low to non-existent.

7.2 Loss of Catchment Area and Changes to Flow Regimes

The total catchment area excised by the existing/approved Stratford Mining Complex and the Project is shown in Table 7.1 (Gilbert & Associates, 2012). The total catchment excision for Avondale Creek, Dog Trap Creek and the Avon River is expected to increase marginally; compared to the existing/approved maximum catchment excised by the Stratford Mining Complex.

Changes to the flood regime and the timing and magnitude of flows in watercourses have the potential to impact on aquatic ecology. Mechanisms that alter the natural flow regimes of rivers and streams is listed as a key threatening process under the FM Act, and alteration to the natural flow regimes of river, streams, floodplains and wetlands is a key threatening process under the TSC Act.

Upslope diversions are proposed for the Project and would intercept and divert upslope runoff water away from the open pits and include:

- A diversion to run parallel and to the east of the Stratford East Open Cut which would divert upslope water to Avondale Creek.
- A proposed diversion east of the Avon North Open Cut (ANOC) which would divert upslope water to Avondale and Dog Trap Creeks.
- A proposed diversion west of the Roseville West Pit Extension which would divert upslope water to Avondale Creek.

Gilbert & Associates (2012) advise that:

- Sreamflow in the Avon River is characterised by strong flow persistence, and no measurable changes in flows in the Avon River are expected as a result of the Project.

- Avondale Creek and Dog Trap Creek are ephemeral and experiences no to negligible flow during dry periods. A negligible reduction in flows will occur in Avondale Creek (particularly upstream of the ephemeral tributary) and in Dog Trap Creek as a result of onsite usage or capture to prevent contaminated water entering the creek and small impacts to groundwater (Section 7.4).

As such, no impacts to the aquatic ecology of the Avon River are expected as a result of changes to flow. The negligible changes to flow in Avondale Creek and Dog Trap Creek are unlikely to result in ecologically significant impacts, as the flow regime will still include periods of high flow during and immediately following rainfall (which is an important migratory and breeding cue for aquatic species), and periods of no to negligible flow during dry periods.

Table 7.1 Total catchment area excised by the existing/approved Stratford Mining Complex and the Project.

		Area Captured in Water Management System				
		Existing (approved Stratford Mining Complex)	Proposed Project		Proposed Project with Concurrent GRL Maximum	
Catchment	**Total Pre-Mining Catchment Area (km^2)**	**– km^2 (%)**	**Project Maximum – km^2 (%)**	**Project Maximum Change (%)**	**Cumulative Maximum – km^2 (%)**	**Cumulative Maximum Change (%)**
Avondale Creek	23	6.2 (27%)	7.1 (31%)	3. 7%	7.1 (31%)	3.7%
Dog Trap Creek	17*	0.2 (0.9%)	0.7 (4.4%)	3.5%	0.7 (4.4%)	3.5%
Avon River at confluence with Oaky Creek**	242	6.4 (2.6%)	7.8 (3.2%)	0.6%	13 (5.3%)	2.6%
Avon River at confluence with Gloucester River	292	6.4 (2.2%)	7.8 (2.7%)	0.5%	13 (4.4%)	2.2%

Source: After Gilbert & Associates (2012).
km^2 = square kilometres.
* To confluence with Avondale Creek.
** Adjacent to GRL's Rocky Hill Project.

7.3 Creek Crossings

Currently, most creek crossings in the Project area are dirt/gravel fords or culverts that have been built for mine road crossings, public road crossings or private tracks on agricultural properties. Two crossings currently exist on Avondale Creek, and these are acting to retain water within the artificial wetland between the Stratford Main Pit and Return Water Dam. The existing crossings have the potential for erosion, which can increase sediment runoff into creeks and increase turbidity (the impacts of which have been discussed in Section 7.1). These existing crossings are also likely to restrict fish passage in low to moderate flow regimes, although this is unlikely to significantly impact fish communities in the catchment, as the crossings are located near the upstream extent of Avondale Creek.

Installation and operation of in-stream structures and other mechanisms that alter the natural flow regimes of rivers and streams is listed as a key threatening process under the FM Act, and alteration to the natural flow regimes of rivers, streams, floodplains and wetlands is a key threatening process under the TSC Act. In-stream structures that can alter natural flow regimes can include culverts and causeways if they are poorly designed (but not bridges, which are unlikely to significantly impact on flows).

Two additional creek crossings are proposed as part of the Project:

- one culvert on a tributary to Avondale Creek, under the haul road to the Avon North Open Cut; and
- one culvert on Avondale Creek under the haul road between the BRNOC and Roseville West Pit Extension.

7.3.1 Construction of Creek Crossings

Construction of the two new permanent crossings on a tributary to Avondale Creek and on Avondale Creek may disturb sediment, leading to increases in localised turbidity and sediment deposition (Figure 1.3). The culverts would be designed so that the length of the crossing (across the stream channel) and width of the crossing (along the length of the stream) are as short as possible to facilitate fish movements.

When construction is carried out during the dry season, impacts will be minimal or absent, although a highly localised loss of macrophytes and riparian vegetation may be expected within the construction footprint. The impacts of disturbance to aquatic habitat will be highly localised and are considered acceptable in both a local and regional context, given the existing disturbed nature of creek crossing locations. However, if appropriate mitigation measures are not put in place after the installation of crossings (refer to Section 8.5), the newly formed bed and banks may continually erode, resulting in an increase in channel width and a loss in channel definition, which could in turn lead to a decrease in downstream flow.

If construction of creek crossings is carried out in the wet season, there will be an temporary impact to passage to fish that may be present, and potentially also to water quality. If the waterway holds water, isolation of the work area may leave fish stranded in the short-term. In order to minimise potential impacts, installation of creek crossing should be undertaken wherever practicable in the dry season.

7.3.2 Obstruction of Fish Passage

Stream crossings can create waterway barriers that prevent or impede movements of aquatic fauna (e.g. fish). Many of the fish native to ephemeral and intermittent systems in Australia migrate up and downstream and between different habitats at particular stages of their life cycle. Poorly designed crossings have the potential to impact on fish movement within the Project area. Where the new crossings follow the *NSW Policy and Guidelines for Fish Friendly Waterway Crossings* (DPI 2004) and *Policy and Guidelines for Aquatic Management and Fish Conservation* (DPI 1999), and the crossings are regularly maintained, the impact to fish passage will be low, particularly because the Project area is located in the upper catchment, and as there will be no new crossings on Dog Trap Creek or Avon River. The risk of impacts due to the construction of creek crossings is likely to be low in the short-term and very low in the long-term term.

7.4 Groundwater

There are no aquatic ecosystems (creeks or wetlands) in the Project area or surrounds that are dependant on groundwater. Some saline groundwater inflow may occur in Dog Trap Creek and Avondale Creek, which may potentially influence the composition of fish and invertebrate communities due to a decline in species that are less tolerant to elevated salinity.

Impacts to stream flows from groundwater drawdown within Avondale Creek and downstream of the Avondale Creek confluence along Dog Trap Creek are anticipated to be negligible (Heritage Computing, 2012). Despite the potential for leakage from Avondale Creek and Dog Trap Creek, the impact on the aquatic ecology is considered to be very minor as the creeks are naturally ephemeral.

Project mining is too far away from Avon River for any discernible effect on that stream (Heritage Computing, 2012).

7.5 Irrigation

Irrigation on rehabilitation areas within a contained catchment is approved for the existing Stratford Mining Complex and would continue for the Project with the proposed irrigation areas draining directly to mine water storages. No impacts on existing aquatic vegetation are likely to occur.

7.6 Operation and Maintenance of Vehicles and Other Equipment

7.6.1 Fuel Spills

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

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

Where the recommended mitigation measures are adopted (Section 8.6), the risk to aquatic ecosystems from a fuel spill, within the maintenance workshop and fuel and oil storage facilities, is likely to be very low, due to the high level of control demanded by Australian Standard 1940:2004 - *The storage and handling of flammable and combustible liquids*.

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

Implementation of best practice fuel management will effectively address this risk (Section 8.6). Additionally, the risk to aquatic flora and fauna within the Project area and downstream waters is reduced as the creeks are dry or are isolated pools for much of the year. Therefore, many spills could be effectively cleaned up before they can disperse downstream.

7.6.2 Litter and Waste

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

7.7 Cumulative Impacts

Cumulative impacts of the Project on aquatic ecosystems were considered in relation to the surrounding land uses and other major projects underway or planned in the local area.

The lands surrounding the Project are predominately utilised for agricultural activities and, in particular, grazing (DECCW 2010). The Project area and its surrounds have been considerably modified as part of past land use practices and logging use over a period of more than 100 years. Historically, the riparian vegetation of the Avon River downstream of Stratford has been heavily degraded (Hose and Turak 2004). Clearing of vegetation has led to bank erosion and invasion of exotic plant species, including willow trees (Raine and Gardiner 1995; Hose and Turak 2004).

The Gloucester Gas Project, the Duralie Extension Project and the Rocky Hill Coal Project are the other three main developments in the area.

The Duralie Coal Mine is located approximately 20 km south of the SMC, within a separate catchment (primarily the Mammy Johnsons River catchment). Aquatic monitoring undertaken at the Duralie Coal Mine has concluded that the current operations are having '*no apparent adverse effects on the aquatic macroinvertebrate fauna in the Mammy Johnson River'* and that the potential impacts of the Duralie Extension Project on aquatic ecology are considered likely to be minimal (Resource Strategies 2009). Thus it is considered unlikely that the Duralie Coal Mine will contribute to cumulative impacts to aquatic ecosystems within and downstream of the Project area.

The Gloucester Gas Project involves the construction and operation of a coal seam gas extraction, processing and transportation system. The Gloucester Gas Project involves the construction and operation of 60 to 90 gas wells and gathering lines to be located throughout the Project area and in lands immediately to the north, south and west of the Project area. A 100 m wide high-pressure pipeline corridor will be located immediately to the south-west of the Project area, between Stratford and Hexham.

Activities related to the construction of the Gloucester Gas Project have the potential to impact water quality and aquatic habitats from earthworks (grading, trenching and excavating), stockpiling of materials, drilling and fracture stimulation. The pipelines will cross Dog Trap Creek six times and Avondale Creek five times using open trenches with flow diversions if required. The Avon River will be crossed three times using a thrust bore or horizontal directional drilling. Gas wells would be located at least 40 m from major watercourses and at least 20 m from minor watercourses. Upon implementation of mitigation measures, residual impacts to watercourses '*would be mainly limited to the construction phase of development and are not expected to be significant'* (AECOM 2009).

It is considered unlikely that the Project would result in a significant increase in cumulative adverse impacts on aquatic ecosystems when compared to the impacts expected from the Gloucester Gas Project and from ongoing regional agricultural activities on aquatic ecosystems.

The Rocky Hill Coal Project is located to the north of the SMC in a different sub-catchment to the Avon River. Regular monitoring has shown that water quality of the waterways within and downstream of the Rocky Hill Project area is similar to the current Project area, and is characterised by high turbidity during flows and sometimes high electrical conductivity (RW Corkery & Co. Pty. Ltd. 2011). It is expected that implementation of appropriate water management and sediment and erosion controls will reduce impacts of the Project on the aquatic environment to acceptable levels. This will be considered further in the Environmental Impact Statement for the proposed project.

It is considered unlikely that the Project would result in a significant increase in cumulative adverse impacts on aquatic ecosystems when compared to the impacts expected from the Rocky Hill Coal Project and from ongoing regional agricultural activities on aquatic ecosystems.

8 Measures to Avoid, Minimise and Mitigate Impacts

A number of impact avoidance and mitigation measures applicable to the aquatic ecology of the Project area have been developed for the Project as listed below and described in Sections 8.1 to 8.6:

- mine design refinements;
- site water management measures;
- weed control and prevention;
- erosion and sediment control measures, including rehabilitation and revegetation of post-mine landforms;
- construction and design of culverts; and
- operation and maintenance of vehicles and equipment.

Long-term remediation, rehabilitation and monitoring requirements are described in Sections 8.7 and 8.8, respectively. The offset proposal is described in Section 8.9.

8.1 Mine Design Refinements

The following refinements to the mine design have resulted in avoiding additional impacts on aquatic flora and fauna and their habitats:

- Optimising the area of the open cut pit that is backfilled to minimise the overall mine footprint, including complete backfilling of the Stratford Main Pit and BRNOC as well as partial backfilling of the Roseville West Pit Extension and Stratford East Open Cut.
- Continued use of several existing features at the Stratford Mining Complex, including:
  - open cut voids for water and rejects storage;
  - Stratford East Dam for water management;
  - CHPP; and
  - rail facilities.

- Avoiding clearance of large areas of surrounding bushland:
  - between the Stratford Main Pit, the Stratford Waste Emplacement, the proposed Avon North Open Cut and the proposed Northern Waste Emplacement Extension;
  - west of the BRNOC; and
  - south of the Stratford Waste Emplacement and west of the proposed Stratford East Open Cut.
- Avoiding disturbance to Avondale Creek, such as diversions.
- Increasing the maximum height of the existing waste emplacements to be comparable to surrounding landform heights and less than the maximum height of ridge line to the east of the Development Application area (470 m Australian Height Datum) to minimise the overall mine footprint.

8.2 Site Water Management Measures

The water storage capacity of the Stratford Main Pit would gradually reduce over time and to compensate for this, water would be pumped temporarily to the BRNOC open pit before being transferred to the Avon North Open Cut.

As part of the Environmental Impact Statement, the existing site water balance model for the Stratford Mining Complex will be updated to incorporate the Project.

In addition, the Stratford Mining Complex has an integrated water management strategy, which includes the following key components:

- separation of undisturbed area runoff from disturbed area runoff;
- collection and re-use of surface runoff from disturbed areas (including mining pre-strip areas, waste emplacements and haul roads);
- design of sediment dams to contain runoff generated from the 1 in 20 year, 1 hour rainfall event;
- capture and on-site containment of mine water, consisting of any groundwater inflows and/or surface water collection in the open pits;
- re-use of captured and contained mine water for dust suppression and CHPP supply; and
- irrigation on rehabilitated areas which drain directly to mine water storages.

It is expected that this strategy would remain generally unchanged for the Project.

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

- Erosion control (e.g. jute matting, rock mulching or similar) placed in ditches and drainage lines running from all cleared areas, especially on slopes and levee banks.
- Contour banks, ditches or similar formed across cleared slopes to direct runoff towards surrounding vegetation and away from creeks.
- Sediment dams and levee banks, constructed during each stage of construction, to protect natural waterways from sediment-laden runoff.
- Monitoring water quality of creeks downstream of clearing/exposed soil during periods of rainfall.

8.3 Weed Control and Prevention

A Biodiversity Management Plan will be prepared for the Project that includes measures to control weeds. Measures include identification of weeds via regular site inspections, mechanical removal of identified weeds and/or the application of approved herbicides in authorised areas, follow-up site inspections to determine the effectiveness of eradication programs and minimisation of seed transport from the site through the use of the site's vehicle wash bay.

8.4 Erosion and Sediment Control Measures

Controls to manage the potential impacts caused by erosion and sediments for works undertaken throughout the life of the Project will be provided. In addition, the risk of sediment-laden runoff to nearby waterways would be reduced where:

- Vegetation clearing and earthworks are done in stages over the life of the mine, with post-mine landforms being progressively rehabilitated and revegetated.
- Timing of clearing and earthworks for the construction of creek crossings is in the dry season, wherever practicable.

8.5 Construction and Design of Culverts

The design and installation of the two culverts (see Section 7.3) can significantly influence fish passage. The culverts would be designed so that they are:

- Located at least 100 m from any other waterway barrier on the creek (e.g. road crossing or dam) in order to minimise the cumulative effects of fish barriers.
- As short (i.e. along the length of the stream) and as narrow (i.e. across the stream channel) as possible, to allow the passage of anticipated flood volumes and associated debris, and to allow enough water depth within the culvert to facilitate fish movement.
- Open-bottomed, if possible, to retain the natural morphological features of the stream. If this is not possible and if practicable, culverts should be countersunk below the stream bed and natural materials such as rocks secured to the base of the culvert to increase roughness and reduce water velocity.
- Constructed without a drop-off at the culvert outlet, as this impedes fish migration upstream.
- Constructed with minimum disturbance to the outer banks on stream bends, as these are usually the most unstable and are prone to erosion.
- Surrounded by riparian vegetation (planted after construction, if necessary) to stabilise banks, provide food and habitat for fauna and prevent predation of aquatic fauna by birds (DPI 1999).

The risk of impacts to in-stream habitat and aquatic fauna and flora would be minimised where culverts are:

- Installed at the driest time of year (preferably in the dry creek bed, avoiding pools).
- Installed using methods to isolate aquatic fauna from impacts during construction (during the wet season).
- Maintained, and there is regular removal of debris or plant growth that would impede fish passage (Cotterell 1998).

8.6 Operation and Maintenance of Vehicles and Equipment

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

- Vehicle maintenance areas, portable refuelling stations and storage of fuels, oils and batteries is undertaken within bunded areas, designed and constructed in accordance with AS 1940:2004 – *The storage and handling of flammable and combustible liquids* and are located above the 100 ARI flood level.
- All spills of contaminants are reported in accordance with mines spill incident procedures.
- Appropriate spill containment kits are available, and used for the clean-up of spills in the field. The kits would contain equipment for clean up of both spill on land or in dry creek beds, and spills to water (e.g. floating booms).

8.7 Long-term Remediation and Rehabilitation

At the completion of mining, permanent and semi-permanent aquatic habitat would be re-instated within the Project area. Adequate permanent and semi-permanent aquatic habitat would be provided in the Stratford East Dam and within the artificial wetland:

- Water and sediment quality in the Stratford East Dam would be used as stock watering dams and would be suitable for colonisation by aquatic flora and fauna.
- Cattle access would be restricted from the artificial wetland area along Avondale Creek (within the Biodiversity Enhancement Area).

Rehabilitation measures specific to aquatic ecology would focus on:

- Salvaging clumps of native grass, shrubs and trees before clearing.
- Replanting along the margins of creeks after the construction of the creek crossings. The width of the replanted riparian vegetation would be equal or greater than the width of existing riparian vegetation at the crossing. Planted trees in the riparian zone would provide canopy cover and have root systems that can stabilise the banks and the disturbed area.

8.8 Monitoring

Where the Project achieves the objective of zero discharge of mine water, the risk of impacts to aquatic ecosystems as a result of the Project is considered low. No measureable changes in flows in the Avon River, Avondale Creek and Dog Trap Creek are expected to result from loss of catchment area or changes to groundwater as a result of the Project.

Survey results show that the ecological condition of the Avon River and its tributaries has improved over the last three years and that the Stratford Mining Complex has had no adverse impacts on the Avon River and Avondale Creek (IIA, 2011).

SCPL would continue to monitor aquatic ecosystems around the mine. If any unpredicted impacts are detected, SCPL would undertake an investigation into the source of the impact and potential remediation.

Water quality and aquatic habitat would be assessed in accordance with AUSRIVAS protocols. The percent cover of each macrophyte species present would also be assessed at each site. This information may also be used in multivariate analyses of macroinvertebrate communities.

Macroinvertebrate samples would be collected from each habitat present at each site. Samples would be sorted, and macroinvertebrates counted and identified to the lowest practical taxonomic level (in most instances family) to comply with methods described by Chessman (2003).

Taxonomic richness, PET richness, SIGNAL 2 scores and abundance would be calculated for each sample collected. Differences in each of the macroinvertebrate indices would be analysed between sites and each area over time, using a two-way nested ANOVA. To determine differences among macroinvertebrate assemblages at different sites, community data would also be analysed for each habitat type sampled, using multivariate techniques.

8.9 Offset areas

The Director-General's Requirements (DGRs) for the Project state that the EIS must include a description of the measures that would be implemented to maintain or improve the aquatic biodiversity values of the surrounding region in the medium to long-term.

The proposed offset areas are located in the local area near the Project area (Figure 8.1). The offset areas also contain a number of drainage lines that would be subject to conservation and enhancement:

- two reaches of the Wards River occur in the proposed Offset Area 3 (approximately 0.5 km and 0.65 km);
- upper reach of the Avondale Creek in the proposed Offset Area 3 (approximately 4.4 km); and
- other drainage lines.

An arrangement would be made to ensure long-term protection and management of the offset areas within 12 months of Project approval. The proposed offset areas provides for a combination of protection and enhancement of existing riparian vegetation as well as active revegetation in the catchment by restoring the internal connectivity of woodland/forest habitats within the proposed offset area (Figure 8.1).

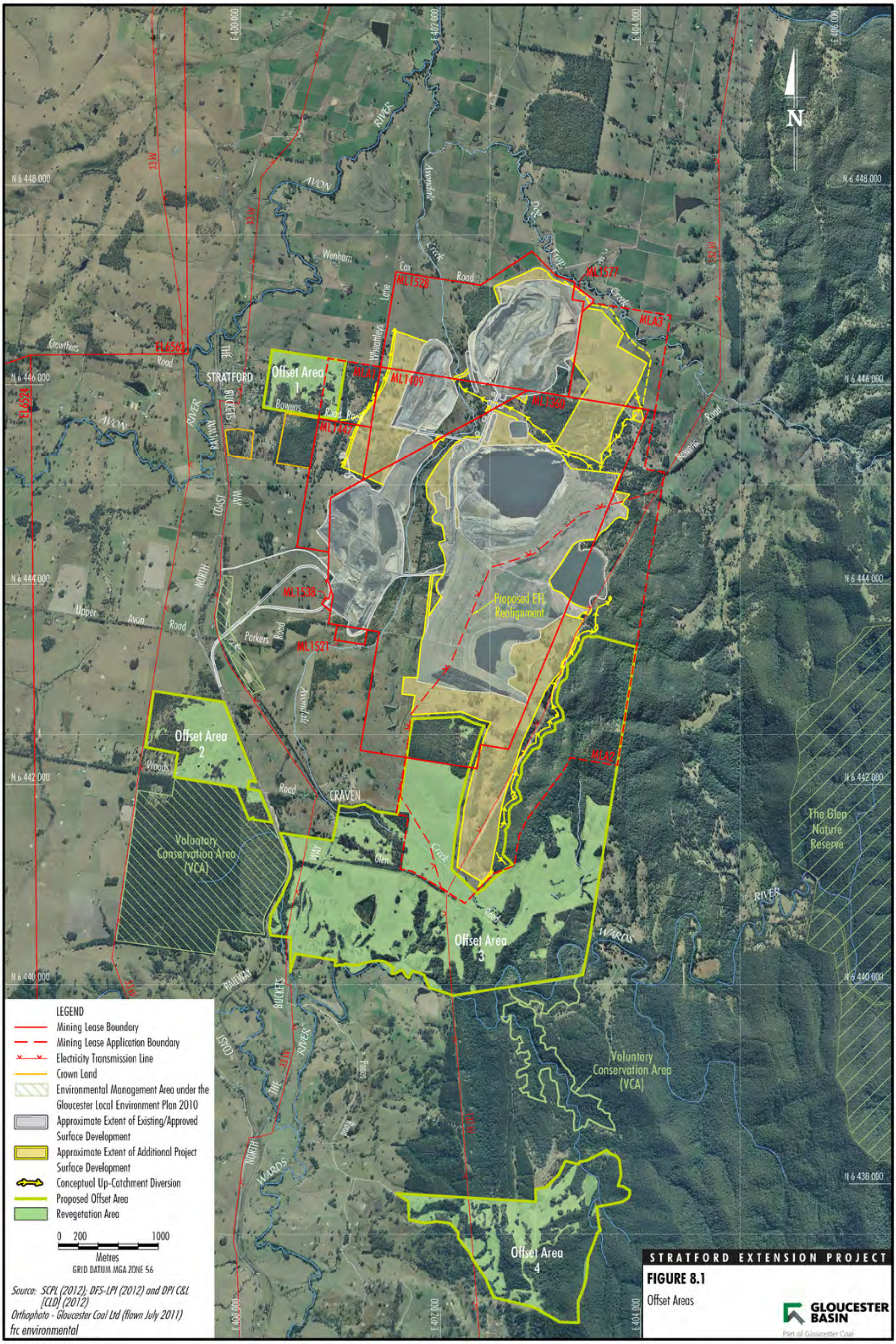

FIGURE 8.1
Offset Areas

GCL-10-12 EIS App Aqu_104I

9 Conclusion

The biological values of aquatic ecosystems within the survey area were moderate to good and consistent with those of the wider catchment. The aquatic ecosystems of Dog Trap Creek and Avondale Creek were of moderate value to aquatic flora and fauna, primarily due to the ephemeral and intermittent nature of the waterways, poor streamside cover, limited depth and some bank erosion. The Avon River provided greater ecological value to aquatic flora and fauna due to its perennial nature and consistent flow. Rivers and creeks in the catchment are generally in moderate condition and are characterised by:

- moderate to high habitat diversity;
- good hydrological condition;
- poor to good water quality;
- a prevalence of exotic weeds;
- degraded riparian vegetation; and
- cattle access to creeks (Thomson et al. 2004, NSW Government 2009).

Physical water quality in the study area was moderate during the survey and was characterised by low dissolved oxygen levels, high turbidity at several sites and low pH at several sites. Aquatic biodiversity was relatively high, with ten species of fish (including two exotic species, one of which was prevalent), three species of macrocrustacean and 31 species of macrophytes (including three exotic species) recorded in the survey area. Platypus and Eastern Snake-necked Turtles (or a hybrid of the species) also inhabit the survey area.

No endangered, vulnerable or near threatened species of aquatic flora or fauna have been recorded from, or are likely to occur in, the waterways of the Project area. There were no wetlands of regional, State or national significance in the Project area.

Potential impacts to aquatic ecology as a result of the Project were assessed including:

- increased turbidity, input of nutrients or contaminants and loss of habitat for aquatic fauna as a result of vegetation clearing and earthworks;
- loss of catchment area and changes to flow regimes;
- obstruction of fish passage due to construction of creek crossings;

- changes to groundwater;
- irrigation runoff;
- fuel spills and litter/waste entering aquatic habitats as a result of operation and maintenance of vehicles and other equipment; and
- cumulative impacts.

Turbidity in the Project area is variable; as such, small increases in turbidity as a result of the Project would unlikely have a significant impact on aquatic ecology. Where turbid runoff to creeks is minimised via the use of sediment dams and upstream diversions (as planned), the impact to aquatic ecology would be low. Furthermore, where the mine achieves zero discharge of mine water (as planned), the risk of impacts to aquatic habitat due to input of nutrients or other contaminants is would also be low.

No measureable changes in flows in the Avon River, Avondale Creek and Dog Trap Creek are expected to result from loss of catchment area or changes to groundwater as a result of the Project. Irrigated water will be drained directly to the mine water storages and no impacts on existing native vegetation are likely to occur.

Construction of the two new permanent crossings on an ephemeral tributary to Avondale Creek and on Avondale Creek may disturb sediment, leading to increases in localised turbidity and sediment deposition. Where construction is carried out in the dry season, the impacts of disturbance to aquatic habitat will be highly localised and are considered acceptable in both a local and regional context, given the existing disturbed nature of creek crossing locations. The impact to fish passage following the installation of the crossings will be moderate to low where crossings are designed and installed following the NSW Policy and Guidelines for Fish Friendly Waterway Crossings (DPI 2004), and the crossings are regularly maintained.

Implementation of best practice fuel and waste management systems will effectively address the risk to aquatic ecology from litter and spills.

It is considered unlikely that the Project would result in a significant increase in cumulative adverse impacts on aquatic ecosystems.

A number of impact avoidance, mitigation and offset measures applicable to the aquatic ecology of the Project area have been developed for the Project, including:

- mine design refinements;
- site water management measures;

- weed control and prevention;
- erosion and sediment control measures;
- rehabilitation and revegetation of post-mine landforms;
- construction and design of culverts;
- operation and maintenance of vehicles and equipment; and
- offset areas.

Where the Project achieves the objective of zero discharge of mine water, the risk of impacts to aquatic ecosystems as a result of the Project is considered low. The offset strategy for the Project would provide for the conservation and enhancement of a number of watercourses (Avondale Creek, Wards River and drainage lines) and their catchments. The Project would maintain and improve aquatic biodiversity values of the region in the medium to long-term, and continued monitoring of aquatic ecosystems is planned.

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Appendix A
Previous Survey Results Recorded by Invertebrate Identification Australasia

Consolidated Recorded Macroinvertebrates

Order	Family	Species	Site										
			S1	S2	S3	W1	W2	W3	W5	W8	CG	DV	EEG1
Acariformes	Eylaidae	*Eylais*		*	*	*	*	*		*	*		
Acariformes	Hygrobatidae	*Undetermined*			*	*	*		*				
Acariformes	Ixodidae	*Ixodes*					*						
Acarina	Pionidae	*Undetermined*				*							
Amphipoda	Talitridae	*Undetermined*				*							
Arachnida	Araneae	*Undetermined*		*							*		
Bivalvia	Hyriidae	*Hyridella*				*	*						*
Bivalvia	Sphaeridae	*Pisidium*			*	*	*	*	*	*	*		
Bivalvia	Corbiculidae	*Corbicula*				*							
Coleoptera	Dytiscidae	*Antiporus*			*	*	*	*					
Coleoptera	Dytiscidae	*Australphilus*					*	*					
Coleoptera	Dytiscidae	*Batrachomatus*	*		*	*	*	*	*	*	*		*
Coleoptera	Dytiscidae	*Bidessodes*	*		*	*	*	*	*	*	*		
Coleoptera	Dytiscidae	*Bidessus*			*	*	*	*	*	*			
Coleoptera	Dytiscidae	*Chostonectes*	*		*	*	*	*	*	*			
Coleoptera	Dytiscidae	*Eretes*								*			
Coleoptera	Dytiscidae	*Gibbidessus*					*			*			
Coleoptera	Dytiscidae	*Hydrovatus*			*	*	*	*		*			
Coleoptera	Dytiscidae	*Hyphydrus*				*	*						
Coleoptera	Dytiscidae	*Lancetes*				*		*					
Coleoptera	Dytiscidae	*Necterosoma*	*	*	*	*	*	*	*	*	*		
Coleoptera	Dytiscidae	*Paroster*				*	*	*	*	*			
Coleoptera	Dytiscidae	*Rhantus*				*	*			*			
Coleoptera	Dytiscidae	*Sternopriscus*		*	*	*	*	*	*				
Coleoptera	Elmidae	*Austrolimnius*			*	*	*	*		*	*		
Coleoptera	Elmidae	*Kingolus*	*			*	*						
Coleoptera	Elmidae	*Notriolus*				*							
Coleoptera	Elmidae	*Simsonia*				*	*						
Coleoptera	Gyrinidae	*Macrogyrus*		*	*	*	*	*	*	*	*		
Coleoptera	Haliplidae	*Haliplus*			*	*	*	*	*	*	*		*
Coleoptera	Hydraenidae	*Undetermined*							*	*			
Coleoptera	Hydraenidae	*Hydraena*	*			*	*	*	*				
Coleoptera	Hydrophilidae	*Berosus*		*	*	*	*	*	*	*	*		
Coleoptera	Hydrophilidae	*Enochrus*	*		*	*	*	*	*	*	*		
Coleoptera	Hydrophilidae	*Helochares*					*	*					
Coleoptera	Hydrophilidae	*Hydrochus*			*	*	*	*	*	*			*
Coleoptera	Hydrophilidae	*Paracymus*				*		*					
Coleoptera	Hydrophilidae	*Sternolophus*							*				
Coleoptera	Psephenidae	*Sclerocyphon*		*	*	*	*	*			*	*	
Coleoptera	Psephenidae	*Sclerocyphon maculatus*			*								
Coleoptera	Scirtidae	*Undetermined*			*	*	*	*	*	*		*	
Coleoptera	Scirtidae	*Scirtis*				*							
Decapoda	Atyidae	*Caridinides*	*	*	*	*	*	*	*	*			
Decapoda	Atyidae	*Paratya*	*	*	*	*	*	*	*	*	*		
Decapoda	Atyidae	*Paratya australiensis*			*	*	*	*	*				
Decapoda	Parastacidae	*Cherax*								*			
Decapoda	Palaemonidae	*Macrobrachium*					*		*				
Diptera	Ceratopogonidae	*Bezzia*	*	*	*	*	*	*	*	*	*	*	
Diptera	Ceratopogonidae	*Atrichopogon*								*			
Diptera	Chironomidae	*Chironominae*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Tanypodinae*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Culicidae	*Anophelini*					*						
Diptera	Culicidae	*Culicinae*			*	*	*	*	*				
Diptera	Dixidae	*Dixa*						*				*	
Diptera	Muscidae	*Undetermined*	*				*						
Diptera	Psychodidae	*Pericoma*						*					
Diptera	Psychodidae	*sp.*						*					
Diptera	Simulidae	*Simulium*	*	*	*	*	*	*	*	*		*	
Diptera	Stratiomyidae	*Odontomyia*					*	*					
Diptera	Tabanidae	*Tabanus*	*	*		*	*		*	*	*		
Diptera	Tipulidae	*Undetermined*		*	*	*	*	*	*	*			*
Ephemeroptera	Baetidae	*Centroptilum*				*	*	*					
Ephemeroptera	Baetidae	*Cloeon*	*	*	*	*	*	*	*	*		*	*
Ephemeroptera	Caenidae	*Tasmanocoenis*	*	*	*	*	*	*	*	*	*		
Ephemeroptera	Leptophlebiidae	*Atalophlebia*		*	*	*	*	*	*	*			*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*				*		*				*	
Ephemeroptera	Leptophlebiidae	*Jappa*				*	*						
Ephemeroptera	Leptophlebiidae	*Koorrnonga*				*	*						
Ephemeroptera	Leptophlebiidae	*Nousia*				*	*	*	*	*			*
Gastropoda	Ancylidae	*Ferrissia*		*	*	*	*		*				
Gastropoda	Ancylidae	*Ferrissia petterdi*			*								

Consolidated Recorded Macroinvertebrates

Order	Family	Species	Site										
			S1	S2	S3	W1	W2	W3	W5	W8	CG	DV	EEG1
Gastropoda	Lymnaeidae	*Austropeplea*	*	*	*	*	*		*	*	*		
Gastropoda	Lymnaeidae	*Austropeplea lessoni*			*				*				
Gastropoda	Lymnaeidae	*Pseudosuccinea*		*				*		*	*		
Gastropoda	Physidae	*Physa*	*	*	*	*	*	*	*	*	*		*
Gastropoda	Physidae	*Physa acuta*			*	*	*		*				
Gastropoda	Physidae	*Physella*	*		*								
Gastropoda	Physidae	*Haitia acuta*			*	*	*		*	*			
Gastropoda	Planorbidae	*Glyptophysa*			*	*	*	*	*	*			
Gastropoda	Planorbidae	*Glyptophysa gibbosa*			*				*				
Gastropoda	Planorbidae	*Gyraulus*			*	*	*		*	*			
Gastropoda	Planorbidae	*Helicorbus*			*	*				*			*
Gastropoda	Planorbidae	*Isidorella*	*	*	*			*	*	*	*	*	*
Neotaenioglossa	Hydrobiidae	*Undetermined*											*
Hemiptera	Corixidae	*Agraptocorixa*			*	*	*	*	*	*	*		*
Hemiptera	Corixidae	*Micronecta*	*		*	*	*	*	*	*	*		
Hemiptera	Corixidae	*Micronecta sp.*				*	*	*					
Hemiptera	Corixidae	*Sigara*		*		*	*	*	*	*			
Hemiptera	Gerridae	*sp.*			*	*	*						
Hemiptera	Gerridae	*Undetermined*			*	*							
Hemiptera	Hydrometridae	*Hydrometra*			*		*						
Hemiptera	Naucoridae	*Naucoris*				*	*		*	*			
Hemiptera	Nepidae	*Laccotrephes tristis*			*								
Hemiptera	Nepidae	*Ranatra*	*	*									
Hemiptera	Notonectidae	*Anisops*		*	*	*	*	*	*	*	*		*
Hemiptera	Notonectidae	*Enithares*	*	*	*	*	*	*	*	*			*
Hemiptera	Pleidae	*Plea*				*	*		*	*			
Hemiptera	Veliidae	*Microvelia*	*		*	*	*	*	*	*		*	
Hirudinea	Glossiphoniidae	*Undetermined*	*		*	*	*	*	*	*	*		
Hirudinea	Richardsonianidae	*Richardsoniana*						*					
Hirudinea	Richardsonianidae	*Undetermined*				*							
Isopoda	Oniscidea	*Undetermined*								*			
Megaloptera	Corydalidae	*Archichauliodes*		*	*	*		*				*	
Megaloptera	Corydalidae	*Archichauliodes guttiferus*							*				
Megaloptera	Sialidae	*Austrosialis*			*	*	*		*		*		
Odonata	Aeshnidae	*Aeshna*	*	*	*		*		*	*	*	*	
Odonata	Coenagrionidae	*Ischnura*	*	*	*	*	*	*	*	*	*		*
Odonata	Cordulephyidae	*Cordulephya*	*	*									
Odonata	Gomphidae	*Austrogomphus*		*		*	*						
Odonata	Gomphidae	*Hemigomphus*				*							
Odonata	Hemicorduliidae	*Hemicordulia*	*	*	*		*	*	*	*			
Odonata	Isostictidae	*Rhadinosticta*				*							
Odonata	Lestidae	*Austrolestes*									*		
Odonata	Libellulidae	*Diplacodes*	*	*	*	*	*	*	*	*	*		
Odonata	Libellulidae	*Nannophlebia*			*	*	*	*	*	*			
Odonata	Libellulidae	*Orthetrum*	*	*					*				
Odonata	Megapodagrionida	*Austroargiolestes*		*	*			*			*		*
Odonata	Synthemistidae	*Eusynthemis*									*		
Oligochaete	Enchytraetidae	*Achaeta*						*		*			
Oligochaete	Lumbriculidae	*Lumbricus*			*	*	*	*	*	*			
Oligochaete	Lumbriculidae	*Lumbricus variegatus*			*	*			*				
Oligochaete	Phreodrilidae	*Phreodrilus*				*							
Oligochaete	Tubificidae	*Undetermined*	*		*	*	*	*	*		*		
Platyhelminthes	Dugesiidae	*Undetermined*			*	*	*	*		*			*
Plecoptera	Eustheniidae	*Thaumatoperla*				*		*					
Plecoptera	Gripopterygidae	*Illiesoperla*			*	*		*				*	*
Trichoptera	Calamoceratidae	*Anisocentropus*	*	*	*	*	*		*				
Trichoptera	Ecnomidae	*Ecnomus*		*		*	*	*	*	*		*	
Trichoptera	Hydrobiosidae	*Apsilochorema*				*	*	*	*				
Trichoptera	Hydropsychidae	*Asmicridea*				*							
Trichoptera	Hydropsychidae	*Cheumatopsyche*				*		*	*				
Trichoptera	Hydroptilidae	*Hellyethira*		*	*	*	*	*	*	*	*	*	
Trichoptera	Leptoceridae	*Notalina*	*	*		*		*	*				*
Trichoptera	Leptoceridae	*Notalina spira*							*				
Trichoptera	Leptoceridae	*Oecetis*	*		*	*	*	*	*	*			*
Trichoptera	Leptoceridae	*Triplectides*	*	*	*	*	*	*	*	*	*	*	*
Trichoptera	Limnephilidae	*Archaeophylax*				*							
Trichoptera	Odontoceridae	*Marilia*				*		*	*	*	*		
Trichoptera	Philopotamidae	*Chimarra*				*							
Trichoptera	Polycentropidae	*Plectrocnemia*						*				*	

Date	Temperature (°C)										
	Sampling Locations										
	EDD1	CG	S1	S2	S3	S6	W1	W2	W3	W5	W8
Sep-01	-	-	18.85	17.3	15	-	-	16.2	-	18.1	-
Autumn 2001	13.8	13.2	-	-	-	-	11.8	12.3	13.2	13.3	11.9
Dec-01	-	-	25	23.7	21.8	23.6	22.5	23	-	-	-
Apr-02	-	-	23.15	20.5	20.9	-	18.7	19.4	-	23.1	18.8
Feb-03	-	-	-	-	22	-	24.66	23.4	25.68	27.08	-
Mar-03	-	-	-	-	18.7	-	19.47	21.6	23.5	23.9	-
Mar-04	-	-	-	-	23.1	-	23.41	22.8	23.8	28.22	-
Nov-04	-	-	-	-	17.01	-	20.26	19.87	20.49	20.4	17.82
Nov-05	-	-	-	-	17.2	-	19.7	20.6	18.4	18.7	19
Oct-06	-	-	-	-	16.6	-	18.4	18.8	22.6	18.9	dry
Oct-07	-	-	-	-	17.4	-	18.6	17.9	20.5	21.8	dry
Oct-08	-	-	-	-	15.6	-	16.25	17.1	18.5	21.2	19.5
Oct-09	-	-	-	-	12.5	-	13.2	14	12.7	13.7	dry
Oct-10	-	-	-	-	15.3	-	14.3	16.4	16	20.7	14.1

Date	Conductivity (mg/l)										
	Sampling Locations										
	EDD1	CG	S1	S2	S3	S6	W1	W2	W3	W5	W8
Sep-01	-	-	2338	1755	2138	-	-	720	-	5460	-
Autumn 2001	136	325	-	-	-	-	182	276	198	514	563
Dec-01	-	-	2465	2220	2145	663	1160	765	-	-	-
Apr-02	-	-	2480	137	2210	-	236	380	-	1096	557
Feb-03	-	-	-	-	2947	-	461	607	1110	3478	-
Mar-03	-	-	-	-	2935	-	287	335	1101	2728	-
Mar-04	-	-	-	-	701	-	134.5	175.6	478	871	-
Nov-04	-	-	-	-	1120	-	254.4	244.2	369	2484	767.2
Nov-05	-	-	-	-	432	-	227	213	306	1076	661
Oct-06	-	-	-	-	3739	-	495	331	632	1750	dry
Oct-07	-	-	-	-	2718	-	492	402	464	3525	dry
Oct-08	-	-	-	-	1302	-	339	483	475	1008	834
Oct-09	-	-	-	-	2916	-	501	534	460	1256	dry
Oct-10	-	-	-	-	4291	-	244	295	439	774	758

Date	pH Units										
	Sampling Locations										
	EDD1	**CG**	**S1**	**S2**	**S3**	**S6**	**W1**	**W2**	**W3**	**W5**	**W8**
Sep-01	-	-	7.81	7.43	7.37	-	-	6	-	5.3	-
Autumn 2001	7.1	7.1	-	-	-	-	7.1	7.2	7.2	7.5	7.1
Dec-01	-	-	7.93	7.68	7.43	7.84	7.67	7.79	-	-	-
Apr-02	-	-	8.75	7.75	8.56	-	7.95	7.94	-	8.3	7.53
Feb-03	-	-	-	-	7.06	-	6.9	6.91	7.6	7.17	-
Mar-03	-	-	-	-	7.05	-	6.87	7.3	7.41	7.44	-
Mar-04	-	-	-	-	7.21	-	6.72	6.63	6.64	7.53	-
Nov-04	-	-	-	-	7.35	-	7.13	7.11	7.15	7.35	7.91
Nov-05	-	-	-	-	6.5	-	7.2	7	7.3	7.6	7.3
Oct-06	-	-	-	-	6.8	-	6.9	6.9	6.8	6.9	dry
Oct-07	-	-	-	-	7.1	-	7.1	7.1	7	7.5	dry
Oct-08	-	-	-	-	6.4	-	6.3	6.5	6.3	6.6	6.5
Oct-09	-	-	-	-	7.1	-	7	7.2	7.2	6.7	dry
Oct-10	-	-	-	-	6.9	-	7.4	7.5	7.4	7.7	7.4

Date	Dissolved Oxygen (mS)										
	Sampling Locations										
	EDD1	**CG**	**S1**	**S2**	**S3**	**S6**	**W1**	**W2**	**W3**	**W5**	**W8**
Sep-01	-	-	8.65	7.8	6.99	-	-	6	-	5.3	-
Autumn 2001	7.5	9.5					9.3	8.6	8.8	9.6	7.6
Dec-01	-	-	4.65	5.7	5.6	3.2	2.08	3.38	-	-	-
Apr-02	-	-	6.76	6.7	6.8	-	6.5	5	-	7.5	3.2
Feb-03	-	-	-	-	4.83	-	4.05	2.31	7	4.54	-
Mar-03	-	-	-	-	3	-	3.75	4.79	3.07	3.96	-
Mar-04	-	-	-	-	6.71	-	5.85	4.64	3.31	8.55	-
Nov-04	-	-	-	-	5.93	-	2.92	2.58	4.32	4.39	6.71
Nov-05	-	-	-	-	4.4	-	3.1	2.7	2.9	3.4	2.9
Oct-06	-	-	-	-	1.7	-	2.1	2.4	3.4	3.8	dry
Oct-07	-	-	-	-	2.1	-	3.3	2.2	3.5	6	dry
Oct-08	-	-	-	-	2.4	-	2.9	2.6	2.9	2.5	2.9
Oct-09	-	-	-	-	1.7	-	1.7	1.8	2.1	2.8	dry
Oct-10	-	-	-	-	1.6	-	3.4	2.7	2.7	4.5	3.8

Date	Turbidity (NTU)					
	Sampling Locations					
	S3	**W1**	**W2**	**W3**	**W5**	**W8**
Oct-10	4.9	11.5	12.7	8	10.4	4.7

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*													
			Site W1													
			Autumn 2000	Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Acariformes	Eylaidae	*Eylais*	*		*			*				*				
Acariformes	Hygrobatidae	*undetermined*														*
Acariformes	Ixodidae	*Ixodes*														
Acarina	Pionidae	*Undetermined*					*									
Amphipoda	Talitridae	*Undetermined*		*												
Arachnida	Araneae	*Undetermined*														
Bivalvia	Hyriidae	*Hyridella*	*	*	*	*				*				*		
Bivalvia	Sphaeridae	*Pisidium*	*	*	*	*	*		*	*	*	*	*	*	*	*
Bivalvia	Corbiculidae	*Corbicula*														
Coleoptera	Dytiscidae	*Antiporus*						*								
Coleoptera	Dytiscidae	*Australphilus*														
Coleoptera	Dytiscidae	*Batrachomatus*		*				*		*		*	*	*		
Coleoptera	Dytiscidae	*Bidessodes*		*						*		*		*		*
Coleoptera	Dytiscidae	*Bidessus*										*	*		*	
Coleoptera	Dytiscidae	*Chostonectes*				*	*		*		*	*				
Coleoptera	Dytiscidae	*Eretes*														
Coleoptera	Dytiscidae	*Gibbidessus*														
Coleoptera	Dytiscidae	*Hydrovatus*									*					
Coleoptera	Dytiscidae	*Hyphydrus*				*	*	*								
Coleoptera	Dytiscidae	*Lancetes*								*						
Coleoptera	Dytiscidae	*Necterosoma*		*	*	*	*	*	*	*	*		*	*	*	*
Coleoptera	Dytiscidae	*Paroster*								*				*	*	
Coleoptera	Dytiscidae	*Rhantus*				*										
Coleoptera	Dytiscidae	*Sternopriscus*			*						*	*	*			
Coleoptera	Elmidae	*Austrolimnius*	*	*		*					*	*			*	*
Coleoptera	Elmidae	*Kingolus*	*								*					
Coleoptera	Elmidae	*Notriolus*														
Coleoptera	Elmidae	*Simsonia*	*													
Coleoptera	Gyrinidae	*Macrogyrus*	*		*	*						*	*	*	*	*
Coleoptera	Haliplidae	*Haliplus*			*		*	*		*	*	*	*	*	*	*
Coleoptera	Hydraenidae	*undetermined*														
Coleoptera	Hydraenidae	*Hydraena*					*									
Coleoptera	Hydrophilidae	*Berosus*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Coleoptera	Hydrophilidae	*Enochrus*			*		*			*				*	*	
Coleoptera	Hydrophilidae	*Helochares*														
Coleoptera	Hydrophilidae	*Hydrochus*					*				*		*	*		
Coleoptera	Hydrophilidae	*Paracymus*					*									
Coleoptera	Hydrophilidae	*Sternolophus*														
Coleoptera	Psephenidae	*Sclerocyphon*	*	*	*								*	*	*	
Coleoptera	Psephenidae	*Sclerocyphon maculatus*														

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*													
			Site W1													
			Autumn 2000	**Autumn 2001**	**Dec-01**	**Apr-02**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Coleoptera	Scirtidae	*Undetermined*	*	*			*					*	*			
Coleoptera	Scirtidae	*Scirtis*						*								
Decapoda	Atyidae	*Caridinides*	*		*	*					*			*	*	*
Decapoda	Atyidae	*Paratya*	*	*	*	*	*					*	*	*	*	*
Decapoda	Atyidae	*Paratya australiensis*						*								
Decapoda	Parastacidae	*Cherax*														
Decapoda	Palaemonidae	*Macrobrachium*														
Diptera	Ceratopogonidae	*Bezzia*		*		*	*	*	*	*		*		*		*
Diptera	Ceratopogonidae	*Atrichopogon*														
Diptera	Chironomidae	*Chironominae*			*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*				*		*	*			*		*	*	*
Diptera	Chironomidae	*Tanypodinae*	*		*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Culicidae	*Anophelini*														
Diptera	Culicidae	*Culicinae*											*			
Diptera	Dixidae	*Dixa*														
Diptera	Muscidae	*Undetermined*														
Diptera	Psychodidae	*Pericoma*														
Diptera	Psychodidae	*sp.*														
Diptera	Simulidae	*Simulium*	*	*		*			*	*	*	*	*	*		*
Diptera	Stratiomyidae	*Odontomyia*														
Diptera	Tabanidae	*Tabanus*		*												
Diptera	Tipulidae	*Undetermined*			*	*			*	*				*		
Ephemeroptera	Baetidae	*Centroptilum*						*								
Ephemeroptera	Baetidae	*Cloeon*		*	*	*	*		*	*	*	*		*	*	*
Ephemeroptera	Caenidae	*Tasmanocoenis*		*	*	*					*			*	*	*
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	*	*		*				*	*	*	*	*	*	*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*	*								*	*			*	*
Ephemeroptera	Leptophlebiidae	*Jappa*				*					*					
Ephemeroptera	Leptophlebiidae	*Koorrnonga*			*	*										
Ephemeroptera	Leptophlebiidae	*Nousia*	*	*						*				*		
Gastropoda	Ancylidae	*Ferrissia*													*	
Gastropoda	Ancylidae	*Ferrissia petterdi*														
Gastropoda	Lymnaeidae	*Austropeplea*										*			*	
Gastropoda	Lymnaeidae	*Austropeplea lessoni*														
Gastropoda	Lymnaeidae	*Pseudosuccinea*														
Gastropoda	Physidae	*Physa*	*	*	*	*	*			*	*	*	*	*		
Gastropoda	Physidae	*Physa acuta*							*							
Gastropoda	Physidae	*Physella*														
Gastropoda	Physidae	*Haitia acuta*													*	*

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*													
			Site W1													
			Autumn 2000	Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Gastropoda	Planorbidae	*Glyptophysa*	*													
Gastropoda	Planorbidae	*Glyptophysa gibbosa*														
Gastropoda	Planorbidae	*Gyraulus*									*	*	*	*		
Gastropoda	Planorbidae	*Helicorbus*		*												
Gastropoda	Planorbidae	*Isidorella*														
Neotaenioglossa	Hydrobiidae	*Undetermined*														
Hemiptera	Corixidae	*Agraptocorixa*		*			*		*	*	*		*			
Hemiptera	Corixidae	*Micronecta*	*		*		*			*	*	*	*	*	*	
Hemiptera	Corixidae	*Micronecta sp.*						*	*							
Hemiptera	Corixidae	*Sigara*			*	*				*	*	*		*		
Hemiptera	Gerridae	*sp.*												*		
Hemiptera	Gerridae	*Undetermined*								*						
Hemiptera	Hydrometridae	*Hydrometra*														
Hemiptera	Naucoridae	*Naucoris*								*						
Hemiptera	Nepidae	*Laccotrephes tristis*														
Hemiptera	Nepidae	*Ranatra*														
Hemiptera	Notonectidae	*Anisops*	*	*	*	*	*			*	*		*	*		
Hemiptera	Notonectidae	*Enithares*					*		*			*		*		
Hemiptera	Pleidae	*Plea*								*				*	*	*
Hemiptera	Veliidae	*Microvelia*			*	*	*			*	*	*	*	*		*
Hirudinea	Glossiphoniidae	*Undetermined*	*		*		*	*	*			*	*		*	*
Hirudinea	Richardsonianidae	*Richardsoniana*														
Hirudinea	Richardsonianidae	*Undetermined*		*												
Isopoda	Oniscidea	*Undetermined*														
Megaloptera	Corydalidae	*Archichauliodes*	*	*												*
Megaloptera	Corydalidae	*Archichauliodes guttiferus*														
Megaloptera	Sialidae	*Austrosialis*	*	*	*	*		*			*	*			*	*
Odonata	Aeshnidae	*Aeshna*														
Odonata	Coenagrionidae	*Ischnura*					*	*	*	*	*	*	*	*	*	*
Odonata	Cordulephyidae	*Cordulephya*														
Odonata	Gomphidae	*Austrogomphus*					*				*					
Odonata	Gomphidae	*Hemigomphus*		*												
Odonata	Hemicorduliidae	*Hemicordulia*														
Odonata	Isostictidae	*Rhadinosticta*			*	*										
Odonata	Lestidae	*Austrolestes*														
Odonata	Libellulidae	*Diplacodes*	*	*						*	*	*	*	*		
Odonata	Libellulidae	*Nannophlebia*							*	*	*					
Odonata	Libellulidae	*Orthetrum*														
Odonata	Megapodagrionida	*Austroargiolestes*														
Odonata	Synthemistidae	*Eusynthemis*														

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*													
			Site W1													
			Autumn 2000	Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Oligochaete	Enchytraetidae	*Achaeta*														
Oligochaete	Lumbriculidae	*Lumbricus*		*	*	*					*	*	*		*	*
Oligochaete	Lumbriculidae	*Lumbricus variegatus*						*	*							
Oligochaete	Phreodrilidae	*Phreodrilus*	*													
Oligochaete	Tubificidae	*Undetermined*				*						*	*	*	*	
Platyhelminthes	Dugesiidae	*Undetermined*			*				*	*	*		*		*	
Plecoptera	Eustheniidae	*Thaumatoperla*		*												
Plecoptera	Gripopterygidae	*Illiesoperla*	*			*			*	*				*		*
Trichoptera	Calamoceratidae	*Anisocentropus*		*											*	
Trichoptera	Ecnomidae	*Ecnomus*	*											*	*	*
Trichoptera	Hydrobiosidae	*Apsilochorema*	*										*	*		*
Trichoptera	Hydropsychidae	*Asmicridea*	*	*												
Trichoptera	Hydropsychidae	*Cheumatopsyche*	*			*				*						*
Trichoptera	Hydroptilidae	*Hellyethira*				*								*		
Trichoptera	Leptoceridae	*Notalina*			*					*						
Trichoptera	Leptoceridae	*Notalina spira*														
Trichoptera	Leptoceridae	*Oecetis*				*				*	*			*	*	*
Trichoptera	Leptoceridae	*Triplectides*			*					*		*	*	*	*	*
Trichoptera	Limnephilidae	*Archaeophylax*		*												
Trichoptera	Odontoceridae	*Marilia*	*	*												
Trichoptera	Philopotamidae	*Chimarra*														*
Trichoptera	Polycentropidae	*Plectrocnemia*														

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*												
			Site W2												
			Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Acariformes	Eylaidae	*Eylais*		*							*		*		*
Acariformes	Hygrobatidae	*undetermined*					*	*							*
Acariformes	Ixodidae	*Ixodes*					*								
Acarina	Pionidae	*Undetermined*													
Amphipoda	Talitridae	*Undetermined*													
Arachnida	Araneae	*Undetermined*													
Bivalvia	Hyriidae	*Hyridella*	*	*											
Bivalvia	Sphaeridae	*Pisidium*	*	*		*	*	*	*	*	*	*	*	*	*
Bivalvia	Corbiculidae	*Corbicula*													
Coleoptera	Dytiscidae	*Antiporus*					*								
Coleoptera	Dytiscidae	*Australphilus*				*									
Coleoptera	Dytiscidae	*Batrachomatus*		*							*	*			
Coleoptera	Dytiscidae	*Bidessodes*		*			*		*		*	*	*	*	*
Coleoptera	Dytiscidae	*Bidessus*							*		*	*	*	*	
Coleoptera	Dytiscidae	*Chostonectes*			*	*		*	*	*	*	*	*		
Coleoptera	Dytiscidae	*Eretes*													
Coleoptera	Dytiscidae	*Gibbidessus*			*										
Coleoptera	Dytiscidae	*Hydrovatus*								*					
Coleoptera	Dytiscidae	*Hyphydrus*			*	*									
Coleoptera	Dytiscidae	*Lancetes*													
Coleoptera	Dytiscidae	*Necterosoma*	*	*	*	*	*	*	*	*	*	*	*	*	
Coleoptera	Dytiscidae	*Paroster*							*				*	*	
Coleoptera	Dytiscidae	*Rhantus*		*											
Coleoptera	Dytiscidae	*Sternopriscus*		*	*	*				*	*				
Coleoptera	Elmidae	*Austrolimnius*	*							*					*
Coleoptera	Elmidae	*Kingolus*	*												
Coleoptera	Elmidae	*Notriolus*													
Coleoptera	Elmidae	*Simsonia*	*												
Coleoptera	Gyrinidae	*Macrogyrus*	*		*					*	*	*	*	*	*
Coleoptera	Haliplidae	*Haliplus*	*	*		*		*	*		*	*	*		*
Coleoptera	Hydraenidae	*undetermined*													
Coleoptera	Hydraenidae	*Hydraena*		*	*										
Coleoptera	Hydrophilidae	*Berosus*		*	*	*	*	*	*	*	*	*	*	*	*
Coleoptera	Hydrophilidae	*Enochrus*		*					*				*	*	
Coleoptera	Hydrophilidae	*Helochares*		*											
Coleoptera	Hydrophilidae	*Hydrochus*	*						*						
Coleoptera	Hydrophilidae	*Paracymus*													
Coleoptera	Hydrophilidae	*Sternolophus*													
Coleoptera	Psephenidae	*Sclerocyphon*	*										*	*	
Coleoptera	Psephenidae	*Sclerocyphon maculatus*													

Order	Family	Species	*Avon River*												
			Site W2												
			Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Coleoptera	Scirtidae	*Undetermined*		*	*	*			*			*	*		
Coleoptera	Scirtidae	*Scirtis*													
Decapoda	Atyidae	*Caridinides*	*	*	*		*	*		*	*		*	*	*
Decapoda	Atyidae	*Paratya*	*	*	*	*			*	*	*	*	*	*	*
Decapoda	Atyidae	*Paratya australiensis*					*	*							
Decapoda	Parastacidae	*Cherax*													
Decapoda	Palaemonidae	*Macrobrachium*									*				*
Diptera	Ceratopogonidae	*Bezzia*			*	*					*		*		*
Diptera	Ceratopogonidae	*Atrichopogon*													
Diptera	Chironomidae	*Chironominae*	*	*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*								*	*			*	*
Diptera	Chironomidae	*Tanypodinae*	*	*	*	*	*	*	*	*	*	*	*	*	*
Diptera	Culicidae	*Anophelini*			*										
Diptera	Culicidae	*Culicinae*										*	*	*	*
Diptera	Dixidae	*Dixa*													
Diptera	Muscidae	*Undetermined*				*									
Diptera	Psychodidae	*Pericoma*													
Diptera	Psychodidae	*sp.*													
Diptera	Simulidae	*Simulium*	*								*		*		*
Diptera	Stratiomyidae	*Odontomyia*												*	
Diptera	Tabanidae	*Tabanus*			*										
Diptera	Tipulidae	*Undetermined*		*	*									*	
Ephemeroptera	Baetidae	*Centroptilum*					*								
Ephemeroptera	Baetidae	*Cloeon*	*	*		*		*	*	*	*	*	*	*	*
Ephemeroptera	Caenidae	*Tasmanocoenis*			*	*	*				*	*			*
Ephemeroptera	Leptophlebiidae	*Atalophlebia*		*						*	*	*	*	*	*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*													
Ephemeroptera	Leptophlebiidae	*Jappa*	*												
Ephemeroptera	Leptophlebiidae	*Koorrnonga*			*										
Ephemeroptera	Leptophlebiidae	*Nousia*	*						*				*		
Gastropoda	Ancylidae	*Ferrissia*												*	
Gastropoda	Ancylidae	*Ferrissia petterdi*													
Gastropoda	Lymnaeidae	*Austropeplea*			*									*	
Gastropoda	Lymnaeidae	*Austropeplea lessoni*													
Gastropoda	Lymnaeidae	*Pseudosuccinea*													
Gastropoda	Physidae	*Physa*		*	*	*			*	*	*	*	*		
Gastropoda	Physidae	*Physa acuta*					*	*							
Gastropoda	Physidae	*Physella*													
Gastropoda	Physidae	*Haitia acuta*												*	*

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*												
			Site W2												
			Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Gastropoda	Planorbidae	*Glyptophysa*						*				*			*
Gastropoda	Planorbidae	*Glyptophysa gibbosa*													
Gastropoda	Planorbidae	*Gyraulus*				*							*		
Gastropoda	Planorbidae	*Helicorbus*													
Gastropoda	Planorbidae	*Isidorella*													
Neotaenioglossa	Hydrobiidae	*Undetermined*													
Hemiptera	Corixidae	*Agraptocorixa*	*				*	*	*	*		*	*	*	*
Hemiptera	Corixidae	*Micronecta*	*	*	*	*			*	*	*	*	*	*	*
Hemiptera	Corixidae	*Micronecta sp.*					*	*							
Hemiptera	Corixidae	*Sigara*		*	*			*	*	*	*		*		
Hemiptera	Gerridae	*sp.*											*		
Hemiptera	Gerridae	*Undetermined*													
Hemiptera	Hydrometridae	*Hydrometra*								*					
Hemiptera	Naucoridae	*Naucoris*		*						*					*
Hemiptera	Nepidae	*Laccotrephes tristis*													
Hemiptera	Nepidae	*Ranatra*													
Hemiptera	Notonectidae	*Anisops*	*	*					*	*	*	*	*		
Hemiptera	Notonectidae	*Enithares*	*	*	*		*	*	*			*	*	*	*
Hemiptera	Pleidae	*Plea*							*				*	*	*
Hemiptera	Veliidae	*Microvelia*			*		*		*	*	*	*	*	*	*
Hirudinea	Glossiphoniidae	*Undetermined*				*	*						*		*
Hirudinea	Richardsonianidae	*Richardsoniana*													
Hirudinea	Richardsonianidae	*Undetermined*													
Isopoda	Oniscidea	*Undetermined*													
Megaloptera	Corydalidae	*Archichauliodes*													
Megaloptera	Corydalidae	*Archichauliodes guttiferus*													
Megaloptera	Sialidae	*Austrosialis*	*							*	*				
Odonata	Aeshnidae	*Aeshna*	*	*					*						*
Odonata	Coenagrionidae	*Ischnura*	*	*	*		*	*	*	*	*	*	*	*	
Odonata	Cordulephyidae	*Cordulephya*													
Odonata	Gomphidae	*Austrogomphus*				*				*					
Odonata	Gomphidae	*Hemigomphus*									*				
Odonata	Hemicorduliidae	*Hemicordulia*		*											
Odonata	Isostictidae	*Rhadinosticta*													
Odonata	Lestidae	*Austrolestes*													
Odonata	Libellulidae	*Diplacodes*				*					*	*			*
Odonata	Libellulidae	*Nannophlebia*								*					
Odonata	Libellulidae	*Orthetrum*													
Odonata	Megapodagrionida	*Austroargiolestes*													
Odonata	Synthemistidae	*Eusynthemis*													

Recorded Macroinvertebrates

Order	Family	Species	*Avon River*												
			Site W2												
			Autumn 2001	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Oligochaete	Enchytraetidae	*Achaeta*													
Oligochaete	Lumbriculidae	*Lumbricus*								*	*	*	*	*	
Oligochaete	Lumbriculidae	*Lumbricus variegatus*													
Oligochaete	Phreodrilidae	*Phreodrilus*													
Oligochaete	Tubificidae	*Undetermined*		*	*						*	*			*
Platyhelminthes	Dugesiidae	*Undetermined*		*	*				*			*	*	*	*
Plecoptera	Eustheniidae	*Thaumatoperla*													
Plecoptera	Gripopterygidae	*Illiesoperla*													
Trichoptera	Calamoceratidae	*Anisocentropus*			*										
Trichoptera	Ecnomidae	*Ecnomus*											*	*	*
Trichoptera	Hydrobiosidae	*Apsilochorema*	*										*		*
Trichoptera	Hydropsychidae	*Asmicridea*													
Trichoptera	Hydropsychidae	*Cheumatopsyche*													
Trichoptera	Hydroptilidae	*Hellyethira*			*								*	*	*
Trichoptera	Leptoceridae	*Notalina*													
Trichoptera	Leptoceridae	*Notalina spira*													
Trichoptera	Leptoceridae	*Oecetis*							*		*	*	*		*
Trichoptera	Leptoceridae	*Triplectides*	*	*	*	*			*	*	*	*	*		*
Trichoptera	Limnephilidae	*Archaeophylax*													
Trichoptera	Odontoceridae	*Marilia*													
Trichoptera	Philopotamidae	*Chimarra*													
Trichoptera	Polycentropidae	*Plectrocnemia*													

Recorded Macroinvertebrates

Order	Family	Species	*Dog Trap Creek*											
			Site W3											
			Autumn 2000	**Autumn 2001**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Acariformes	Eylaidae	*Eylais*										*		
Acariformes	Hygrobatidae	*undetermined*												
Acariformes	Ixodidae	*Ixodes*												
Acarina	Pionidae	*Undetermined*												
Amphipoda	Talitridae	*Undetermined*												
Arachnida	Araneae	*Undetermined*												
Bivalvia	Hyriidae	*Hyridella*												
Bivalvia	Sphaeridae	*Pisidium*					*	*	*		*	*	*	*
Bivalvia	Corbiculidae	*Corbicula*												
Coleoptera	Dytiscidae	*Antiporus*				*								
Coleoptera	Dytiscidae	*Australphilus*			*									
Coleoptera	Dytiscidae	*Batrachomatus*						*				*		
Coleoptera	Dytiscidae	*Bidessodes*				*		*			*	*		*
Coleoptera	Dytiscidae	*Bidessus*						*				*		
Coleoptera	Dytiscidae	*Chostonectes*			*		*	*	*	*	*	*		
Coleoptera	Dytiscidae	*Eretes*												
Coleoptera	Dytiscidae	*Gibbidessus*												
Coleoptera	Dytiscidae	*Hydrovatus*							*					
Coleoptera	Dytiscidae	*Hyphydrus*												
Coleoptera	Dytiscidae	*Lancetes*				*		*						
Coleoptera	Dytiscidae	*Necterosoma*	*		*	*	*	*	*		*			*
Coleoptera	Dytiscidae	*Paroster*						*				*	*	
Coleoptera	Dytiscidae	*Rhantus*												
Coleoptera	Dytiscidae	*Sternopriscus*							*	*				
Coleoptera	Elmidae	*Austrolimnius*						*						
Coleoptera	Elmidae	*Kingolus*												
Coleoptera	Elmidae	*Notriolus*												
Coleoptera	Elmidae	*Simsonia*												
Coleoptera	Gyrinidae	*Macrogyrus*	*			*				*	*			
Coleoptera	Haliplidae	*Haliplus*		*		*			*		*			
Coleoptera	Hydraenidae	*undetermined*												
Coleoptera	Hydraenidae	*Hydraena*			*									
Coleoptera	Hydrophilidae	*Berosus*	*	*	*	*	*		*		*			
Coleoptera	Hydrophilidae	*Enochrus*		*				*	*			*	*	
Coleoptera	Hydrophilidae	*Helochares*			*	*								
Coleoptera	Hydrophilidae	*Hydrochus*						*				*		
Coleoptera	Hydrophilidae	*Paracymus*			*									
Coleoptera	Hydrophilidae	*Sternolophus*												
Coleoptera	Psephenidae	*Sclerocyphon*						*						
Coleoptera	Psephenidae	*Sclerocyphon maculatus*												

Recorded Macroinvertebrates

Order	Family	Species	*Dog Trap Creek*											
			Site W3											
			Autumn 2000	Autumn 2001	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Coleoptera	Scirtidae	*Undetermined*	*		*									
Coleoptera	Scirtidae	*Scirtis*												
Decapoda	Atyidae	*Caridinides*	*	*					*		*	*	*	
Decapoda	Atyidae	*Paratya*	*		*									
Decapoda	Atyidae	*Paratya australiensis*					*							
Decapoda	Parastacidae	*Cherax*												
Decapoda	Palaemonidae	*Macrobrachium*												
Diptera	Ceratopogonidae	*Bezzia*			*	*	*	*		*		*		
Diptera	Ceratopogonidae	*Atrichopogon*												
Diptera	Chironomidae	*Chironominae*		*	*	*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*	*	*			*		*					
Diptera	Chironomidae	*Tanypodinae*	*	*	*		*	*	*	*	*	*		*
Diptera	Culicidae	*Anophelini*												
Diptera	Culicidae	*Culicinae*				*				*	*	*	*	*
Diptera	Dixidae	*Dixa*											*	
Diptera	Muscidae	*Undetermined*												
Diptera	Psychodidae	*Pericoma*			*									
Diptera	Psychodidae	*sp.*				*								
Diptera	Simulidae	*Simulium*	*	*			*	*	*			*		*
Diptera	Stratiomyidae	*Odontomyia*	*		*				*					*
Diptera	Tabanidae	*Tabanus*												
Diptera	Tipulidae	*Undetermined*											*	
Ephemeroptera	Baetidae	*Centroptilum*				*								
Ephemeroptera	Baetidae	*Cloeon*		*			*	*						
Ephemeroptera	Caenidae	*Tasmanocoenis*		*				*						
Ephemeroptera	Leptophlebiidae	*Atalophlebia*							*	*		*		*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*	*						*					
Ephemeroptera	Leptophlebiidae	*Jappa*												
Ephemeroptera	Leptophlebiidae	*Koorrnonga*												
Ephemeroptera	Leptophlebiidae	*Nousia*		*					*					
Gastropoda	Ancylidae	*Ferrissia*												
Gastropoda	Ancylidae	*Ferrissia petterdi*												
Gastropoda	Lymnaeidae	*Austropeplea*												
Gastropoda	Lymnaeidae	*Austropeplea lessoni*												
Gastropoda	Lymnaeidae	*Pseudosuccinea*	*											
Gastropoda	Physidae	*Physa*	*					*	*	*	*	*		
Gastropoda	Physidae	*Physa acuta*												
Gastropoda	Physidae	*Physella*												
Gastropoda	Physidae	*Haitia acuta*												

Recorded Macroinvertebrates

Order	Family	Species	*Dog Trap Creek*											
			Site W3											
			Autumn 2000	**Autumn 2001**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Gastropoda	Planorbidae	*Glyptophysa*									*			
Gastropoda	Planorbidae	*Glyptophysa gibbosa*												
Gastropoda	Planorbidae	*Gyraulus*												
Gastropoda	Planorbidae	*Helicorbus*												
Gastropoda	Planorbidae	*Isidorella*											*	
Neotaenioglossa	Hydrobiidae	*Undetermined*												
Hemiptera	Corixidae	*Agraptocorixa*	*		*				*	*	*	*		
Hemiptera	Corixidae	*Micronecta*		*	*			*	*	*	*	*	*	*
Hemiptera	Corixidae	*Micronecta sp.*				*								
Hemiptera	Corixidae	*Sigara*				*		*	*			*	*	*
Hemiptera	Gerridae	*sp.*												
Hemiptera	Gerridae	*Undetermined*												
Hemiptera	Hydrometridae	*Hydrometra*												
Hemiptera	Naucoridae	*Naucoris*												
Hemiptera	Nepidae	*Laccotrephes tristis*												
Hemiptera	Nepidae	*Ranatra*												
Hemiptera	Notonectidae	*Anisops*			*			*	*	*	*	*		
Hemiptera	Notonectidae	*Enithares*	*		*									*
Hemiptera	Pleidae	*Plea*												
Hemiptera	Veliidae	*Microvelia*		*	*					*			*	
Hirudinea	Glossiphoniidae	*Undetermined*			*	*	*		*			*		*
Hirudinea	Richardsonianidae	*Richardsoniana*												*
Hirudinea	Richardsonianidae	*Undetermined*												
Isopoda	Oniscidea	*Undetermined*												
Megaloptera	Corydalidae	*Archichauliodes*	*											
Megaloptera	Corydalidae	*Archichauliodes guttiferus*												
Megaloptera	Sialidae	*Austrosialis*												
Odonata	Aeshnidae	*Aeshna*												
Odonata	Coenagrionidae	*Ischnura*		*				*						
Odonata	Cordulephyidae	*Cordulephya*												
Odonata	Gomphidae	*Austrogomphus*												
Odonata	Gomphidae	*Hemigomphus*												
Odonata	Hemicorduliidae	*Hemicordulia*		*										
Odonata	Isostictidae	*Rhadinosticta*												
Odonata	Lestidae	*Austrolestes*												
Odonata	Libellulidae	*Diplacodes*						*	*					
Odonata	Libellulidae	*Nannophlebia*					*	*						
Odonata	Libellulidae	*Orthetrum*												
Odonata	Megapodagrionida	*Austroargiolestes*		*										
Odonata	Synthemistidae	*Eusynthemis*												

Recorded Macroinvertebrates

Order	Family	Species	*Dog Trap Creek*											
			Site W3											
			Autumn 2000	Autumn 2001	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Oligochaete	Enchytraetidae	*Achaeta*	*											*
Oligochaete	Lumbriculidae	*Lumbricus*	*					*	*	*	*	*	*	*
Oligochaete	Lumbriculidae	*Lumbricus variegatus*												
Oligochaete	Phreodrilidae	*Phreodrilus*												
Oligochaete	Tubificidae	*Undetermined*				*		*			*	*	*	*
Platyhelminthes	Dugesiidae	*Undetermined*	*					*	*		*	*	*	*
Plecoptera	Eustheniidae	*Thaumatoperla*	*											
Plecoptera	Gripopterygidae	*Illiesoperla*	*	*			*							
Trichoptera	Calamoceratidae	*Anisocentropus*												
Trichoptera	Ecnomidae	*Ecnomus*		*								*		
Trichoptera	Hydrobiosidae	*Apsilochorema*		*										
Trichoptera	Hydropsychidae	*Asmicridea*												
Trichoptera	Hydropsychidae	*Cheumatopsyche*	*	*										
Trichoptera	Hydroptilidae	*Hellyethira*		*				*			*			
Trichoptera	Leptoceridae	*Notalina*							*					
Trichoptera	Leptoceridae	*Notalina spira*												
Trichoptera	Leptoceridae	*Oecetis*		*										
Trichoptera	Leptoceridae	*Triplectides*		*	*				*					
Trichoptera	Limnephilidae	*Archaeophylax*												
Trichoptera	Odontoceridae	*Marilia*	*											
Trichoptera	Philopotamidae	*Chimarra*												
Trichoptera	Polycentropidae	*Plectrocnemia*		*										

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*												
			Site W5												
			Autumn 2000	Autumn 2001	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Acariformes	Eylaidae	*Eylais*													
Acariformes	Hygrobatidae	*undetermined*					*								
Acariformes	Ixodidae	*Ixodes*													
Acarina	Pionidae	*Undetermined*													
Amphipoda	Talitridae	*Undetermined*													
Arachnida	Araneae	*Undetermined*													
Bivalvia	Hyriidae	*Hyridella*													
Bivalvia	Sphaeridae	*Pisidium*													*
Bivalvia	Corbiculidae	*Corbicula*													
Coleoptera	Dytiscidae	*Antiporus*													
Coleoptera	Dytiscidae	*Australphilus*													
Coleoptera	Dytiscidae	*Batrachomatus*		*			*			*			*		
Coleoptera	Dytiscidae	*Bidessodes*					*								*
Coleoptera	Dytiscidae	*Bidessus*													*
Coleoptera	Dytiscidae	*Chostonectes*			*	*									*
Coleoptera	Dytiscidae	*Eretes*													
Coleoptera	Dytiscidae	*Gibbidessus*													
Coleoptera	Dytiscidae	*Hydrovatus*													
Coleoptera	Dytiscidae	*Hyphydrus*													
Coleoptera	Dytiscidae	*Lancetes*													
Coleoptera	Dytiscidae	*Necterosoma*				*	*				*	*	*		
Coleoptera	Dytiscidae	*Paroster*							*				*		
Coleoptera	Dytiscidae	*Rhantus*													
Coleoptera	Dytiscidae	*Sternopriscus*				*									
Coleoptera	Elmidae	*Austrolimnius*													
Coleoptera	Elmidae	*Kingolus*													
Coleoptera	Elmidae	*Notriolus*													
Coleoptera	Elmidae	*Simsonia*													
Coleoptera	Gyrinidae	*Macrogyrus*				*	*				*				
Coleoptera	Haliplidae	*Haliplus*				*									
Coleoptera	Hydraenidae	*undetermined*					*								
Coleoptera	Hydraenidae	*Hydraena*			*	*									
Coleoptera	Hydrophilidae	*Berosus*		*	*	*	*		*		*	*	*		*
Coleoptera	Hydrophilidae	*Enochrus*				*			*	*	*	*	*		*
Coleoptera	Hydrophilidae	*Helochares*													
Coleoptera	Hydrophilidae	*Hydrochus*													*
Coleoptera	Hydrophilidae	*Paracymus*													
Coleoptera	Hydrophilidae	*Sternolophus*			*										
Coleoptera	Psephenidae	*Sclerocyphon*													
Coleoptera	Psephenidae	*Sclerocyphon maculatus*													

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*												
			Site W5												
			Autumn 2000	Autumn 2001	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Coleoptera	Scirtidae	*Undetermined*			*							*			
Coleoptera	Scirtidae	*Scirtis*													
Decapoda	Atyidae	*Caridinides*	*		*		*	*	*	*	*	*	*		*
Decapoda	Atyidae	*Paratya*	*							*	*				
Decapoda	Atyidae	*Paratya australiensis*					*								
Decapoda	Parastacidae	*Cherax*													
Decapoda	Palaemonidae	*Macrobrachium*													*
Diptera	Ceratopogonidae	*Bezzia*	*			*	*	*	*		*				
Diptera	Ceratopogonidae	*Atrichopogon*													
Diptera	Chironomidae	*Chironominae*	*	*		*	*	*	*	*	*	*	*		*
Diptera	Chironomidae	*Orthocladinae*	*				*		*						*
Diptera	Chironomidae	*Tanypodinae*				*	*	*	*	*	*	*	*		*
Diptera	Culicidae	*Anophelini*													
Diptera	Culicidae	*Culicinae*										*	*		
Diptera	Dixidae	*Dixa*													
Diptera	Muscidae	*Undetermined*													
Diptera	Psychodidae	*Pericoma*													
Diptera	Psychodidae	*sp.*													
Diptera	Simulidae	*Simulium*	*	*	*			*		*					*
Diptera	Stratiomyidae	*Odontomyia*													
Diptera	Tabanidae	*Tabanus*		*											
Diptera	Tipulidae	*Undetermined*	*							*	*		*		
Ephemeroptera	Baetidae	*Centroptilum*													
Ephemeroptera	Baetidae	*Cloeon*	*		*	*		*		*	*	*	*		*
Ephemeroptera	Caenidae	*Tasmanocoenis*	*	*	*	*							*		
Ephemeroptera	Leptophlebiidae	*Atalophlebia*				*							*		*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*								*					
Ephemeroptera	Leptophlebiidae	*Jappa*													
Ephemeroptera	Leptophlebiidae	*Koorrnonga*													
Ephemeroptera	Leptophlebiidae	*Nousia*		*											
Gastropoda	Ancylidae	*Ferrissia*							*				*		
Gastropoda	Ancylidae	*Ferrissia petterdi*													
Gastropoda	Lymnaeidae	*Austropeplea*	*		*				*		*	*	*		
Gastropoda	Lymnaeidae	*Austropeplea lessoni*					*								
Gastropoda	Lymnaeidae	*Pseudosuccinea*													
Gastropoda	Physidae	*Physa*	*	*	*	*			*	*	*	*	*		
Gastropoda	Physidae	*Physa acuta*					*	*							
Gastropoda	Physidae	*Physella*													
Gastropoda	Physidae	*Haitia acuta*													*

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*												
			Site W5												
			Autumn 2000	Autumn 2001	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Gastropoda	Planorbidae	*Glyptophysa*		*		*		*		*	*				*
Gastropoda	Planorbidae	*Glyptophysa gibbosa*					*								
Gastropoda	Planorbidae	*Gyraulus*	*		*	*									
Gastropoda	Planorbidae	*Helicorbus*													
Gastropoda	Planorbidae	*Isidorella*	*							*	*				*
Neotaenioglossa	Hydrobiidae	*Undetermined*													
Hemiptera	Corixidae	*Agraptocorixa*							*			*			
Hemiptera	Corixidae	*Micronecta*							*		*	*	*		
Hemiptera	Corixidae	*Micronecta sp.*													
Hemiptera	Corixidae	*Sigara*					*			*	*				*
Hemiptera	Gerridae	*sp.*													
Hemiptera	Gerridae	*Undetermined*													
Hemiptera	Hydrometridae	*Hydrometra*													
Hemiptera	Naucoridae	*Naucoris*	*				*								
Hemiptera	Nepidae	*Laccotrephes tristis*													
Hemiptera	Nepidae	*Ranatra*													
Hemiptera	Notonectidae	*Anisops*					*		*	*			*		
Hemiptera	Notonectidae	*Enithares*			*			*							
Hemiptera	Pleidae	*Plea*													
Hemiptera	Veliidae	*Microvelia*										*			*
Hirudinea	Glossiphoniidae	*Undetermined*								*					
Hirudinea	Richardsonianidae	*Richardsoniana*													
Hirudinea	Richardsonianidae	*Undetermined*													
Isopoda	Oniscidea	*Undetermined*													
Megaloptera	Corydalidae	*Archichauliodes*													
Megaloptera	Corydalidae	*Archichauliodes guttiferus*					*								
Megaloptera	Sialidae	*Austrosialis*	*												
Odonata	Aeshnidae	*Aeshna*			*										
Odonata	Coenagrionidae	*Ischnura*	*		*	*	*	*	*	*		*	*		*
Odonata	Cordulephyidae	*Cordulephya*													
Odonata	Gomphidae	*Austrogomphus*													
Odonata	Gomphidae	*Hemigomphus*													
Odonata	Hemicorduliidae	*Hemicordulia*						*			*				*
Odonata	Isostictidae	*Rhadinosticta*													
Odonata	Lestidae	*Austrolestes*													
Odonata	Libellulidae	*Diplacodes*		*		*	*						*		*
Odonata	Libellulidae	*Nannophlebia*						*	*						
Odonata	Libellulidae	*Orthetrum*			*										
Odonata	Megapodagrionida	*Austroargiolestes*													
Odonata	Synthemistidae	*Eusynthemis*													

Recorded Macroinvertebrates

Order	Family	Species	***Avondale Creek***												
			Site W5												
			Autumn 2000	**Autumn 2001**	**Apr-02**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Oligochaete	Enchytraetidae	*Achaeta*													
Oligochaete	Lumbriculidae	*Lumbricus*								*	*	*			
Oligochaete	Lumbriculidae	*Lumbricus variegatus*					*								
Oligochaete	Phreodrilidae	*Phreodrilus*													
Oligochaete	Tubificidae	*Undetermined*							*	*			*		
Platyhelminthes	Dugesiidae	*Undetermined*													
Plecoptera	Eustheniidae	*Thaumatoperla*													
Plecoptera	Gripopterygidae	*Illiesoperla*													
Trichoptera	Calamoceratidae	*Anisocentropus*											*		
Trichoptera	Ecnomidae	*Ecnomus*				*							*		
Trichoptera	Hydrobiosidae	*Apsilochorema*	*	*											
Trichoptera	Hydropsychidae	*Asmicridea*													
Trichoptera	Hydropsychidae	*Cheumatopsyche*	*												
Trichoptera	Hydroptilidae	*Hellyethira*			*				*	*	*		*		
Trichoptera	Leptoceridae	*Notalina*													
Trichoptera	Leptoceridae	*Notalina spira*					*								
Trichoptera	Leptoceridae	*Oecetis*			*								*		
Trichoptera	Leptoceridae	*Triplectides*	*							*					
Trichoptera	Limnephilidae	*Archaeophylax*													
Trichoptera	Odontoceridae	*Marilia*		*											
Trichoptera	Philopotamidae	*Chimarra*													
Trichoptera	Polycentropidae	*Plectrocnemia*													

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*								
			Site W8							Site CG	
			Autumn 2000	Autumn 2001	Apr-02	Nov-04	Nov-05	Oct-08	Oct-10	Autumn 2000	Autumn 2001
Acariformes	Eylaidae	*Eylais*	*					*			*
Acariformes	Hygrobatidae	*undetermined*									
Acariformes	Ixodidae	*Ixodes*									
Acarina	Pionidae	*Undetermined*									
Amphipoda	Talitridae	*Undetermined*									
Arachnida	Araneae	*Undetermined*								*	
Bivalvia	Hyriidae	*Hyridella*									
Bivalvia	Sphaeridae	*Pisidium*	*	*							*
Bivalvia	Corbiculidae	*Corbicula*									
Coleoptera	Dytiscidae	*Antiporus*									
Coleoptera	Dytiscidae	*Australphilus*									
Coleoptera	Dytiscidae	*Batrachomatus*		*			*				*
Coleoptera	Dytiscidae	*Bidessodes*		*		*		*			*
Coleoptera	Dytiscidae	*Bidessus*	*			*		*	*		
Coleoptera	Dytiscidae	*Chostonectes*			*	*	*	*	*		
Coleoptera	Dytiscidae	*Eretes*					*				
Coleoptera	Dytiscidae	*Gibbidessus*			*						
Coleoptera	Dytiscidae	*Hydrovatus*					*				
Coleoptera	Dytiscidae	*Hyphydrus*									
Coleoptera	Dytiscidae	*Lancetes*									
Coleoptera	Dytiscidae	*Necterosoma*	*		*	*	*	*			*
Coleoptera	Dytiscidae	*Paroster*				*		*			
Coleoptera	Dytiscidae	*Rhantus*			*						
Coleoptera	Dytiscidae	*Sternopriscus*									
Coleoptera	Elmidae	*Austrolimnius*			*		*				*
Coleoptera	Elmidae	*Kingolus*									
Coleoptera	Elmidae	*Notriolus*									
Coleoptera	Elmidae	*Simsonia*									
Coleoptera	Gyrinidae	*Macrogyrus*	*		*	*	*	*	*	*	*
Coleoptera	Haliplidae	*Haliplus*				*	*		*		*
Coleoptera	Hydraenidae	*undetermined*							*		
Coleoptera	Hydraenidae	*Hydraena*									
Coleoptera	Hydrophilidae	*Berosus*	*	*		*	*	*	*		*
Coleoptera	Hydrophilidae	*Enochrus*	*		*	*	*	*	*		*
Coleoptera	Hydrophilidae	*Helochares*									
Coleoptera	Hydrophilidae	*Hydrochus*				*		*			
Coleoptera	Hydrophilidae	*Paracymus*									
Coleoptera	Hydrophilidae	*Sternolophus*									
Coleoptera	Psephenidae	*Sclerocyphon*									*
Coleoptera	Psephenidae	*Sclerocyphon maculatus*									

Order	Family	Species	*Avondale Creek*								
			Site W8							Site CG	
			Autumn 2000	Autumn 2001	Apr-02	Nov-04	Nov-05	Oct-08	Oct-10	Autumn 2000	Autumn 2001
Coleoptera	Scirtidae	*Undetermined*	*		*	*					
Coleoptera	Scirtidae	*Scirtis*									
Decapoda	Atyidae	*Caridinides*	*		*				*		
Decapoda	Atyidae	*Paratya*	*		*	*		*		*	*
Decapoda	Atyidae	*Paratya australiensis*									
Decapoda	Parastacidae	*Cherax*				*					
Decapoda	Palaemonidae	*Macrobrachium*									
Diptera	Ceratopogonidae	*Bezzia*		*						*	
Diptera	Ceratopogonidae	*Atrichopogon*				*					
Diptera	Chironomidae	*Chironominae*		*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*	*					*	*	*	
Diptera	Chironomidae	*Tanypodinae*			*	*		*	*	*	
Diptera	Culicidae	*Anophelini*									
Diptera	Culicidae	*Culicinae*									
Diptera	Dixidae	*Dixa*									
Diptera	Muscidae	*Undetermined*									
Diptera	Psychodidae	*Pericoma*									
Diptera	Psychodidae	*sp.*									
Diptera	Simulidae	*Simulium*	*	*			*		*		
Diptera	Stratiomyidae	*Odontomyia*									
Diptera	Tabanidae	*Tabanus*		*							*
Diptera	Tipulidae	*Undetermined*			*		*		*		
Ephemeroptera	Baetidae	*Centroptilum*									
Ephemeroptera	Baetidae	*Cloeon*			*	*	*	*	*		
Ephemeroptera	Caenidae	*Tasmanocoenis*	*	*		*		*		*	*
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	*					*			
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*									
Ephemeroptera	Leptophlebiidae	*Jappa*									
Ephemeroptera	Leptophlebiidae	*Koorrnonga*									
Ephemeroptera	Leptophlebiidae	*Nousia*	*								
Gastropoda	Ancylidae	*Ferrissia*									
Gastropoda	Ancylidae	*Ferrissia petterdi*									
Gastropoda	Lymnaeidae	*Austropeplea*	*	*	*		*	*			*
Gastropoda	Lymnaeidae	*Austropeplea lessoni*									
Gastropoda	Lymnaeidae	*Pseudosuccinea*		*							*
Gastropoda	Physidae	*Physa*	*	*		*	*	*		*	*
Gastropoda	Physidae	*Physa acuta*									
Gastropoda	Physidae	*Physella*									
Gastropoda	Physidae	*Haitia acuta*							*		

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*								
			Site W8							Site CG	
			Autumn 2000	Autumn 2001	Apr-02	Nov-04	Nov-05	Oct-08	Oct-10	Autumn 2000	Autumn 2001
Gastropoda	Planorbidae	*Glyptophysa*	*	*	*		*		*		
Gastropoda	Planorbidae	*Glyptophysa gibbosa*									
Gastropoda	Planorbidae	*Gyraulus*	*	*		*	*	*	*		
Gastropoda	Planorbidae	*Helicorbus*		*							
Gastropoda	Planorbidae	*Isidorella*	*							*	
Neotaenioglossa	Hydrobiidae	*Undetermined*									
Hemiptera	Corixidae	*Agraptocorixa*		*		*					*
Hemiptera	Corixidae	*Micronecta*		*	*	*	*			*	
Hemiptera	Corixidae	*Micronecta sp.*									
Hemiptera	Corixidae	*Sigara*	*		*	*	*	*			
Hemiptera	Gerridae	*sp.*									
Hemiptera	Gerridae	*Undetermined*									
Hemiptera	Hydrometridae	*Hydrometra*									
Hemiptera	Naucoridae	*Naucoris*			*						
Hemiptera	Nepidae	*Laccotrephes tristis*									
Hemiptera	Nepidae	*Ranatra*									
Hemiptera	Notonectidae	*Anisops*			*	*		*		*	*
Hemiptera	Notonectidae	*Enithares*							*		
Hemiptera	Pleidae	*Plea*							*		
Hemiptera	Veliidae	*Microvelia*			*	*	*	*	*		
Hirudinea	Glossiphoniidae	*Undetermined*		*				*		*	*
Hirudinea	Richardsonianidae	*Richardsoniana*									
Hirudinea	Richardsonianidae	*Undetermined*									
Isopoda	Oniscidea	*Undetermined*			*						
Megaloptera	Corydalidae	*Archichauliodes*									
Megaloptera	Corydalidae	*Archichauliodes guttiferus*									
Megaloptera	Sialidae	*Austrosialis*									*
Odonata	Aeshnidae	*Aeshna*	*		*				*		*
Odonata	Coenagrionidae	*Ischnura*	*			*	*	*	*	*	
Odonata	Cordulephyidae	*Cordulephya*									
Odonata	Gomphidae	*Austrogomphus*									
Odonata	Gomphidae	*Hemigomphus*									
Odonata	Hemicorduliidae	*Hemicordulia*	*			*		*			
Odonata	Isostictidae	*Rhadinosticta*									
Odonata	Lestidae	*Austrolestes*									*
Odonata	Libellulidae	*Diplacodes*				*	*	*	*	*	*
Odonata	Libellulidae	*Nannophlebia*				*					
Odonata	Libellulidae	*Orthetrum*									
Odonata	Megapodagrionida	*Austroargiolestes*									
Odonata	Synthemistidae	*Eusynthemis*									*

Recorded Macroinvertebrates

Order	Family	Species	*Avondale Creek*								
			Site W8							Site CG	
			Autumn 2000	**Autumn 2001**	**Apr-02**	**Nov-04**	**Nov-05**	**Oct-08**	**Oct-10**	**Autumn 2000**	**Autumn 2001**
Oligochaete	Enchytraetidae	*Achaeta*	*								
Oligochaete	Lumbriculidae	*Lumbricus*				*	*	*			
Oligochaete	Lumbriculidae	*Lumbricus variegatus*									
Oligochaete	Phreodrilidae	*Phreodrilus*									
Oligochaete	Tubificidae	*Undetermined*								*	
Platyhelminthes	Dugesiidae	*Undetermined*	*				*	*	*		
Plecoptera	Eustheniidae	*Thaumatoperla*									
Plecoptera	Gripopterygidae	*Illiesoperla*									
Trichoptera	Calamoceratidae	*Anisocentropus*									
Trichoptera	Ecnomidae	*Ecnomus*	*						*		
Trichoptera	Hydrobiosidae	*Apsilochorema*									
Trichoptera	Hydropsychidae	*Asmicridea*									
Trichoptera	Hydropsychidae	*Cheumatopsyche*									
Trichoptera	Hydroptilidae	*Hellyethira*		*							*
Trichoptera	Leptoceridae	*Notalina*									
Trichoptera	Leptoceridae	*Notalina spira*									
Trichoptera	Leptoceridae	*Oecetis*	*								
Trichoptera	Leptoceridae	*Triplectides*			*	*	*	*	*	*	
Trichoptera	Limnephilidae	*Archaeophylax*									
Trichoptera	Odontoceridae	*Marilia*	*								*
Trichoptera	Philopotamidae	*Chimarra*									
Trichoptera	Polycentropidae	*Plectrocnemia*									

Recorded Macroinvertebrates

Order	Family	Species	*Unnamed Creek*	*Stratford East Water Storage Dam*			*Eastern Diversion Drain*			
			Site DV	**Site S1**			**Site EED1**	**Site S2**		
			Autumn 2000	**Sep-01**	**Dec-01**	**Apr-02**	**Autumn 2001**	**Sep-01**	**Dec-01**	**Apr-02**
Acariformes	Eylaidae	*Eylais*						*		
Acariformes	Hygrobatidae	*undetermined*								
Acariformes	Ixodidae	*Ixodes*								
Acarina	Pionidae	*Undetermined*								
Amphipoda	Talitridae	*Undetermined*								
Arachnida	Araneae	*Undetermined*							*	
Bivalvia	Hyriidae	*Hyridella*					*			
Bivalvia	Sphaeridae	*Pisidium*								
Bivalvia	Corbiculidae	*Corbicula*								
Coleoptera	Dytiscidae	*Antiporus*								
Coleoptera	Dytiscidae	*Australphilus*								
Coleoptera	Dytiscidae	*Batrachomatus*				*	*			
Coleoptera	Dytiscidae	*Bidessodes*		*						
Coleoptera	Dytiscidae	*Bidessus*								
Coleoptera	Dytiscidae	*Chostonectes*				*				
Coleoptera	Dytiscidae	*Eretes*								
Coleoptera	Dytiscidae	*Gibbidessus*								
Coleoptera	Dytiscidae	*Hydrovatus*								
Coleoptera	Dytiscidae	*Hyphydrus*								
Coleoptera	Dytiscidae	*Lancetes*								
Coleoptera	Dytiscidae	*Necterosoma*		*		*		*	*	*
Coleoptera	Dytiscidae	*Paroster*								
Coleoptera	Dytiscidae	*Rhantus*								
Coleoptera	Dytiscidae	*Sternopriscus*							*	
Coleoptera	Elmidae	*Austrolimnius*								
Coleoptera	Elmidae	*Kingolus*		*						
Coleoptera	Elmidae	*Notriolus*								
Coleoptera	Elmidae	*Simsonia*								
Coleoptera	Gyrinidae	*Macrogyrus*							*	
Coleoptera	Haliplidae	*Haliplus*					*			
Coleoptera	Hydraenidae	*undetermined*								
Coleoptera	Hydraenidae	*Hydraena*								
Coleoptera	Hydrophilidae	*Berosus*								*
Coleoptera	Hydrophilidae	*Enochrus*		*		*				
Coleoptera	Hydrophilidae	*Helochares*								
Coleoptera	Hydrophilidae	*Hydrochus*					*			
Coleoptera	Hydrophilidae	*Paracymus*								
Coleoptera	Hydrophilidae	*Sternolophus*								
Coleoptera	Psephenidae	*Sclerocyphon*	*						*	
Coleoptera	Psephenidae	*Sclerocyphon maculatus*								

Recorded Macroinvertebrates

Order	Family	Species	*Unnamed Creek*	*Stratford East Water Storage Dam*			*Eastern Diversion Drain*			
			Site DV	**Site S1**			**Site EED1**	**Site S2**		
			Autumn 2000	**Sep-01**	**Dec-01**	**Apr-02**	**Autumn 2001**	**Sep-01**	**Dec-01**	**Apr-02**
Coleoptera	Scirtidae	*Undetermined*	*							
Coleoptera	Scirtidae	*Scirtis*								
Decapoda	Atyidae	*Caridinides*				*				*
Decapoda	Atyidae	*Paratya*				*		*	*	*
Decapoda	Atyidae	*Paratya australiensis*								
Decapoda	Parastacidae	*Cherax*								
Decapoda	Palaemonidae	*Macrobrachium*								
Diptera	Ceratopogonidae	*Bezzia*	*		*			*	*	
Diptera	Ceratopogonidae	*Atrichopogon*								
Diptera	Chironomidae	*Chironominae*	*	*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*	*	*			*	*		
Diptera	Chironomidae	*Tanypodinae*	*	*	*	*	*	*	*	*
Diptera	Culicidae	*Anophelini*								
Diptera	Culicidae	*Culicinae*								
Diptera	Dixidae	*Dixa*	*							
Diptera	Muscidae	*Undetermined*								
Diptera	Psychodidae	*Pericoma*								
Diptera	Psychodidae	*sp.*								
Diptera	Simulidae	*Simulium*	*			*			*	
Diptera	Stratiomyidae	*Odontomyia*								
Diptera	Tabanidae	*Tabanus*			*	*			*	
Diptera	Tipulidae	*Undetermined*					*	*		
Ephemeroptera	Baetidae	*Centroptilum*								
Ephemeroptera	Baetidae	*Cloeon*	*		*		*		*	*
Ephemeroptera	Caenidae	*Tasmanocoenis*			*	*			*	*
Ephemeroptera	Leptophlebiidae	*Atalophlebia*					*	*	*	*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*	*							
Ephemeroptera	Leptophlebiidae	*Jappa*								
Ephemeroptera	Leptophlebiidae	*Koorrnonga*								
Ephemeroptera	Leptophlebiidae	*Nousia*					*			
Gastropoda	Ancylidae	*Ferrissia*							*	
Gastropoda	Ancylidae	*Ferrissia petterdi*								
Gastropoda	Lymnaeidae	*Austropeplea*				*			*	
Gastropoda	Lymnaeidae	*Austropeplea lessoni*								
Gastropoda	Lymnaeidae	*Pseudosuccinea*							*	
Gastropoda	Physidae	*Physa*				*	*			*
Gastropoda	Physidae	*Physa acuta*								
Gastropoda	Physidae	*Physella*		*						
Gastropoda	Physidae	*Haitia acuta*								

Recorded Macroinvertebrates

Order	Family	Species	Unnamed Creek	Stratford East Water Storage Dam			Eastern Diversion Drain			
			Site DV	Site S1			Site EED1	Site S2		
			Autumn 2000	Sep-01	Dec-01	Apr-02	Autumn 2001	Sep-01	Dec-01	Apr-02
Gastropoda	Planorbidae	*Glyptophysa*								
Gastropoda	Planorbidae	*Glyptophysa gibbosa*								
Gastropoda	Planorbidae	*Gyraulus*								
Gastropoda	Planorbidae	*Helicorbus*					*			
Gastropoda	Planorbidae	*Isidorella*	*	*	*		*			*
Neotaenioglossa	Hydrobiidae	*Undetermined*					*			
Hemiptera	Corixidae	*Agraptocorixa*					*			
Hemiptera	Corixidae	*Micronecta*		*						
Hemiptera	Corixidae	*Micronecta sp.*								
Hemiptera	Corixidae	*Sigara*							*	
Hemiptera	Gerridae	*sp.*								
Hemiptera	Gerridae	*Undetermined*								
Hemiptera	Hydrometridae	*Hydrometra*								
Hemiptera	Naucoridae	*Naucoris*								
Hemiptera	Nepidae	*Laccotrephes tristis*								
Hemiptera	Nepidae	*Ranatra*			*					*
Hemiptera	Notonectidae	*Anisops*					*	*		
Hemiptera	Notonectidae	*Enithares*			*		*	*	*	
Hemiptera	Pleidae	*Plea*								
Hemiptera	Veliidae	*Microvelia*	*			*				
Hirudinea	Glossiphoniidae	*Undetermined*				*				
Hirudinea	Richardsonianidae	*Richardsoniana*								
Hirudinea	Richardsonianidae	*Undetermined*								
Isopoda	Oniscidea	*Undetermined*								
Megaloptera	Corydalidae	*Archichauliodes*	*						*	
Megaloptera	Corydalidae	*Archichauliodes guttiferus*								
Megaloptera	Sialidae	*Austrosialis*								
Odonata	Aeshnidae	*Aeshna*	*			*		*	*	*
Odonata	Coenagrionidae	*Ischnura*		*	*	*	*	*	*	
Odonata	Cordulephyidae	*Cordulephya*			*					
Odonata	Gomphidae	*Austrogomphus*							*	
Odonata	Gomphidae	*Hemigomphus*								
Odonata	Hemicorduliidae	*Hemicordulia*		*	*			*	*	*
Odonata	Isostictidae	*Rhadinosticta*								
Odonata	Lestidae	*Austrolestes*								
Odonata	Libellulidae	*Diplacodes*			*	*			*	*
Odonata	Libellulidae	*Nannophlebia*								
Odonata	Libellulidae	*Orthetrum*				*				*
Odonata	Megapodagrionida	*Austroargiolestes*					*			*
Odonata	Synthemistidae	*Eusynthemis*								

Recorded Macroinvertebrates

Order	Family	Species	*Unnamed Creek*	*Stratford East Water Storage Dam*			*Eastern Diversion Drain*			
			Site DV	**Site S1**			**Site EED1**	**Site S2**		
			Autumn 2000	**Sep-01**	**Dec-01**	**Apr-02**	**Autumn 2001**	**Sep-01**	**Dec-01**	**Apr-02**
Oligochaete	Enchytraetidae	*Achaeta*								
Oligochaete	Lumbriculidae	*Lumbricus*								
Oligochaete	Lumbriculidae	*Lumbricus variegatus*								
Oligochaete	Phreodrilidae	*Phreodrilus*								
Oligochaete	Tubificidae	*Undetermined*			*					
Platyhelminthes	Dugesiidae	*Undetermined*					*			
Plecoptera	Eustheniidae	*Thaumatoperla*								
Plecoptera	Gripopterygidae	*Illiesoperla*	*				*			
Trichoptera	Calamoceratidae	*Anisocentropus*				*			*	*
Trichoptera	Ecnomidae	*Ecnomus*	*						*	*
Trichoptera	Hydrobiosidae	*Apsilochorema*								
Trichoptera	Hydropsychidae	*Asmicridea*								
Trichoptera	Hydropsychidae	*Cheumatopsyche*								
Trichoptera	Hydroptilidae	*Hellyethira*	*					*	*	
Trichoptera	Leptoceridae	*Notalina*		*			*	*		
Trichoptera	Leptoceridae	*Notalina spira*								
Trichoptera	Leptoceridae	*Oecetis*			*	*	*			
Trichoptera	Leptoceridae	*Triplectides*	*	*	*	*	*		*	*
Trichoptera	Limnephilidae	*Archaeophylax*								
Trichoptera	Odontoceridae	*Marilia*								
Trichoptera	Philopotamidae	*Chimarra*								
Trichoptera	Polycentropidae	*Plectrocnemia*	*							

Recorded Macroinvertebrates

Order	Family	Species	*Dam Discharge Gully*												
			Site S3												
			Sep-01	**Dec-01**	**Apr-02**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Acariformes	Eylaidae	*Eylais*	*	*								*			
Acariformes	Hygrobatidae	*undetermined*													*
Acariformes	Ixodidae	*Ixodes*													
Acarina	Pionidae	*Undetermined*													
Amphipoda	Talitridae	*Undetermined*													
Arachnida	Araneae	*Undetermined*													
Bivalvia	Hyriidae	*Hyridella*													
Bivalvia	Sphaeridae	*Pisidium*	*	*	*					*			*	*	*
Bivalvia	Corbiculidae	*Corbicula*													
Coleoptera	Dytiscidae	*Antiporus*													
Coleoptera	Dytiscidae	*Australphilus*													
Coleoptera	Dytiscidae	*Batrachomatus*		*				*			*		*		
Coleoptera	Dytiscidae	*Bidessodes*	*	*								*			*
Coleoptera	Dytiscidae	*Bidessus*							*			*		*	
Coleoptera	Dytiscidae	*Chostonectes*			*										
Coleoptera	Dytiscidae	*Eretes*													
Coleoptera	Dytiscidae	*Gibbidessus*													
Coleoptera	Dytiscidae	*Hydrovatus*								*					
Coleoptera	Dytiscidae	*Hyphydrus*													
Coleoptera	Dytiscidae	*Lancetes*													
Coleoptera	Dytiscidae	*Necterosoma*	*	*		*	*			*	*	*	*	*	*
Coleoptera	Dytiscidae	*Paroster*													
Coleoptera	Dytiscidae	*Rhantus*													
Coleoptera	Dytiscidae	*Sternopriscus*		*						*	*	*			
Coleoptera	Elmidae	*Austrolimnius*					*			*				*	
Coleoptera	Elmidae	*Kingolus*													
Coleoptera	Elmidae	*Notriolus*													
Coleoptera	Elmidae	*Simsonia*													
Coleoptera	Gyrinidae	*Macrogyrus*	*								*			*	*
Coleoptera	Haliplidae	*Haliplus*	*				*		*	*			*	*	
Coleoptera	Hydraenidae	*undetermined*													
Coleoptera	Hydraenidae	*Hydraena*				*									
Coleoptera	Hydrophilidae	*Berosus*	*	*	*		*			*	*	*		*	
Coleoptera	Hydrophilidae	*Enochrus*								*		*			
Coleoptera	Hydrophilidae	*Helochares*													
Coleoptera	Hydrophilidae	*Hydrochus*							*						*
Coleoptera	Hydrophilidae	*Paracymus*													
Coleoptera	Hydrophilidae	*Sternolophus*													
Coleoptera	Psephenidae	*Sclerocyphon*	*	*					*	*	*		*	*	
Coleoptera	Psephenidae	*Sclerocyphon maculatus*					*								

Recorded Macroinvertebrates

Order	Family	Species	*Dam Discharge Gully*												
			Site S3												
			Sep-01	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Coleoptera	Scirtidae	*Undetermined*			*									*	
Coleoptera	Scirtidae	*Scirtis*													
Decapoda	Atyidae	*Caridinides*	*		*				*	*			*	*	*
Decapoda	Atyidae	*Paratya*	*								*	*			
Decapoda	Atyidae	*Paratya australiensis*					*								
Decapoda	Parastacidae	*Cherax*													
Decapoda	Palaemonidae	*Macrobrachium*													
Diptera	Ceratopogonidae	*Bezzia*					*			*	*				*
Diptera	Ceratopogonidae	*Atrichopogon*													
Diptera	Chironomidae	*Chironominae*	*				*		*	*	*	*	*	*	*
Diptera	Chironomidae	*Orthocladinae*	*		*				*	*	*		*		
Diptera	Chironomidae	*Tanypodinae*	*		*		*		*	*	*	*	*	*	*
Diptera	Culicidae	*Anophelini*													
Diptera	Culicidae	*Culicinae*						*				*		*	*
Diptera	Dixidae	*Dixa*													
Diptera	Muscidae	*Undetermined*				*									
Diptera	Psychodidae	*Pericoma*													
Diptera	Psychodidae	*sp.*													
Diptera	Simulidae	*Simulium*			*					*					
Diptera	Stratiomyidae	*Odontomyia*													
Diptera	Tabanidae	*Tabanus*													
Diptera	Tipulidae	*Undetermined*		*											
Ephemeroptera	Baetidae	*Centroptilum*													
Ephemeroptera	Baetidae	*Cloeon*	*		*			*	*	*	*	*	*	*	
Ephemeroptera	Caenidae	*Tasmanocoenis*	*				*		*				*	*	
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	*		*				*	*	*	*	*	*	*
Ephemeroptera	Leptophlebiidae	*Austrophlebioides*													
Ephemeroptera	Leptophlebiidae	*Jappa*													
Ephemeroptera	Leptophlebiidae	*Koorrnonga*													
Ephemeroptera	Leptophlebiidae	*Nousia*													
Gastropoda	Ancylidae	*Ferrissia*	*											*	
Gastropoda	Ancylidae	*Ferrissia petterdi*					*								
Gastropoda	Lymnaeidae	*Austropeplea*	*						*				*		*
Gastropoda	Lymnaeidae	*Austropeplea lessoni*					*								
Gastropoda	Lymnaeidae	*Pseudosuccinea*													
Gastropoda	Physidae	*Physa*							*		*	*			
Gastropoda	Physidae	*Physa acuta*					*	*							
Gastropoda	Physidae	*Physella*	*												
Gastropoda	Physidae	*Haitia acuta*												*	*

Recorded Macroinvertebrates

Order	Family	Species	*Dam Discharge Gully*												
			Site S3												
			Sep-01	**Dec-01**	**Apr-02**	**Feb-03**	**Mar-03**	**Mar-04**	**Nov-04**	**Nov-05**	**Oct-06**	**Oct-07**	**Oct-08**	**Oct-09**	**Oct-10**
Gastropoda	Planorbidae	*Glyptophysa*			*				*				*		*
Gastropoda	Planorbidae	*Glyptophysa gibbosa*					*								
Gastropoda	Planorbidae	*Gyraulus*										*		*	*
Gastropoda	Planorbidae	*Helicorbus*												*	
Gastropoda	Planorbidae	*Isidorella*	*		*					*	*				
Neotaenioglossa	Hydrobiidae	*Undetermined*													
Hemiptera	Corixidae	*Agraptocorixa*									*	*			
Hemiptera	Corixidae	*Micronecta*									*	*			*
Hemiptera	Corixidae	*Micronecta sp.*													
Hemiptera	Corixidae	*Sigara*													
Hemiptera	Gerridae	*sp.*											*		
Hemiptera	Gerridae	*Undetermined*							*						
Hemiptera	Hydrometridae	*Hydrometra*													*
Hemiptera	Naucoridae	*Naucoris*													
Hemiptera	Nepidae	*Laccotrephes tristis*													*
Hemiptera	Nepidae	*Ranatra*													
Hemiptera	Notonectidae	*Anisops*							*			*	*		
Hemiptera	Notonectidae	*Enithares*	*		*										*
Hemiptera	Pleidae	*Plea*													
Hemiptera	Veliidae	*Microvelia*		*					*	*		*	*		
Hirudinea	Glossiphoniidae	*Undetermined*			*		*						*		
Hirudinea	Richardsonianidae	*Richardsoniana*													
Hirudinea	Richardsonianidae	*Undetermined*													
Isopoda	Oniscidea	*Undetermined*													
Megaloptera	Corydalidae	*Archichauliodes*	*												
Megaloptera	Corydalidae	*Archichauliodes guttiferus*													
Megaloptera	Sialidae	*Austrosialis*	*				*								
Odonata	Aeshnidae	*Aeshna*		*	*										
Odonata	Coenagrionidae	*Ischnura*		*	*		*		*			*	*	*	
Odonata	Cordulephyidae	*Cordulephya*													
Odonata	Gomphidae	*Austrogomphus*													
Odonata	Gomphidae	*Hemigomphus*													
Odonata	Hemicorduliidae	*Hemicordulia*	*		*										
Odonata	Isostictidae	*Rhadinosticta*													
Odonata	Lestidae	*Austrolestes*													
Odonata	Libellulidae	*Diplacodes*			*		*			*	*		*	*	
Odonata	Libellulidae	*Nannophlebia*					*								
Odonata	Libellulidae	*Orthetrum*													
Odonata	Megapodagrionida	*Austroargiolestes*	*	*	*				*					*	*
Odonata	Synthemistidae	*Eusynthemis*													

Recorded Macroinvertebrates

Order	Family	Species	Dam Discharge Gully												
			Site S3												
			Sep-01	Dec-01	Apr-02	Feb-03	Mar-03	Mar-04	Nov-04	Nov-05	Oct-06	Oct-07	Oct-08	Oct-09	Oct-10
Oligochaete	Enchytraetidae	*Achaeta*													
Oligochaete	Lumbriculidae	*Lumbricus*								*		*		*	
Oligochaete	Lumbriculidae	*Lumbricus variegatus*						*							
Oligochaete	Phreodrilidae	*Phreodrilus*													
Oligochaete	Tubificidae	*Undetermined*		*	*		*		*			*			
Platyhelminthes	Dugesiidae	*Undetermined*								*		*			
Plecoptera	Eustheniidae	*Thaumatoperla*													
Plecoptera	Gripopterygidae	*Illiesoperla*							*						
Trichoptera	Calamoceratidae	*Anisocentropus*											*		
Trichoptera	Ecnomidae	*Ecnomus*													
Trichoptera	Hydrobiosidae	*Apsilochorema*													
Trichoptera	Hydropsychidae	*Asmicridea*													
Trichoptera	Hydropsychidae	*Cheumatopsyche*													
Trichoptera	Hydroptilidae	*Hellyethira*		*					*	*	*	*	*		*
Trichoptera	Leptoceridae	*Notalina*													
Trichoptera	Leptoceridae	*Notalina spira*													
Trichoptera	Leptoceridae	*Oecetis*								*	*			*	*
Trichoptera	Leptoceridae	*Triplectides*	*		*		*		*	*	*	*	*	*	*
Trichoptera	Limnephilidae	*Archaeophylax*													
Trichoptera	Odontoceridae	*Marilia*													
Trichoptera	Philopotamidae	*Chimarra*													
Trichoptera	Polycentropidae	*Plectrocnemia*													

Appendix B
Site Descriptions

This appendix provides detailed descriptions and photographs of each site surveyed during the current surveys and the date and type of survey conducted at each site.

Reach	Description	Photograph
Upstream Sites		
Site AR Avon River, upstream of Crowthers Road bridge	Site comprised a meandering narrow channel. Several bridge pylons crossed the stream. The lower bank was steeply sloping and moderately high (3 to 4 metres [m]) with moderate stability. The riparian zone was 10 m on the left bank and was dominated by Lomandra and Casuarina trees; on the right bank the riparian zone was 5 m and dominated by grass. Limited in-stream habitat included mostly detritus and trailing bank vegetation. In-stream substrate was dominated by sand. Overall disturbance was moderate due to sandy deposition from upstream erosion, the road crossing and access by livestock.	 View upstream of Crowthers Road bridge at Site AR
Site AC Avondale Creek, north of Glen Road	Site comprised a shallow channel draining the upper reaches of Avondale Creek. Although typically dry, the waterway was flowing during the survey due to recent rain. Both banks were relatively low (0.2 to 2 m) with low stability. Erosion was evident on both banks. The riparian zone was <5 m on each bank and dominated by grass. In-stream habitat included extensive vegetation, mainly grasses. In-stream substrate was dominated by sand and silt/clay. Overall disturbance was high due to surrounding agriculture and livestock.	 View upstream at Site AC

Reach	Description	Photograph
Site W3 Dog Trap Creek, north-east of Wenhams Cox Road	Site comprised a shallow, narrow channel meandering through grazing pasture, and downstream from a cement bridge with pylons. Cattle accessed the stream during the survey. Both the left and right banks were moderately sloping and relatively low (0.5 to 2 m) with moderate stability. The riparian zone was 5 to 10 m on each bank and dominated by grass, shrubs and several Casuarina trees. Limited in-stream habitat included some vegetation, detritus and some filamentous algae. In-stream substrate was dominated by sand with some gravel and silt/clay. Overall disturbance was high due to access by livestock, weeds and discarded rubbish.	 View downstream at Site W3
Downstream Sites		
Site W1 Avon River, ~3.0 kilometres (km) upstream of the confluence of Avon River and Avondale Creek	Site comprised a 5 m wide channel both upstream and downstream of a cement bridge with pylons in the stream. Both the left and right banks were steep and moderately high (2 to 8 m) with high stability. The riparian zone was 10 to 15 m on each bank and was densely vegetated by shrubs, vines and Casuarina trees. In-stream habitat included woody debris, detritus and vegetation. In-stream substrate was dominated by sand and silt/clay with pebbles and gravel around the bridge. Overall disturbance was moderate due to proximity to the mine and the bridge.	 View downstream at Site W1

Reach	Description	Photograph
Site W2 Avon River, ~0.1 km downstream of the confluence of Avon River and Avondale Creek	Site comprised a 5 m wide channel with several deep pools. A gravel ford crossed the river. Both the left and right banks were steep and moderately low (1 to 4.5 m) with high stability. The riparian zone was 10 m on each bank, densely vegetated by grass and shrubs together with Eucalypt and Casuarina trees. In-stream habitat was sub-dominated by cobbles, overhanging, trailing and in-stream vegetation. In-stream substrate was dominated by sand, gravel and pebbles. Overall disturbance was moderate due to local agriculture, livestock and the road crossing.	 View downstream at Site W2
Site W5 Avondale Creek, ~1.7 km downstream of Site W8 on mining lease application boundary	Site comprised a straight, narrow channel upstream from a several large culverts. Livestock were excluded from the waterway for the previous 12 months. Both the left and right banks were relatively low (0.5 to 3 m) with moderate stability. The riparian zone was <5 m on each bank and dominated by grass. In-stream vegetation was extensive, consisting of macrophytes and filamentous algae. In-stream substrate was composed mostly of silt/clay. Overall disturbance was high due to the bridge crossing and proximity to the mine.	 View upstream at Site W5

Reach	Description	Photograph
Site W8 Avondale Creek, within mining lease and directly downstream of mining operations	Site comprised a narrow channel with several small deep pools and boulders upstream near two large culverts. Both the left and right banks were relatively low (1 to 2 m) with low to moderate stability. The riparian zone was <5 m on each bank and dominated by grass. In-stream habitat was dominated by boulders, together with vegetation and detritus. In-stream substrate was composed of sand and silt/clay, boulders and cobble. Overall disturbance was high due to proximity to the mine.	 View downstream at Site W8
Site S3 East of Stratford Main Pit, in a dam discharge gully feeding into Avondale Creek	Site comprised a sinuous stream flowing through a small wetland. Both the left and right banks were moderately low (0.5 to 4 m) with moderate to high stability. The riparian zone was 20 to 30 m on each bank and dominated by rushes, ferns, grass, Eucalypt, Melaleuca and Casuarina trees. In-stream habitat was dominated by woody debris, together with vegetation and detritus. In-stream substrate was composed of silt/clay with small amounts of sand and gravel. Overall disturbance was moderate due to past livestock access and proximity to the mine.	 View upstream at Site S3

Reach	Description	Photograph
Site SD7 Sediment dam north of mine water storage area and waste rock emplacement	Site comprised a disused sediment dam ~0.2 km from an open pit. Several culverts located to the south of the dam, led under the road to the mining works, providing a flow path from the mine to the dam. The banks were gently sloping and low (0.5 to 2 m) with moderate stability. The riparian zone was <5 m around the dam and dominated by grass. In-stream vegetation was extensive, consisting of macrophytes and filamentous algae. In-stream substrate was composed mostly of silt/clay. Overall disturbance was high due to discarded rubbish, local agriculture and proximity to the mine.	 View east across Site SD7

Date and Type of Survey at Each Site.

Site	Location	Survey					
		Aquatic Habitat	Aquatic Flora	Aquatic Macroinvertebrates	Fish	Turtles	Platypus
Upstream Sites							
AR	Avon River, upstream of Crowthers Road bridge	08/06/11	08/06/11	08/06/11	08/06/11	08/06/11	08/06/11
AC	Avondale Creek, north of Glen Road	07/06/11	07/06/11	–	–	–	–
W1	Avon River, upstream of confluence of Avon River and Avondale Creek	12/06/11	12/06/11	12/06/11	12/06/11	12/06/11	–
W3	Dog Trap Creek, north-east of Wenhams Cox Road	07/06/11	07/06/11	07/06/11	07/06/11	–	–
Downstream Sites							
W2	Avon River, downstream of confluence of Avon River and Avondale Creek	06/06/11	07/06/11	07/06/11	06/06/11	06/06/11	07/06/11
W5	Avondale Creek, downstream of Site W8 on mining lease application boundary	07/06/11	07/06/11	07/06/11	07/06/11	–	–
W8	Avondale Creek, within mining lease and directly downstream of mining operations	08/06/11	08/06/11	08/06/11	08/06/11	08/06/11	–
S3	East of Stratford Main Pit, in ephemeral stream feeding into Avondale Creek	08/06/11	08/06/11	08/06/11	08/06/11	–	–
SD7	Sediment dam north of mine water storage area and waste rock emplacement	07/06/11	12/06/11	12/06/11	12/06/11	12/06/11	–

– not surveyed

Appendix C
Habitat and Water Quality within the Survey Area

Contents

Tables

Figures

Plates

This appendix provides additional information on aquatic habitat and water quality within the study area.

Section 1 presents photographs of habitat features within the study area; Section 2 provides additional information on water quality parameters recorded during the current survey and compares these results with previous records, and Section 3 describes the habitat for aquatic fauna within the study from a regional and ecological perspective.

1 Photographs of Habitat Features within the Study Area

Photographs depicting habitat features within the study area are shown on Plates 1.1 to 1.8.

Plate 1.1

Boulders at Site W8.

Plate 1.2

A small cascade at Site W1.

Plate 1.3

The riparian zone at Site W8 was dominated by pasture grasses.

Plate 1.4

The riparian zone at Site W1 included vines and several mature trees.

Plate 1.5

The land adjacent to Site AC was used for grazing by cattle.

Plate 1.6

Bank erosion at Site W3 due to cattle.

Plate 1.7

Bank erosion at Site W5 due to clearance of vegetation.

Plate 1.8

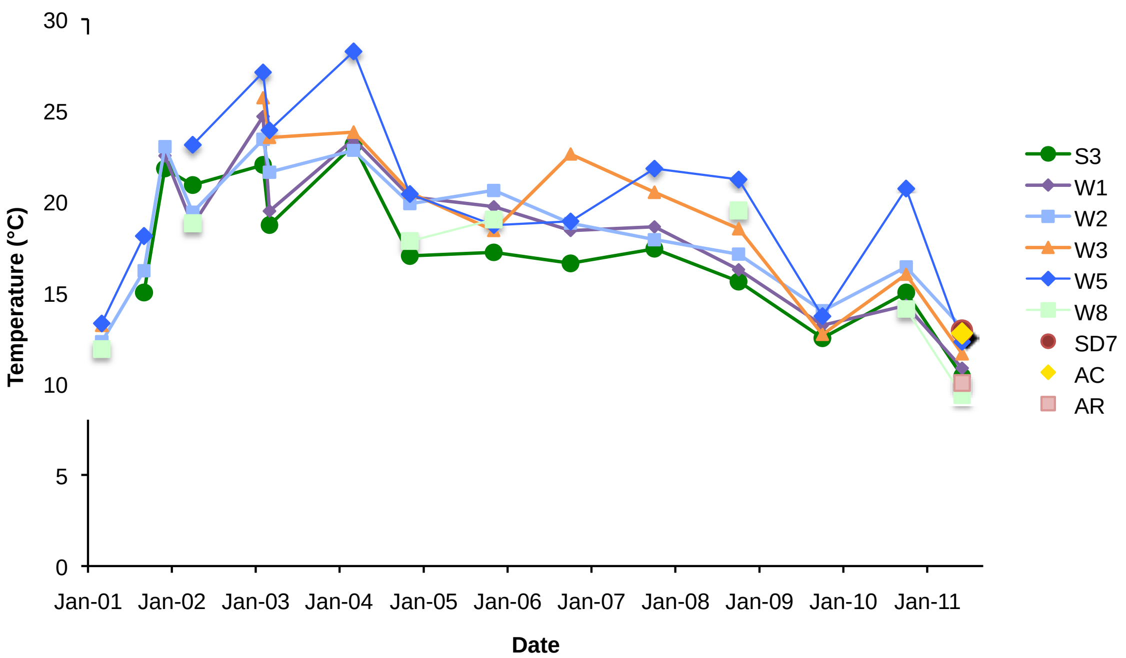
Overhanging and trailing bank vegetation at Site W1.

2 Water Quality

This section provides additional information on water quality parameters recorded during the survey. Current water quality parameters were compared with previous surveys undertaken by Invertebrate Identification Australasia (IIA) (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) and are described below.

2.1 Water Temperature

Temperatures recorded in the current survey were slightly lower than those of previous surveys undertaken by IIA (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) (Figure 2.1). This was due to the timing in which the temperature was taken during the 2011 survey. The 2011 survey was undertaken during winter, while previous surveys (IIA 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010) were undertaken in summer.



°C = degrees Celsius

Figure 2.1 Temperature at each site from 2001 to 2011.

Turbidity

Turbidity at each site was recorded in the 2010 survey by IIA (2010). Turbidity was higher at all sites in 2011 than in 2010 (Table 2.1). This was likely to be due to recent high flows.

Table 2.1 Turbidity in 2011 compared to turbidity in 2010.

Year	Upstream Sites				Downstream Sites				
	AR	**AC**	**W1**	**W3**	**W2**	**W5**	**W8**	**S3**	**SD7**
2010	–	–	11.1	8.0	12.7	10.4	4.7	4.9	–
2011	41.2	56.6	27.9	29.0	56.2	45.9	14.1	44.7	52.9

– not recorded.

pH

The pH in 2011 was lower than previous surveys conducted by IIA (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010), particularly at Site W1. The pH remained relatively consistent at most sites over the previous five years (Figure 2.2).

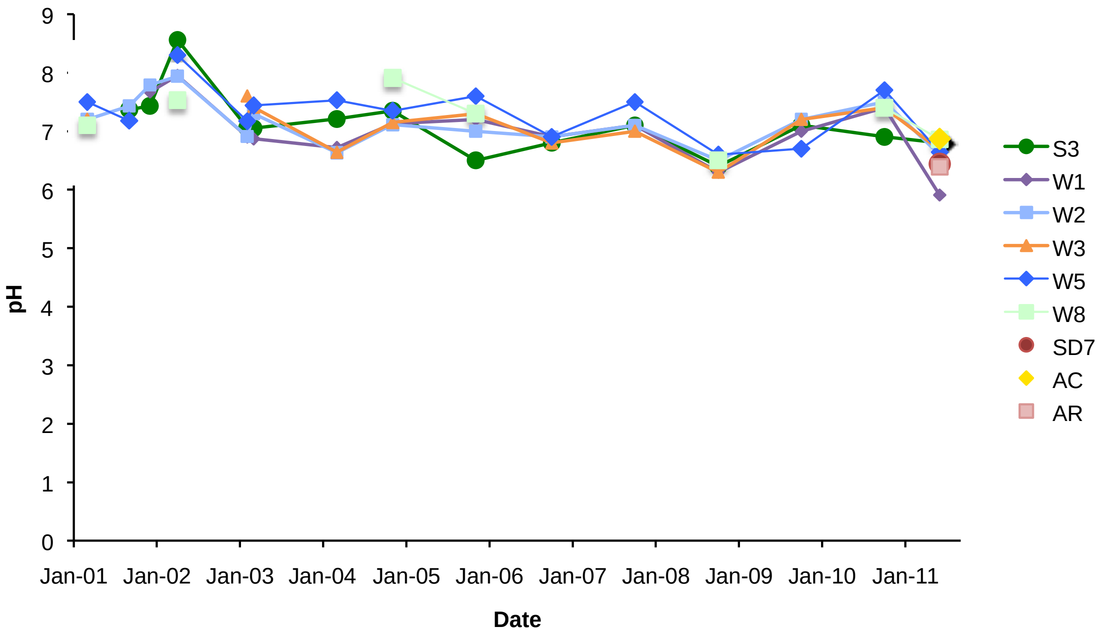
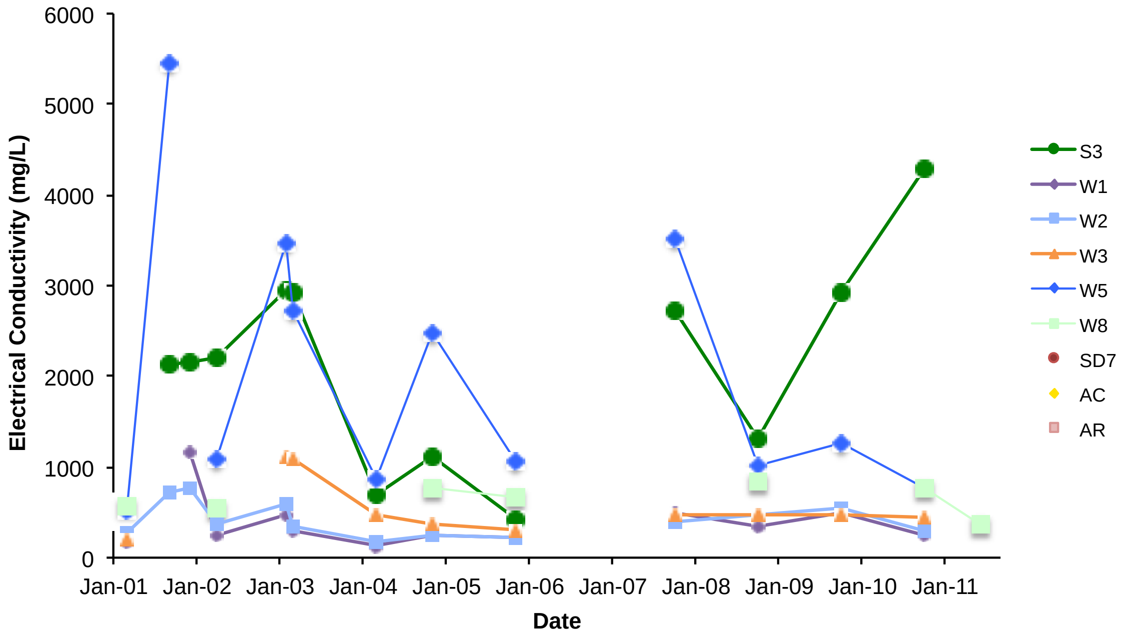


Figure 2.2 The pH at each site from 2001 to 2011.

Electrical Conductivity

The range in electrical conductivity in 2011 was much less than in previous surveys conducted by IIA (2001a, 2001b, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010). Electrical conductivity at all sites, except sites S3 and W5 (downstream of mining activities), were relatively consistent over time. Historically, sites S3 and W5 had highly variable electrical conductivity compared to the other sites (Figure 2.3).



mg/L = milligrams per litre

Figure 2.3 Electrical conductivity at each site from 2001 to 2011.

Dissolved Oxygen

Dissolved oxygen was much higher in 2011 than in previous surveys conducted by IIA (2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010). Ranges of dissolved oxygen were:

- 8.1 to 12.6 milligrams per litre (mg/L) in 2011; compared to
- 1.6 to 4.5 mg/L in 2010.

This may be related to a combination of high flows during the 2011 survey, site-specific levels of solar exposure and the production of algae (Figure 2.4).

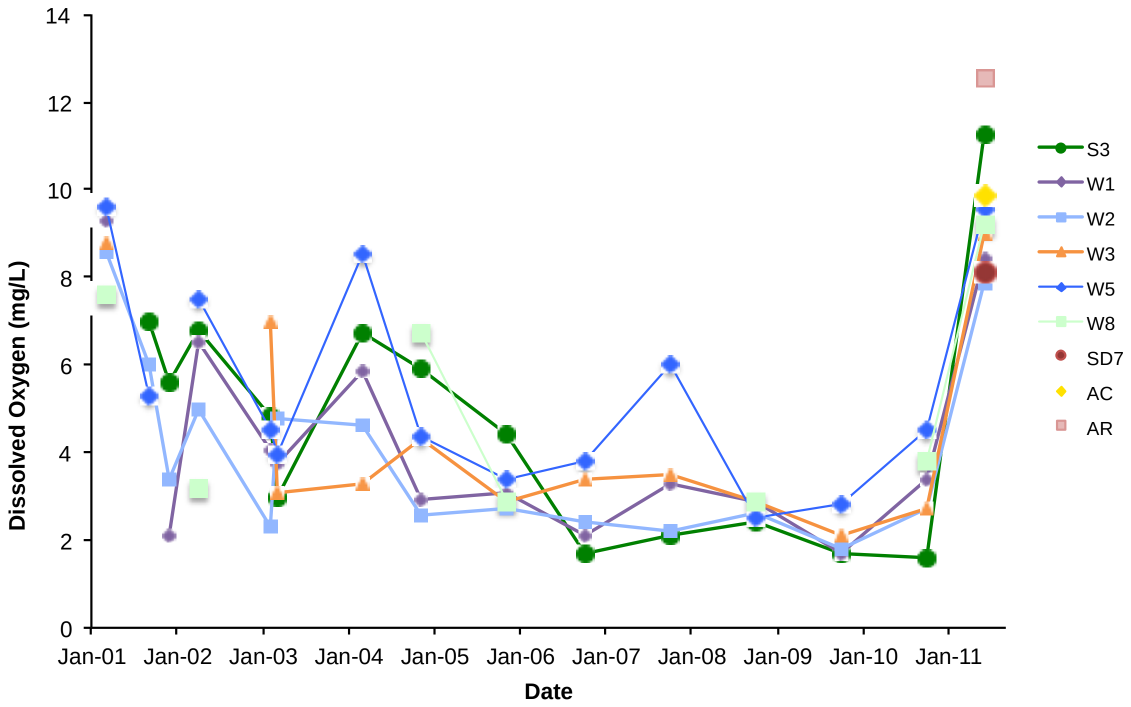


Figure 2.4 Dissolved oxygen at each site from 2001 to 2011.

Alkalinity

Alkalinity was lower in 2011 than in June 2010 (2011: 39 to 92 mg $CaCO_3$/L, 2010: ~50 to 250 mg $CaCO_3$/L). This was most likely due to the high rainfall in the months before the survey. The lower alkalinity may explain the lower pH in 2011. Alkalinity data were not provided in the IIA reports.

3 Regional and Ecological Perspective

The first State of the Catchments assessment was completed for the Hunter-Central Rivers Catchment of New South Wales (NSW) in 2010 (NSW Department of Environment, Climate Change and Water [DECCW] 2010a). The Hunter-Central Rivers Catchment covers 37,000 square kilometres of the east coast of NSW from Taree in the north to Gosford in the south (Figure 3.1). It includes the Manning River and the major tributaries of the Manning Catchment; the Barrington and Gloucester Rivers.

Hose and Turak (2004) provide further information on the health of the local aquatic habitat. Their report provides a regional summary of Australian River Assessment System (AUSRIVAS) assessments sampled in the Central Coast, Hunter and Lower North Catchments from 1994 to 1999. Three sites were near the current survey area:

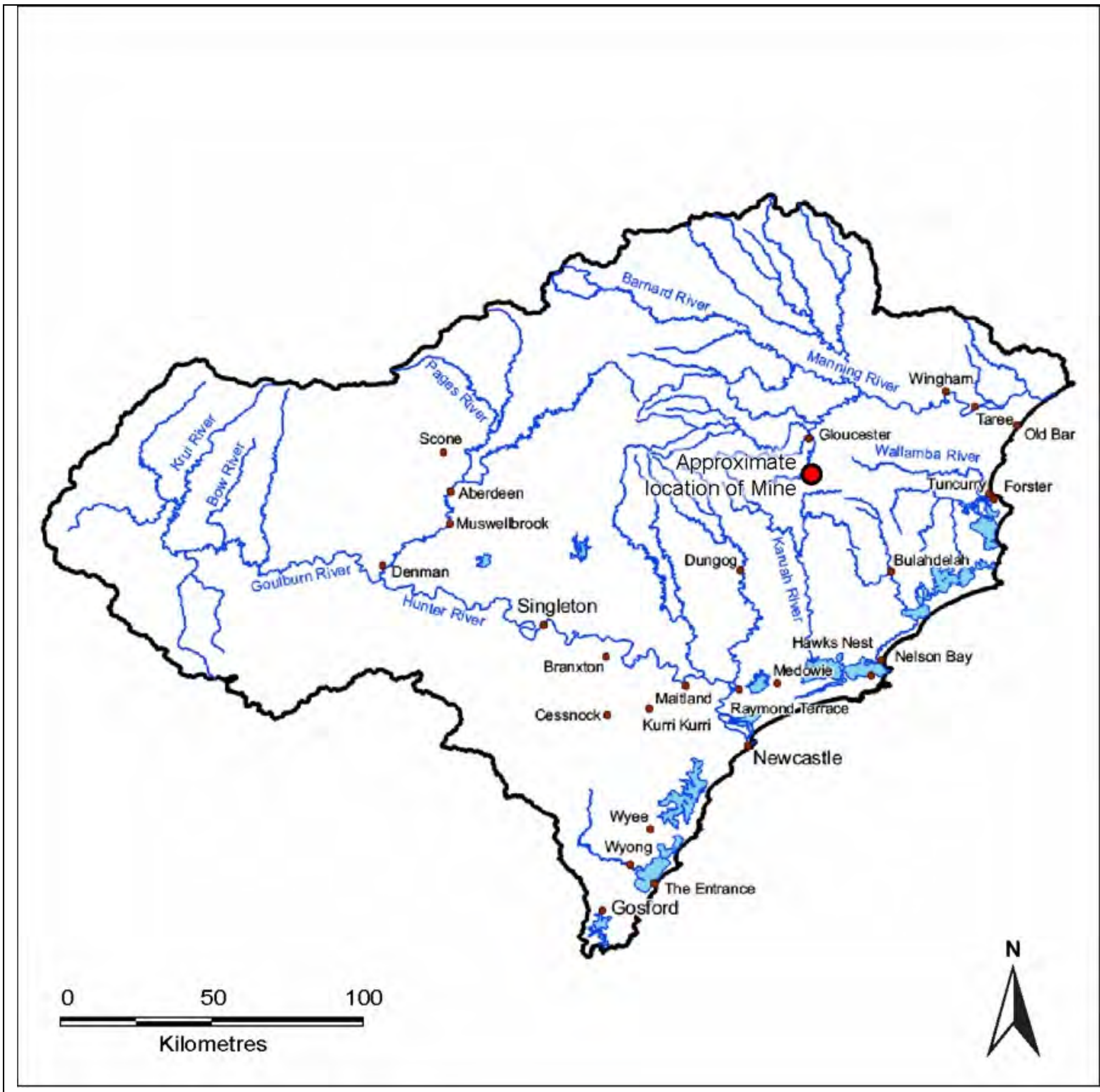
- one site on the Avon River downstream of Stratford; and
- two sites on the Gloucester River:
  - one site upstream of Gloucester; and
  - one site at Gloucester Road on the edge of Barrington Tops National Park.

Raine and Gardiner (1995) present the results of an inventory of riparian vegetation at 16 sites in the Manning River Catchment.

3.1 Riparian Vegetation and Adjacent Land Use

Historically, the riparian vegetation of the Avon River downstream of Stratford has been heavily degraded. Clearing of vegetation has led to bank erosion and invasion of exotic plant species, including willow trees (Hose and Turak 2004). The dominant species of the southern tributaries of the Manning River Catchment (including the Gloucester and Avon Rivers) include:

- Weeping Bottlebrush (*Callistemon viminalis*);
- River Oak (*Casuarina cunninghamiana*); and
- Water Gum (*Tristaniopsis laurina*) (Raine and Gardiner 1995).



frc environmental AQUATIC ECOLOGISTS deep thinking. science.	Stratford Aquatic Ecology	
	Figure 3.1 The Hunter-Central Rivers Catchment.	
	Source: DECCW (2010a)	

Large numbers of exotic weeds are present across the catchment, including:

- Privets (*Ligustrum sinense* and *L. lucidum*);
- Lantana (*Lantana camara*);
- Blackberry (*Rubus fruticosus*); and
- Madeira Vine (*Anredera cordifolia*) (Raine and Gardiner 1995).

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

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

3.2 Bank Stability

The main erosion problems in the Manning River Catchment are:

- floodplain stripping; and
- bank erosion.

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

3.3 Substrate Composition

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

3.4 Channel Diversity

The Manning River Catchment contains a variety of channels, with pools and extensive runs, separated by riffles and occasional boulder/gravel bars. In-stream zones may comprise pool-riffle sequences with cascades, runs and glides (Thomson *et al.* 2004).

3.5 In-stream Habitat

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

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

3.6 Water Quality

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

Historically water quality at the Avon River AUSRIVAS site downstream of Stratford has been poor, with low turbidity and high levels of nutrients, which may contribute to the growth of filamentous algae (Hose and Turak 2004). At the Gloucester River site at Gloucester Road, water quality was good, with all variables within the ranges expected for a relatively undisturbed stream of this type. At the Gloucester River site upstream of Gloucester, water quality was good. However, patches of filamentous algae, covering up to 80% of the stream, were noted in several surveys.

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Appendix D
Aquatic Flora

This appendix provides photographs of macrophytes recorded during the current surveys and a table that lists the macrophyte species recorded at each site and the total percent cover of each macrophyte species.

Plate 1

Persicaria decipiens at Site W2.

Plate 2

Schoenoplectus mucronatus at Site S3.

Plate 3

Juncus usitatus (Common Rush) at Site W8.

Plate 4

Callitriche stagnalis (Common Starwort) at Site W1.

Plate 5

Cardamine hirsuta (Common Bittercress) at Site AR.

Plate 6

Cyperus eragrostis (Umbrella Sedge) at Site W5.

Total percent cover of macrophyte species at each site.

Species	Common Name	Growth Form	Upstream Sites				Downstream Sites				
			AR	AC	W1	W3	W2	W5	W8	S3	SD7
Callitriche stagnalis [a]	Common Starwort	FR	–	–	1	–	–	–	–	–	–
Cardamine hirsuta [a]	Common Bittercress	E	1	–	–	–	–	–	–	–	–
Carex appressa	Tall Sedge	E	–	–	–	–	–	–	–	1	–
Cyperus eragrostis [a]	Umbrella Sedge	E	–	–	–	–	–	3	–	–	–
Cyperus polystachyos	Bunchy Sedge	E	–	–	–	–	–	–	–	1	1
Cyperus sp. [b]	–	E	–	–	–	–	5	–	–	–	–
Eleocharis eqisetina	–	E	–	–	–	–	–	–	–	–	10
Eleocharis sphacelata	Tall Spikerush	E	–	–	–	–	–	–	5	–	60
Isolepis sp. [b]	–	E	–	–	1	–	–	–	–	–	–
Juncus prismatocarpus	–	E	–	–	–	–	–	–	2	1	–
Juncus sp. [b]	–	E	–	–	–	–	–	3	–	–	–
Juncus usitatus	Common Rush	E	–	5	–	3	–	2	3	–	5
Leptochloa digitata	Umbrella Canegrass	E	–	–	–	–	–	–	1	–	–
Lomandra longifolia	Honey Reed	E	–	–	2	–	10	–	–	15	–
Marsilea mutica	Nardoo	FR	–	–	–	–	–	–	1	–	–
Oplismenus aemulus	Australian Basket Grass	E	–	–	–	–	20	–	–	–	–
Ottelia ovalifolia	Swamp Lily	FR	–	1	–	–	–	–	–	1	–
Persicaria decipiens	Slender Knotweed	E	1	2	–	–	7	5	–	–	5
Persicaria sp. [b]	–	E	1	–	3	–	–	–	5	2	–

Species	Common Name	Growth Form	Upstream Sites				Downstream Sites				
			AR	AC	W1	W3	W2	W5	W8	S3	SD7
Philydrum lanuginosum	Frogmouth	E	–	3	–	–	–	1	–	–	–
Schoenoplectus mucronatus	–	E	–	5	–	–	–	–	–	5	–
Typha latifolia	–	E	–	–	–	–	–	30	–	–	5
Typha sp. [b]	Cumbungi	E	–	–	1	–	–	–	2	1	–
Cyperaceae [b]	–	E	–	–	–	3	–	–	–	–	–
Junacaeae [b]	–	E	1	–	–	–	–	–	–	–	–
Unidentifiable sp. 1 [c]	–	E	2	–	–	–	–	–	–	–	–
Unidentifiable sp. 2 [c]	–	S	–	–	–	–	–	–	–	2	–
Unidentifiable sp. 3 [c]	–	S	–	–	–	–	–	–	1	–	–
Unidentifiable sp. 4 [c]	–	FR	–	–	1	–	–	–	–	–	–
Unidentifiable sp. 5 [c]	–	FR	–	–	1	–	–	–	–	–	–
Unidentifiable sp. 6 [c]	–	S	–	–	–	–	5	–	–	–	–
Total			**6**	**16**	**10**	**6**	**47**	**44**	**20**	**29**	**86**

E: emergent, S: submerged, FR: free-floating, rooted.

[a] introduced species.

[b] unable to be identified by National Herbarium of New South Wales.

[c] unable to be identified by National Herbarium of New South Wales due to lack of reproductive units.

Appendix E
Aquatic Macroinvertebrate Communities

Contents

Tables

Figures

Plates

1 Methods

Aquatic macroinvertebrate communities were assessed at eight sites in a survey from 6 to 12 June 2011. Site AC was not surveyed as the water level was too low.

Details of the sites surveyed are presented in Appendix B.

The sampling of macroinvertebrates was conducted under New South Wales (NSW) Scientific Licence SL100158 issued to frc environmental.

1.1 Sample Collection

Quantitative Samples

At each site, five macroinvertebrate samples were collected from bed habitat and five samples were collected from the edge habitat. Although riffle habitat was available at Site W3, it was of insufficient area to sample. Sediment was disturbed within a 30 x 30 centimetre area for five seconds and each sample was then collected by sweeping a standard triangular-framed, macroinvertebrate sampling net, with 250 micrometres (µm) mesh, through the disturbed area five times. This quantitative sampling enabled a more rigorous analysis of the variability within and between sites.

AUSRIVAS Samples

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

Macrocrustacean Samples

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

Details on fishing methods and survey efforts are presented in Section 6 of the Main Text.

1.2 Data Analysis

Calculation of Indices

Abundance, taxonomic richness, PET richness and SIGNAL 2 scores were calculated for each sample. These indices were used to indicate the current ecological health of surveyed waterways.

Abundance

Abundance is the total number of macroinvertebrates.

Taxonomic Richness

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

PET Richness

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

SIGNAL 2 Scores

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

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

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

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

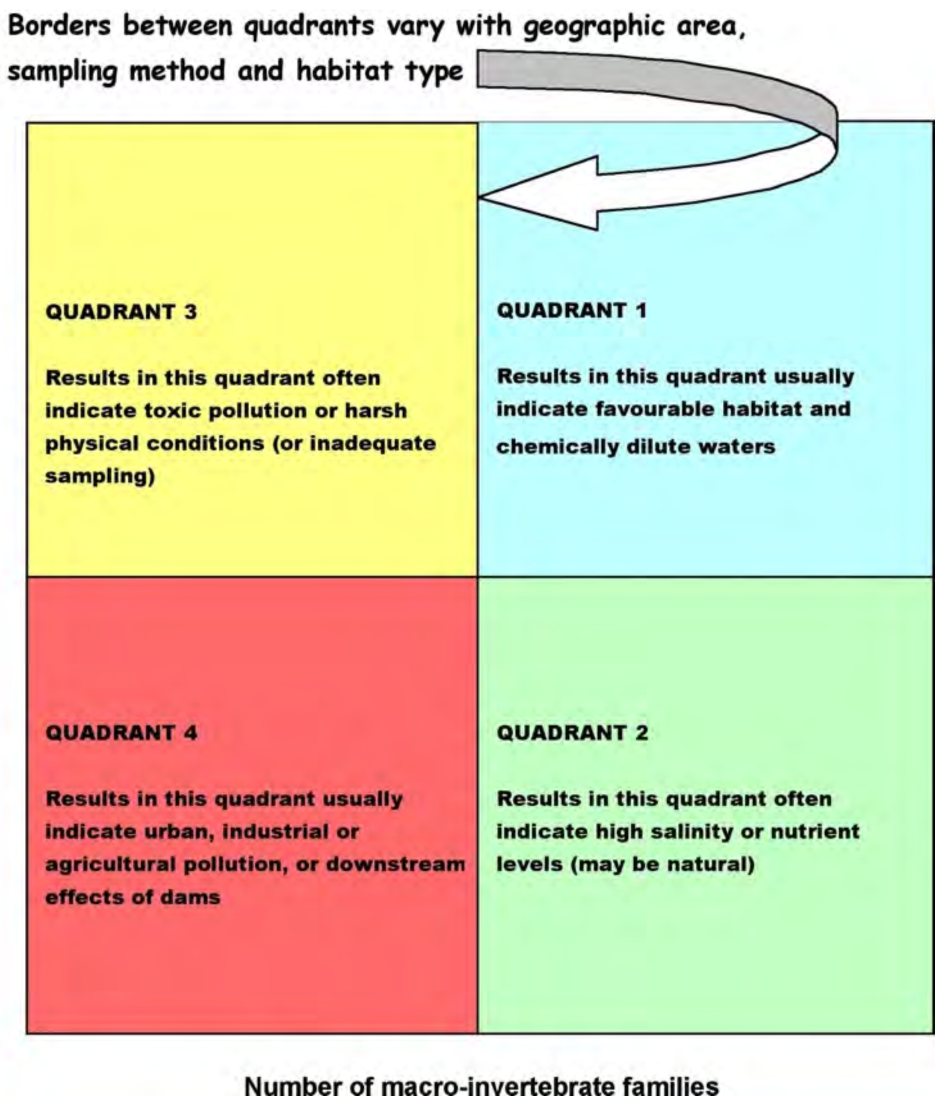

Figure 1.1 Quadrant diagram for SIGNAL 2/Family Bi-plot.

Univariate Statistical Analyses

Analysis of variance (ANOVA) is a statistical hypothesis testing procedure that compares the mean and variance around the mean within each test group (e.g. among replicates within a site) with that among each test group (e.g. sites). The null hypothesis is that this mean is the same for all groups. Generally, if the significance level of the F-test (*p* value) is below 0.05, the null hypothesis can be rejected. A one-way ANOVA test was used to determine differences in the macroinvertebrate indices among sites. A significant difference ($p < 0.05$) at a downstream site, relative to upstream sites, may indicate an impact associated with the mine.

As macroinvertebrate richness is strongly linked to habitat type, differences were analysed separately for each habitat. Where an ANOVA test indicated significant differences among sites, a Tukey's Honestly Significant Difference (HSD) test was used to determine which pairs of sites differed. Data were log-transformed to correct for heterogeneity of variance following the Cochran C Hartley Bartlett test.

Multivariate Analyses of Quantitative Samples

Multivariate analyses consider changes to the macroinvertebrate community structure as a whole, rather than to a single component of the community (e.g. indicator species) or single indices derived to represent the community (i.e. univariate analyses). Multivariate analyses provide a powerful tool to determine similarities or dissimilarities in community composition (i.e. type and abundance of each taxa) between pre-determined factors (e.g. sites and impacts).

We examined differences in community composition between sites, using a one-way analysis of similarity. Prior to analysis, community data were log-transformed and converted to a Bray-Curtis similarity matrix. Community differences between sites were displayed visually, using the averaged data for each habitat at each site, using non-metric multi-dimensional scaling ordinations. Where sites were closely grouped, these were overlaid by lines indicating 40 percent (%) and/or 60% similarity between sites, as determined using Cluster analysis (Clarke 1993). Individual taxa, that contributed to the differences between sites, were identified using the similarity percentages (SIMPER) species contributions routine (Clarke, 1993).

Assessment of AUSRIVAS Samples

The following were calculated for the AUSRIVAS samples, as described above:

- taxonomic richness;
- PET richness; and
- SIGNAL 2/family bi-plots.

Data for the AUSRIVAS samples from edge habitat at river and stream sites (all sites except Site SD7) were also run through the *AUSRIVAS Macroinvertebrate Bioassessment Predictive Modelling Software V3.1.1* to determine the AURIVAS bandings for each site (Table 1.1).

Table 1.1 New South Wales AUSRIVAS bandings for autumn surveys of invertebrate communities in edge habitat.

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

Source Turak and Waddell (2002).

Data were compared to the results of previous surveys by Invertebrate Identification Australasia (IIA) from 2000 to 2010 where relevant. These surveys were undertaken in the following seasons (IIA 2000, 2001a, 2001b, 2001c, 2002, 2003a, 2003b, 2004a, 2004b, 2005, 2006, 2007, 2008, 2009, 2010):

- autumn (2000, 2001, April 2002, March 2003 and March 2004);
- spring (September 2001, November 2004, November 2005, October 2006, October 2007, October 2008, October 2009 and October 2010); and
- summer (December 2001 and February 2003).

Total taxonomic richness and PET richness were compared to surveys undertaken in by IIA in autumn (2000 to 2004) to allow direct comparison of these indices with the data from the current survey.

2 Results and Discussion

2.1 Quantitative Samples

Community Composition

Bed Habitat

Variation in community composition between sites was due to differences in the abundance of non-biting midge larvae (subfamilies Chironominae and Tanypodinae), water boatman (family Corixidae), mayfly nymphs (family Baetidae) and riffle beetles (family Elmidae). Site W5 was significantly different to other sites due to lower numbers of non-biting midge larvae (subfamily Chironominae) and the presence of crane flies (family Tipulidae) and dragonflies (family Libellulidae). Site W8 was significantly different due to the presence of freshwater yabbies (family Parastacidae) (SIMPER). These differences do not infer poor habitat or water quality at these sites.

Edge Habitat

Variation in community composition between sites was due to differences in the abundance of non-biting midge larvae (subfamilies Chironominae and Tanypodinae), mayfly nymphs (family Baetidae), gastropods (family Physidae), pea shells (family Sphaeriidae) and diving beetles (family Dytiscidae). Site W2 was significantly different to other sites due to the lack of non-biting midge larvae (subfamily Chironominae and Tanypodinae) (SIMPER). This would have contributed to the lower richness and abundance at Site W2 (see below), but as these taxa are tolerant of poor habitat and water quality, it is not necessarily indicative of degradation.

Mean Abundance

Significant differences in abundance between sites were due to the lower abundance in edge habitat at Site W2, and in bed habitat at sites W2 and W8 (Table 2.1, ANOVA, Tukey's HSD test). Aquatic habitat was moderately disturbed at Site W2 due to cattle access to the creek, high turbidity and low dissolved oxygen; and habitat at Site W8 was highly disturbed due to a lack of trees in the riparian zone (Appendix C), although habitat condition and physicochemical water quality was also poor to moderate at other sites surveyed (such as sites W5 and SD7). As discussed above, community composition at sites W2 and W8 does not necessarily reflect a degraded condition.

Table 2.1 ANOVA results for differences in mean abundance among sites in bed and edge habitat.

Mean Abundance	Bed Habitat			Edge Habitat		
Factor	**df**	**MS**	**F/Sig.**	**df**	**MS**	**F/Sig.**
Site	7	8.13	10.13**	7	5.02	5.62**
Error	31	0.80		32	0.89	

Abundance data were log(x+1) transformed to correct for heterogeneity of variance following Cochran C Hartley Bartlett test ($p < 0.05$).

* denotes a $p < 0.01$ and ** $p < 0.001$.

Total Taxonomic Richness

Total taxonomic richness in downstream sites was within the range of the upstream sites, except in edge habitat at sites W2 and SD7 and bed habitat at sites W8 and SD7. This may be due to the poor habitat and/or physicochemical water quality at these sites (Appendix C), however as discussed above low richness at Site W2 was in part due to a lack of non-biting midge larvae, which are tolerant species that are often abundant in degraded habitats.

Mean Taxonomic Richness

Significant differences in taxonomic richness between sites were due to the lower richness in edge habitat at Site W2, and in bed habitat at Site W8, compared to the majority of other sites (Table 2.2, ANOVA, Tukey's HSD test).

Table 2.2 ANOVA results for differences in mean taxonomic richness among sites in bed and edge habitat.

Mean Taxonomic Richness	Bed Habitat			Edge Habitat		
Factor	**df**	**MS**	**F/Sig.**	**df**	**MS**	**F/Sig.**
Site	7	0.97	4.09*	7	1.07	4.45*
Error	31	0.24		32	0.24	

Richness data were log(x+1) transformed to correct for heterogeneity of variance following Cochran C Hartley Bartlett test ($p < 0.05$).

* denotes a $p < 0.01$ and ** $p < 0.001$.

2.2 AUSRIVAS Samples

Total Taxonomic Richness

Total taxonomic richness was compared to surveys conducted by IIA (2000, 2001c, 2002, 2003b, 2004a). Results indicated that total taxonomic richness was variable at each site over time. Taxonomic richness has increased at sites W3 and W5 since autumn 2004 (Figure 2.1).

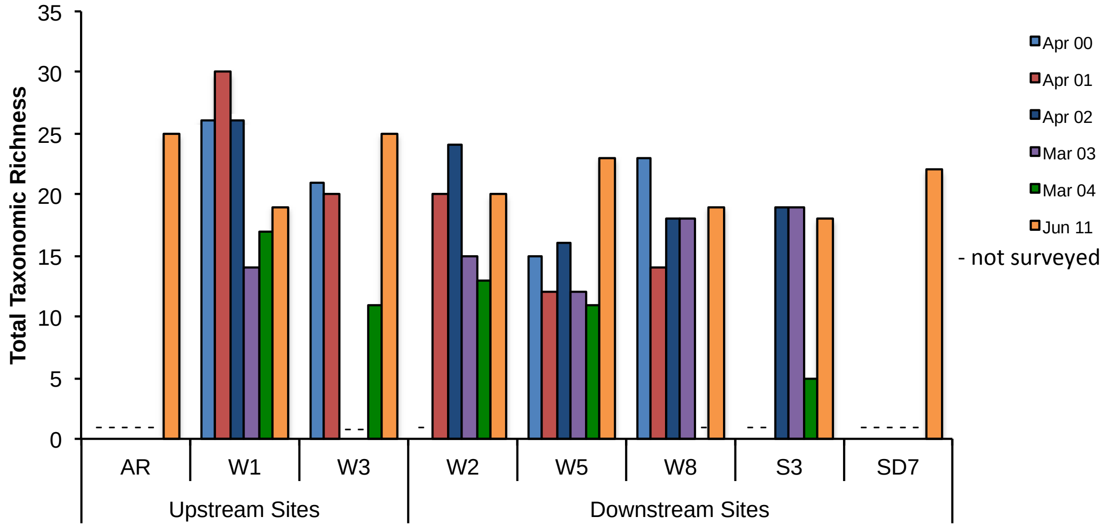

Figure 2.1 Total taxonomic richness in edge habitat at each site, surveyed in autumn by IIA in 2000 to 2004, and frc environmental in 2011.

Total PET Richness

Total PET richness was compared to surveys conducted by IIA (2000, 2001c, 2002, 2003b, 2004a). Total PET richness was generally lower in 2011 than in autumn 2000 to 2002, but higher than or similar to total PET richness in autumn 2003 and 2004. At Site W2 on the Avon River, total PET richness has decreased over time (Figure 2.2).

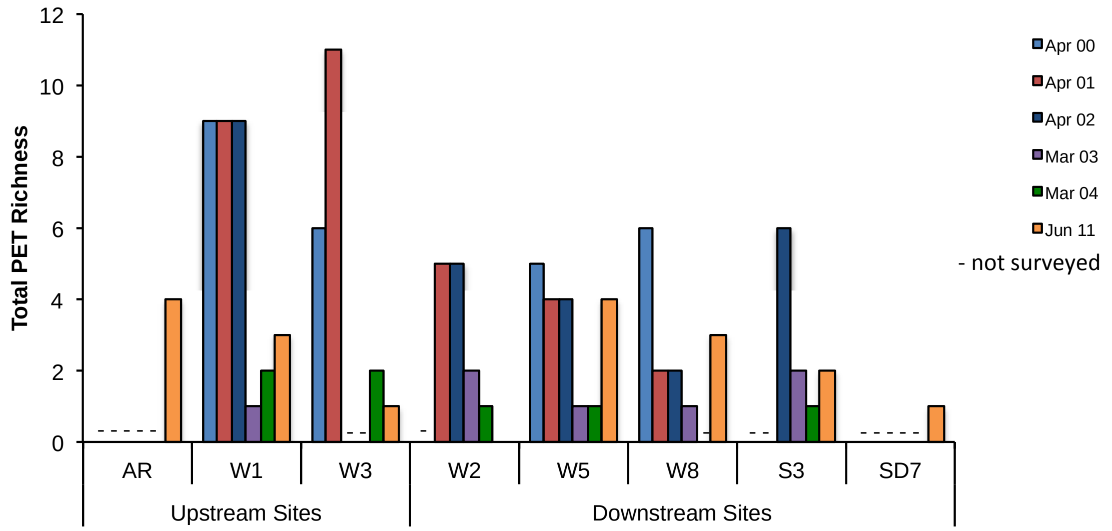

Figure 2.2 Total PET richness in edge habitat at each site, surveyed in autumn by IIA in 2000 to 2004, and frc environmental in 2011.

SIGNAL 2/Family Bi-plot

Communities at upstream and downstream sites were generally within quadrants 2 (which indicates high salinity or nutrient levels) and quadrant 4 (which indicates industrial or agricultural pollution). Sites surveyed in 2004 (IIA 2004a) were also in quadrants 2 and 4, which suggests the condition of sites have remained relatively consistent over time. Upstream Site W3 and two downstream sites were within quadrant 1, which indicates favourable habitat and chemically dilute waters. Site SD7 was within quadrant 3, which indicates toxic pollution or harsh physical conditions.

AUSRIVAS Bandings

The AUSRIVAS results indicate that sites AR and W2 on the Avon River had the lowest overall condition for macroinvertebrate communities (i.e. there were less taxa than were expected at these sites). The reasons for this are unclear; however, the low AUSRIVAS results may be because the AUSRIVAS model used the biodiversity and water conditions of a local reference site to compare conditions of the survey sites. The AUSRIVAS model includes factors such as:

- alkalinity;
- altitude;

- substrate components;
- distance from the source;
- slope; and
- rainfall.

The AUSRIVAS reference site closely reflects the conditions found at Site W3 and does not closely reflect the other sites.

The condition of the aquatic macroinvertebrate community at upstream Site W3 (Dog Trap Creek, north-east of Wenhams Cox Road) had improved compared to the previous year, while the condition of the community at Site W2 (Avon River, below confluence of Avon River and Avondale Creek) had declined. Since 2010, the condition at all other sites remained consistent (IIA 2010). The 2011 AUSRIVAS survey was in autumn, and the 2010 AUSRIVAS survey was in spring (IIA 2010) (Table 2.3).

Table 2.3 AUSRIVAS bandings for invertebrate communities in edge habitat in 2010 and 2011.

Survey	Upstream Sites			Downstream Sites			
	AR	**W1**	**W3**	**W2**	**W5**	**W8**	**S3**
2010 (IIA 2010)	–	B	C	A	B	B	B
2011 (Current survey)	C	B	A	C	B	B	B

– not surveyed.
A = reference condition.
B = impaired.
C = severely impaired.

2.3 Macrocrustaceans

Freshwater Prawns

Three species of macrocrustaceans were caught during the survey:

- freshwater prawn (family Atyidae) (Plate 2.1);
- freshwater shrimp (*Macrobrachium* sp.) (Plate 2.2); and
- common yabby (*Cherax destructor*) (Plate 2.3).

Plate 2.1

Freshwater prawn caught at all sites.

Plate 2.2

Freshwater shrimp caught at sites W2, W3, W5 and W8.

Plate 2.3

Freshwater yabby caught at sites W8 and S3.

Freshwater prawns dominated the catch of macrocrustaceans, accounting for approximately 80 to 100% at all sites where macrocrustaceans were found. Several freshwater shrimp were also caught at sites W3, W2, W5 and W8. The common yabby was caught at sites W8 and S3 (Table 2.4). The common yabby is listed as vulnerable on the International Union for Conservation of Nature and Resources Red List of Threatened Species, but is not listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999,* or the NSW *Threatened Species Conservation Act 1995*.

Table 2.4 Abundance of macrocrustaceans at each site.

Family Common name	**Upstream Sites**			**Downstream Sites**					**Total**
	AR	**W1**	**W3**	**W2**	**W5**	**W8**	**S3**	**SD7**	
Atyidae Freshwater prawn	155	55	160	68	12	33	171	–	**654**
Palaemonidae Freshwater shrimp	–	–	5	1	3	2	–	–	**11**
Parastacidae Common yabby	–	–	–	–	–	4	8	–	**12**
Total	**155**	**55**	**165**	**69**	**15**	**39**	**179**	**–**	**677**

– not caught

2.4 Listed Species

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

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Appendix F
Aquatic Vertebrates

Contents

Tables

Plates

1 Aquatic Vertebrates Recorded During the Current Survey

Ten species of fish were caught during the survey (Table 1.1):

- Eastern Gambusia (*Gambusia holbrooki*) (Plate 1.1);
- Firetail Gudgeon (*Hypseleotris galii*) (Plate 1.2);
- Flathead Gudgeon (*Philypnodon grandiceps*) (Plate 1.3);
- Australian Smelt (*Retropinna semoni*) (Plate 1.4);
- Common Goldfish (*Carassius auratus*) (Plate 1.5);
- Striped Gudgeon (*Gobiomorphus australis*) (Plate 1.6);
- Dwarf Flathead Gudgeon (*Philypnodon macrostomus*) (Plate 1.7);
- Freshwater Mullet (*Myxus petardi*) (Plate 1.8);
- Short-finned Eel (*Anguilla australis*) (Plate 1.9); and
- Marbled Eel (*Anguilla reinhardtii*) (also known as the Long-finned Eel).

In addition, one turtle carapace was found on the bank of Site SD7 (Plate 1.10) and one platypus was recorded along the Avon River at Site W2.

Plate 1.1

Eastern Gambusia, caught at all sites.

Table 1.1 Abundance of each fish species collected at each site.

Species	Common Name	Upstream Sites			Downstream Sites					Total
		AR	W1	W3	W2	W5	W8	S3	SD7	
Gambusia holbrooki	Eastern Gambusia [a]	13	4	14	4	1	5	59	81	**181**
Hypseleotris galii	Firetail Gudgeon	2	–	1	1	–	–	52	11	**67**
Philypnodon grandiceps	Flathead Gudgeon	–	–	–	7	–	–	–	–	**7**
Retropinna semoni	Australian Smelt	–	–	–	4	–	–	–	–	**4**
Carassius auratus	Common Goldfish [a]	–	–	–	2	3	–	–	–	**5**
–	Striped Gudgeon	–	–	–	1	–	–	–		**1**
Philypnodon macrostomus	Dwarf Flathead Gudgeon	1	–	–	–	–	–	–	–	**1**
Myxus petardi	Freshwater Mullet	–	–	–	1	–	–	–	–	**1**
Anguilla australis	Short-finned Eel	1	–	–	–	–	–	–	–	**1**
Anguilla reinhardtii	Marbled Eel	–	1	–	–	–	–	–	1	**2**
	Total	**17**	**5**	**15**	**20**	**4**	**5**	**111**	**93**	**270**
	% exotic species	**76%**	**80%**	**93%**	**30%**	**100%**	**100%**	**53%**	**87%**	**69%**

– not caught.
[a] exotic non-indigenous species.
% = percent.

Plate 1.2

Firetail Gudgeon, caught at sites AR, W3, W2, S3 and SD7.

Plate 1.3

Flathead Gudgeon, caught at Site W2.

Plate 1.4

Australian Smelt, caught at Site W2.

Plate 1.5

Common Goldfish, caught at sites W2 and W5.

Plate 1.6

Striped Gudgeon, caught at Site W2.

Plate 1.7

Dwarf Flathead Gudgeon, caught at Site AR.

Plate 1.8

Freshwater Mullet, caught at Site W2.

Plate 1.9

Short-finned Eel, caught at Site AR.

Plate 1.10

Turtle carapace at Site SD7.

2 Regional and Ecological Perspective

2.1 Fish Communities

Community Composition

Twenty native fish species have been recorded from the Manning River Catchment, including two exotic species (Eastern Gambusia and the Common Goldfish) (Harris *et al.* 1996; Howell and Creese 2010).

The fish communities within the Manning River Catchment (as of 2004) are relatively healthy (Howell and Creese 2010). In 2004, 16 fish species were sampled from 11 sites in the Manning River Catchment (Howell and Creese 2010). Species richness averaged 6.45 ± 0.3 species per sampling site, and the average abundance of fish per site was 160 ± 22 individuals. Abundance and biomass was dominated by native species, with 75% of the fish sampled belonging to the following four species:

- Australian Smelt;
- Marbled Eel;
- Freshwater Mullet; and
- Freshwater Herring (*Potamalosa richmondia*).

Except at highland sites, where large numbers of Eastern Gambusia dominated the total abundance, the proportion of native fish species was relatively high (91%).

In the wider Hunter-Central River Catchment, 52 species of finfish (species that inhabit freshwater or estuarine systems) have been recorded (New South Wales [NSW] Department of Primary Industries 2006). The Hunter-Central Rivers Catchment includes key protected species such as the threatened Black Cod (*Epinephelus daemelii*) and Estuary Cod (*Epinephelus coioides*).

Fish Environmental Tolerances

Waterways of the Hunter-Central Rivers Catchment support a wide range of temperate landscape regions including major rivers, wetlands and estuaries (NSW Department of Water and Energy [DWE] 2009). Rivers and creeks of the Manning Catchment are unregulated and there are few major rural dams. Therefore, most water users rely on natural flows for their water supplies (Australian Government 2011). The Manning River also receives annual winter snowmelt from the Barrington Tops Mountains, which are fed from its tributary, the Barrington River.

Many rivers and creeks within the Hunter-Rivers Central Catchment are connected to estuarine habitats, so many species can tolerate a wide range in salinity and require the habitats of both fresh and brackish conditions to complete their life cycles (e.g. marbled eel). The firetail carp gudgeon is perhaps the hardiest of the species caught in the current survey, and tolerates:

- pH from 4.4 to 8.9;
- water temperatures from 8.4 to 31.2 degrees Celsius (ºC); and
- conductivity from 51.0 to 4123.0 microSiemens per centimetre (µS/cm) (Allen *et al.* 2002; Pusey *et al*. 2004).

Most of the species caught can tolerate a large range of water quality conditions (Table 2.1).

The Importance of Flow

Fish dispersal within the Manning Catchment is not often affected by man-made structures, as the catchment is unregulated and flow is not directly obstructed. The Manning Catchment has an average annual rainfall of 1,216 millimetres (DWE 2009), and an annual snowmelt that contributes to the year-round flow of the main river tributaries and creeks.

Fish Caught in this Survey

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

Table 2.1 Fish species in the current survey and the range of water quality conditions in which they were caught.

Family *Latin Name*	**Common name**	**Water Temperature (ºC)**	**Dissolved Oxygen (mg/L)**	**pH**	**Conductivity (µS/cm)**	**Turbidity (NTU)**
Anguillidae						
Anguilla australis	Short-fin Eel [a]	8.4–27.8	2.6–10.4	5.9–8.5	110.0–1231.7	0.5–112.3
Anguilla reinhardtii	Marbled Eel [a]	8.4–31.7	0.3–16.2	5.6–9.1	19.5–2247.0	0.4–331.4
Eleotridae						
Carassius auratus	Common Goldfish*	–	–	–	–	–
Eleotridae						
Gobiomorphus australis	Striped Gudgeon [a]	8.4–29.3	1.7–11.9	4.4–8.5	97.5–2247.0	0.3–200.0
Hypseleotris galii	Firetail Gudgeon [a]	8.4–31.2	0.3–19.5	4.4–8.9	51.0–4123.0	0.1–331.4
Philypnodon grandiceps	Flathead Gudgeon [a]	11.0–31.0	2.6–12.0	6.0–8.6	122.1–2495.0	0.7–36.0
Philypnodon macrostomus	Dwarf Flathead Gudgeon [a]	8.4–31.7	0.3–12.7	6.3–8.9	107.0–4002.0	0.2–36.0
Mugilidae						
Myxus petardi	Freshwater Mullet [b]	9–27	–	–	–	–
Poecilidae						
Gambusia holbrooki	Eastern Gambusia*	–	–	–	–	–
Retropinnidae						
Retropinna semoni	Australian Smelt [c]	8.4–31.7	0.6–16.2	6–9.1	51–1624.2	0.4–144

mg/L = milligrams per litre.
NTU = nephelometric turbidity unit.
[a] Pusey *et al*. 2004.
[b] Allen *et al.* 2002.
[c] frc environmental data from captures during surveys in south-east Queensland. The range in water temperature is expected to be lower in NSW.
* Exotic.

Short-finned Eel

The Short-finned Eel (*Anguilla australis*) is not overly common but occurs within the south-east corner of Australia. It is less common in the northern reaches of NSW and increases in abundance further south in NSW, Victoria and Tasmania (Pusey *et al.* 2004). Although generally a still-water species, it will inhabit a range of aquatic conditions (Table 2.1). The tolerance of the species is considerable as they inhabit freshwater, but in the spawning run, the final stage of the animal's life cycle is spent in oceanic waters (Allen *et al.* 2002; Pusey *et al.* 2004).

Marbled Eel

The Marbled Eel (*Anguilla reinhardtii*) is a common species that occurs from the eastern drainages of Cape York, south through to Melbourne. The species is found throughout freshwater streams, lakes and swamps but prefer flowing water. The Marbled Eel is tolerant of increased salinity as they move to oceanic waters during annual spawning (Allen & Steene 2002).

Common Goldfish

Common Goldfish are an exotic species, introduced into Australia in the 1960s as an ornamental fish (Allen *et al.* 2002). They have now become widely distributed throughout lowland rivers. Inhabiting slow or still water, they are able to tolerate high temperatures and low oxygen concentrations (Allen *et al.* 2002). Common Goldfish feed on plant materials, organic detritus and a variety of small insects (McDowall 1996). Eggs are laid among aquatic plants and hatch after a few days, at which point the young attach themselves to aquatic plants for a few days while they absorb the remainder of their egg yolk (McDowall 1996).

Striped Gudgeon

The Striped Gudgeon (*Gobiomorphus australis*) occurs in eastern coastal catchments of Australia from central Queensland to Wilsons Promontory in eastern Victoria. This species has a patchy distribution north of the Mary River and is more prevalent near the coast at lower altitudes. This species can occupy a wide variety of habitats from large water bodies to small creeks with variable water flow (Allen *et al.* 2002; Pusey *et al.* 2004).

Firetail Gudgeon

The Firetail Gudgeon (*Hypseleotris galii*) has a narrow distribution but is common in coastal drainages of eastern Australia from as far north as Baffle Creek, north of Bundaberg, to the Georges River just south of Sydney (Allen *et al.* 2002). This species can occur in a variety of habitats from flowing streams and rivers to weirs and billabongs (Pusey *et al.* 2004).

Flathead Gudgeon

The Flathead Gudgeon (*Philypnodon grandiceps*) has a widespread and varied distribution. They occur commonly in the south-east coast drainage division between the Burdekin River in Queensland and the Murray River mouth in South Australia (Allen *et al.* 2002; Pusey *et al.* 2004).

Dwarf Flathead Gudgeon

The Dwarf Flathead Gudgeon (*Philypnodon macrostomus*) is widespread within the coastal drainages of eastern Australia from southern Queensland to the Murray River mouth in South Australia and in to Victoria. The Dwarf Flathead Gudgeon is more common in the northern part of the range and is abundant further south and inland (Allen *et al*. 2002; Pusey *et al.* 2004). It is suspected that the range of this species is greater than previously thought as they have been previously confused with Flathead Gudgeon (*Philypnodon grandiceps*) due to the similarities between the juveniles and sub-adults (Pusey *et al.* 2004).

Freshwater Mullet

Freshwater Mullet (*Myxus petardi*) have a restricted range, limited to drainages of the east coast between the Burnett River in Queensland and Georges River in NSW. Despite the narrow range, this species is common. Freshwater Mullet are often found in deep, gently flowing sections of rivers.

Eastern Gambusia

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

Australian Smelt

Australian Smelt are common from the Fitzroy River in Queensland to the Murray River mouth in South Australia, and are also found in Cooper Creek (Allen *et al.* 2002). Australian Smelt are usually found in slow flowing streams and still water, and they shoal near the surface or around aquatic plants and woody debris (Allen *et al.* 2002). Their diet included insects, microcrustaceans and algae (Allen *et al*. 2002). Spawning tends to occur at temperatures over 15^{o}C, usually in late winter and spring (Pusey *et al.* 2004). Eggs generally hatch 10 days after being laid and are placed among aquatic vegetation (Allen *et al.* 2002).

2.2 Other Aquatic Vertebrates

Turtles

Two species of turtles (protected under the NSW *National Parks and Wildlife Act 1974*) may occur in the Manning River Catchment: the Eastern Snake-necked Turtle (*Chelodina longicollis*) and Manning River Snapping Turtle (*Myuchelys purvisi*, previously *Wollumbinia purvisi* / *Elseya purvisi*).

Freshwater turtles are mainly aquatic but come out of the water to lay eggs, to move to other water bodies, and to bask on emergent rocks and logs. Females lay eggs during or after rain, in a nesting chamber in moist soil, usually near water.

The Eastern Snake-necked Turtle is common in most of NSW where it inhabits freshwater ponds, lakes and streams. They are active foragers and sit-and-wait predators, and have a diverse diet of amphibians and other aquatic vertebrates and invertebrates (Green 1992). Their nests are constructed in clay soils, and nesting occurs in early summer (Cogger 1992).

The Manning River Snapping Turtle is found only in the Manning River Catchment. They are omnivorous and consume benthic macroinvertebrates, terrestrial fruit and aquatic vegetation (Allanson & Georges 1999). They feed upon prey that are relatively sedentary such as caddis-fly larvae and lepidopteron larvae (Allanson & Georges 1999).

There are no known records of exotic or threatened turtles in the Hunter-Central Rivers Catchment.

Platypus

The Platypus (*Ornithorhynchus anatinus*) is found throughout the freshwater reaches of the Manning River. Platypuses are found in:

- highly modified streams (with no riparian vegetation) that flow through agricultural land;
- artificial dams; and
- forested habitats with dense riparian vegetation (Fanning *et al.* 1997).

Platypuses eat a variety of macroinvertebrates including shrimps, mayfly and stonefly nymphs, and caddisfly larvae, which they locate by electro-reception (Lake 1995). Platypuses require access to riffle and pool habitats when feeding, and to firm banks for the construction of burrows and nests, for rearing young (Grant 1991). Firm banks are very important from November to March, when the females suckle their young inside the burrows (Grant 1991).

Platypus breeding season varies with latitude. In NSW, mating takes place in September. The intrauterine gestation period lasts about two weeks and eggs hatch after one to two weeks. The young are then suckled for four to five months (Strahan 1995). Food availability is critical from October to January, when females are lactating (Strahan 1995).

While Platypuses are common throughout most of their range, they are dependent on river systems for survival, and major or prolonged disturbance of these systems could lead to a reduction in their distribution (Grant 1991). The Platypus is not listed as threatened under the NSW *Threatened Species Conservation Act 1995* or Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.* However, they are protected (like all native species) under the *National Parks and Wildlife Act 1974*.

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