WILPINJONG COAL PROJECT

APPENDIX HD

Aquatic Ecosystem Assessment

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AQUATIC ECOSYSTEM ASSESSMENT

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BIO-ANALYSIS: Marine, Estuarine & Freshwater Ecology

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HD1 INTRODUCTION

BIO-ANALYSIS was commissioned to conduct an aquatic ecosystem assessment for the Wilpinjong Coal Project (the Project), located in the New South Wales (NSW) Western Coalfield approximately 11 kilometres (km) north-east of the Ulan Coal Mines and approximately 40 km north-east of Mudgee (Figure HD-1).

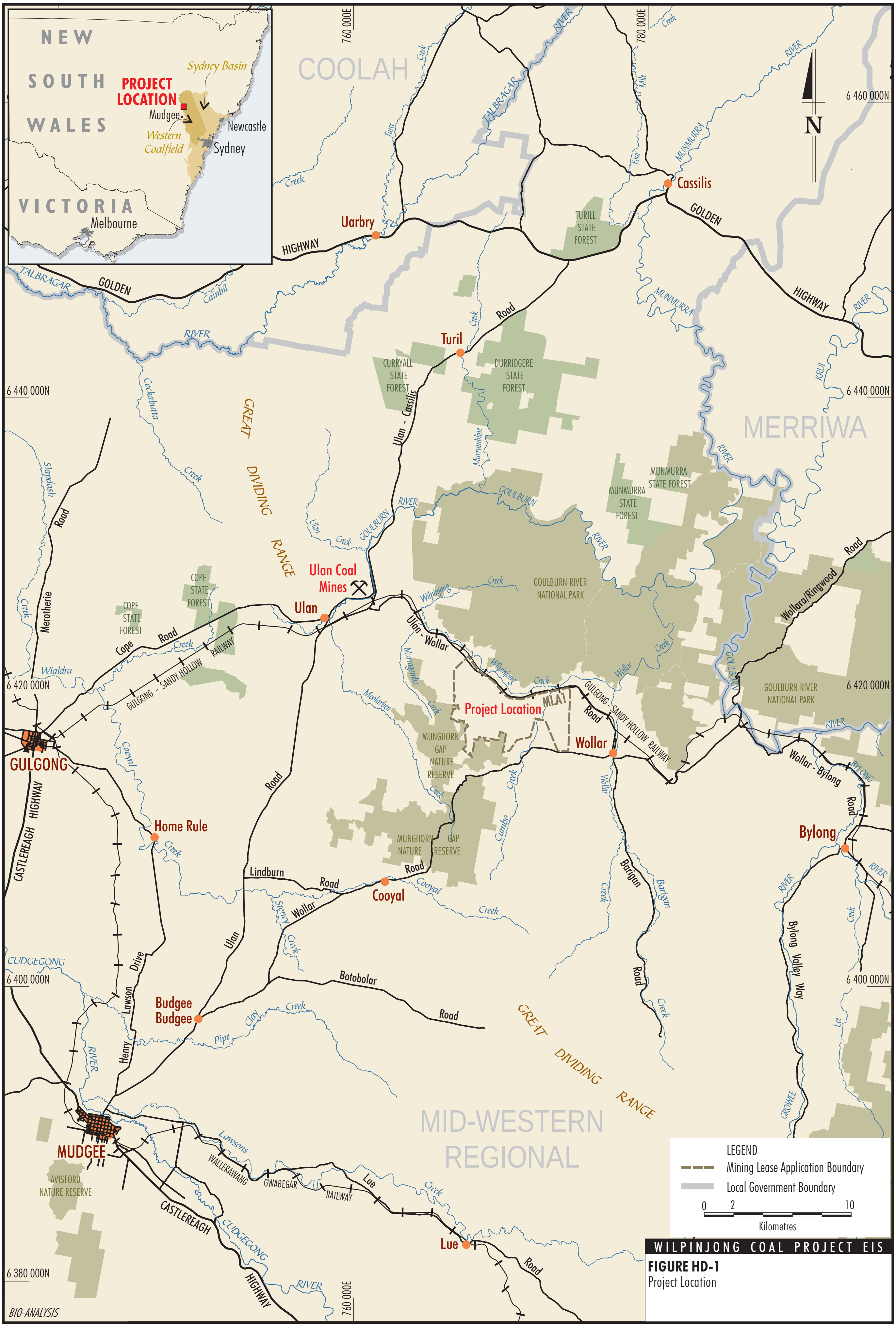
The main activities associated with development of the Project would include:

- development and operation of an open cut mine within the Mining Lease Application (MLA 1) area to produce coal for domestic electricity generation and export markets;
- selective highwall mining of the Ulan Seam within the MLA 1 area;
- a Coal Handling and Preparation Plant (CHPP) and mine facilities area;
- water management infrastructure including the relocation of Cumbo Creek;
- water supply bores and associated pump and pipeline system;
- placement of mine waste rock (i.e. overburden, interburden/partings and coarse rejects) predominantly within mined-out voids;
- placement of tailings within a combination of out-of-pit and in-pit tailings storages;
- development and rehabilitation of final mine landforms and establishment of woodland vegetation in areas adjacent to the Project;
- a mine access road, temporary construction camp access road, internal access roads and haul roads;
- closure of Wilpinjong Road and Bungulla Road;
- realignment of two sections of Ulan-Wollar Road (including the relocation of two road-rail crossings);
- relocation of the existing 11 kilovolt (kV) electricity transmission line;
- an on-site temporary construction camp to accommodate up to 100 people during the construction phase;
- a rail spur and rail loop;
- coal handling and train loading infrastructure;
- transportation of product coal to market via train; and
- Enhancement and Conservation Areas (ECAs).

The Project general arrangement is shown on Figure HD-2. A detailed description of the Project is provided in Section 2, Volume 1, of the Project Environmental Impact Statement (EIS).

HD1.1 BACKGROUND

Urbanisation and development of catchments has caused major disturbances to aquatic systems in NSW. The impacts associated with anthropogenic disturbance generally include the loss of aquatic habitat and reduced biodiversity. Examples of disturbance include water pollution and eutrophication and in some systems, river regulation. The health and function of an aquatic ecosystem is directly dependant on the integrity and influence of its surrounding catchment. Changes to catchment hydraulics through increased percentage of hard surfaces will drastically alter the amount of run-off, which can lead to streambank erosion and greater amounts of sediments leaving the catchment and entering the waterways. With increased urbanisation and poor landuse practices, the degradation of natural vegetation has placed receiving waters under greater pressure resulting in the intrusion of weeds and erosion of riverbanks (Smith *et al*., 1991).



WILPINJONG COAL PROJECT EIS

FIGURE HD-1
Project Location

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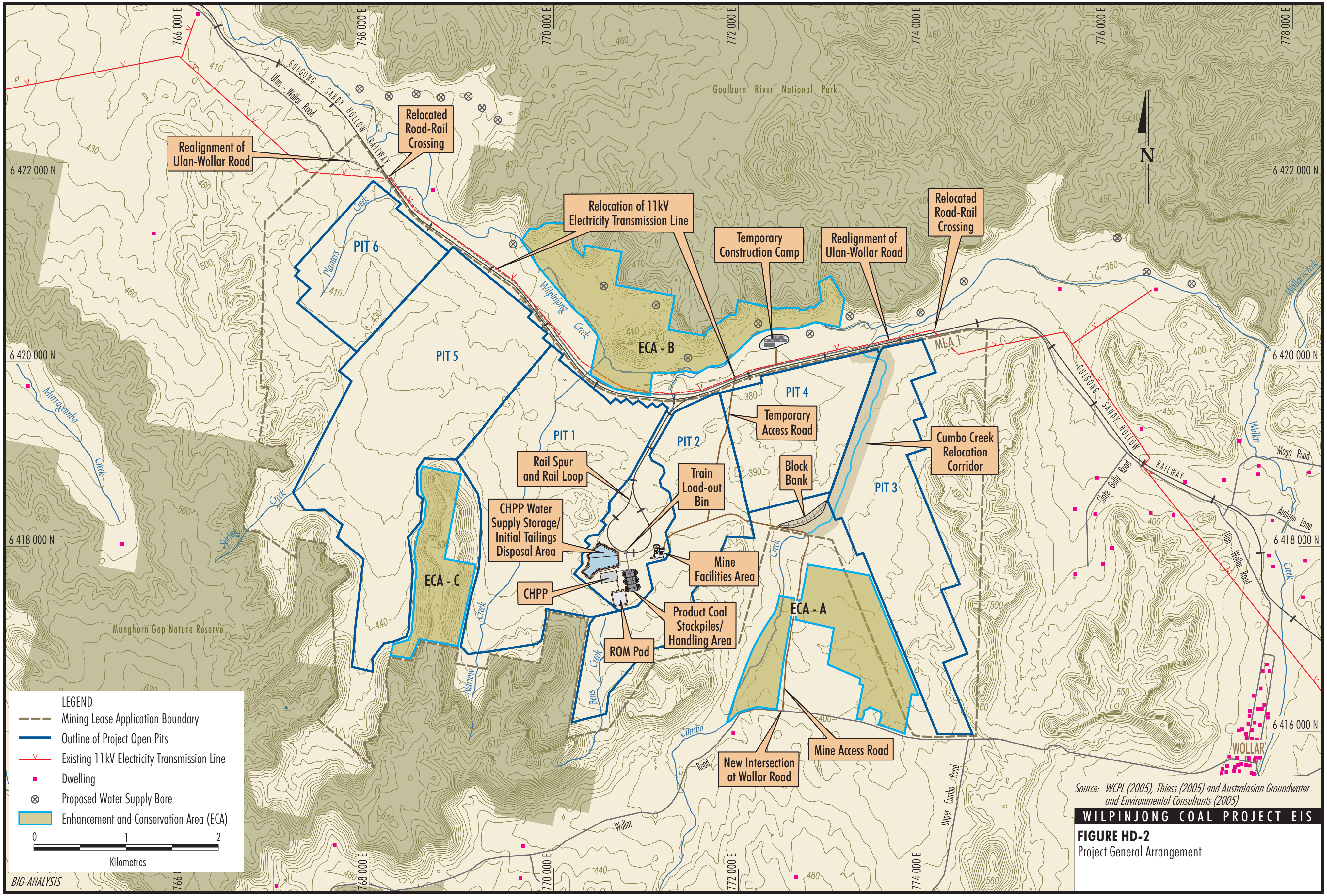


WILPINJONG COAL PROJECT EIS

FIGURE HD-2

Project General Arrangement

WIL-04-01 AqFauna_003M

The native aquatic organisms that inhabit rivers, streams and wetlands in Australia have adapted to millions of years of cycles of drought and flood, which provide natural variability to river ecosystems. The variation in water flows helps to maintain the natural biodiversity within the aquatic ecosystem. River regulation, water consumption and pollution from development all threaten these ecosystems by reducing this variability (Walker and Thoms, 1993; Harris, 1995; Gehrke and Harris, 1996). The composition and abundance of assemblages of macroinvertebrates and fish is controlled by the flow regime, food supply, water quality, biotic interactions and habitat structure (Harris, 1995). Impoundments and structures can create barriers that obstruct the movement of aquatic organisms within river systems and greatly affect their lifecycles (Gehrke and Harris, 1996). Aquatic macrophytes (aquatic plants) are important to the ecology of freshwater ecosystems (Westlake, 1975). They play a significant role as a structural habitat and food source for invertebrates, fish and birds; reducing stream bank erosion; and removing excessive nutrients from aquatic systems (Westlake, 1975; Carpenter and Lodge, 1986; Barko *et al*., 1991). The occurrence of significant beds of aquatic macrophytes can help to reduce algal blooms by either directly competing for nutrients (Rattray *et al*., 1991) or by providing habitats for grazing zooplankton (Moss, 1990). Under pristine conditions a diverse range of aquatic macrophytes can be found within an aquatic system.

These native plants include emergent, submerged and floating species, and their distributions and abundances generally reflect the water quality of the system in which they are found. Macrophyte assemblages in riverine systems in NSW have undergone significant changes in their distribution and abundance over recent years as a result of a variety of anthropogenic disturbances. These disturbances include increased nutrient loading and sedimentation, river regulation, persistent algal blooms, recreational activities such as boating and the deterioration of riparian zones (Roberts *et al*., 1999).

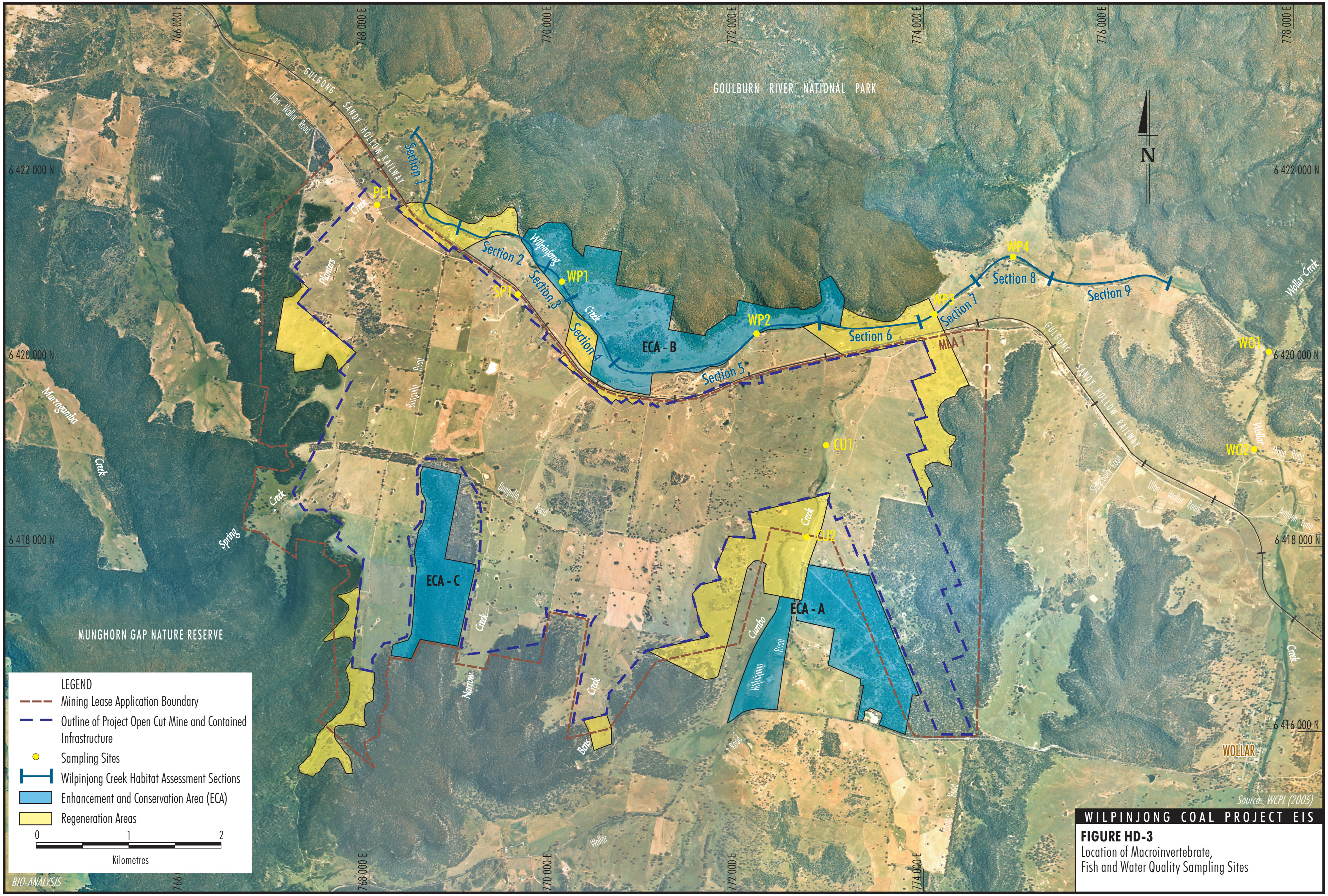
HD1.2 STUDY OBJECTIVES

This report forms the aquatic ecosystem component of the ecological investigations undertaken for the Wilpinjong Coal Project. This report presents the results of an aquatic assessment conducted of Planters, Spring, Cumbo, Wilpinjong and Wollar Creeks (Figure HD-3). The objectives of the study were to:

- assess the characteristics and condition of the habitats available to aquatic biota;
- identify and survey for any aquatic species, populations or ecological communities listed under the NSW *Threatened Species Conservation Act, 1995* (TSC Act), the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) and the *Fisheries Management Act, 1994* considered possible occurrences within the study area;
- collect baseline data on the assemblages of macroinvertebrates, fish and aquatic plants;
- sample stream water quality at the time of the survey;
- quantify the aquatic "health" of the creeks by assessing the assemblages of macroinvertebrates, fish and aquatic plants, the nature of their habitats; and
- report on the findings of the aquatic ecosystem assessment.

HD2 OVERVIEW OF STREAM AND CATCHMENT CHARACTERISTICS

The Project is located at the headwaters of the Hunter River Catchment, which drains some 22,000 square kilometres (km^2) of central eastern NSW to the Pacific Ocean at Newcastle. The Project is located within the Greater Wollar Creek Catchment adjacent to Wilpinjong Creek (Figure HD-2). A number of local watercourses drain the study area to Wilpinjong Creek including Cumbo, Narrow, Bens, Spring and Planters Creeks (Figure HD-2). Wilpinjong Creek flows into Wollar Creek approximately 4 km downstream of the confluence of Cumbo and Wilpinjong Creeks. Wollar Creek flows into the Goulburn River approximately 8 km to the north of the Wollar Creek and Wilpinjong Creek confluence which, in turn, flows to the east of the Project to the Hunter River.



WILPINJONG COAL PROJECT EIS

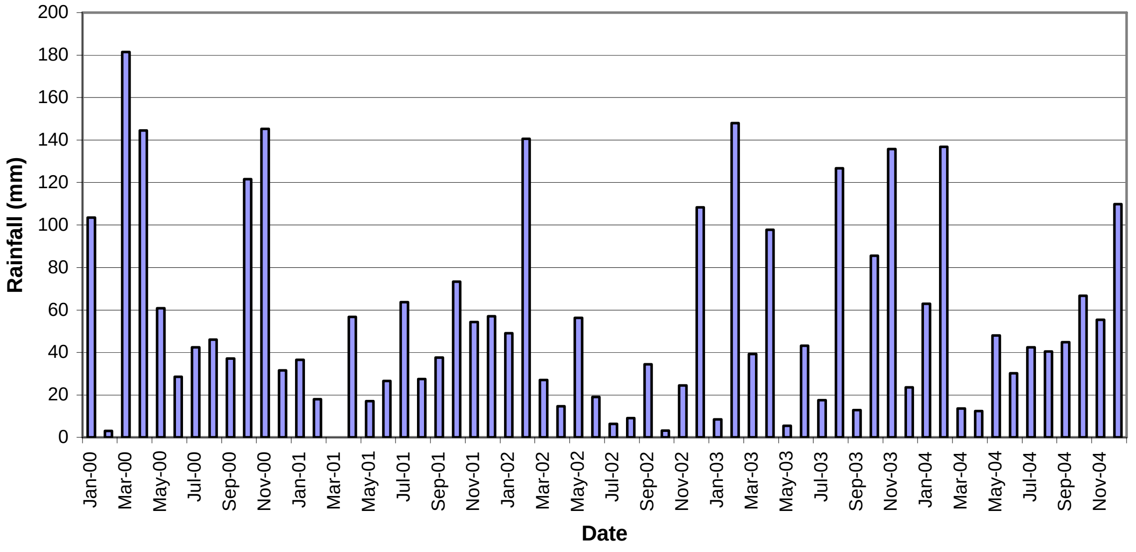
FIGURE HD-3
Location of Macroinvertebrate, Fish and Water Quality Sampling Sites

WIL-04-01 AqFauna_001J

The flow characteristics of the creeks is variable and largely dependent on the intensity and duration of rainfall, as well as soil moisture, degree and type of vegetative cover, evapotranspiration, catchment aquifer baseflow and catchment modifications (Gilbert and Associates, 2005). For the majority of the local watercourses, stream flow is closely related to significant rainfall events. Planters, Spring, Narrow and Bens Creeks are the main natural drainage lines flowing through the Project area. During normal dry weather conditions flow in these creeks would range from semi-perennial, spring fed pools and soaks in the upper reaches near Munghorn Gap Nature Reserve, to wide, ill-defined dry channels in the mid and lower reaches. The creeks would have a rapid response to intense storm rainfall with recession following cessation of rainfall. Often, the only aquatic habitat available is in the form of farm dams located along the drainage lines. Springs and saline groundwater seepages occur along Wilpinjong Creek, Cumbo Creek and lower half of Wollar Creek.

Rainfall is relatively evenly distributed throughout the year, with slightly higher monthly summer falls (Figure HD-4). However, intense rainfall is characteristic of the area and may produce local flash floods. An average annual rainfall of approximately 592 millimetres (mm)/year has been recorded at the Wollar meteorological station (Station Number 62032) for the period 1901 to 2004. The recorded annual rainfall has ranged over this time between 128 mm (1922) and 1,205 mm (1950). Recorded average monthly pan evaporation generally exceeds rainfall for the majority of the year (GeoTerra, 2004).

Figure HD-4
Monthly Rainfall, January 2000 to December 2004



HD3 METHODS

HD3.1 SURVEY TIMING

A preliminary inspection of the study area was undertaken on the 21 May 2004 to identify suitable sampling sites and to conduct the stream habitat assessments. Ten sampling sites were selected from the five creeks; primarily chosen on the basis of available water habitat. Quantitative field surveys of the 10 sampling sites were conducted from the 25 to 27 May 2004. The location of the 10 sampling sites is shown on Figure HD-3.

Weather conditions experienced during this period were generally cool with temperatures of approximately 15 to 17 degrees centigrade (^{o}C). There had been little rain prior to the survey period, with only 13.6 mm recorded in March 2004 and 12.4 mm recorded in April 2004, compared to average monthly rainfalls for March (51.5 mm) and April (39.6 mm) (Wollar meteorological station data from the period 1901 to 2004). During the survey, the Wollar meteorological station recorded a total of 13.6 mm of rain on 25 May and 33.4 mm on the 26 May (the majority of which fell overnight). No rain fell on the 27 May 2004.

HD3.2 AQUATIC HABITAT ASSESSMENT

Habitat characteristics were assessed by walking the length of each stream within the study area. Qualitative information collected included attributes of the riparian zone, surrounding landuse, bank erosion, stream width, water depth, occurrence of pools, riffles and runs, substratum type, presence of snags and woody debris, instream and emergent macrophytes, algae, and barriers to fish passage. Photographs were also taken to help characterise the streams. The aquatic habitat within the study area was given one of three "health" classifications based on the quality of water, sedimentation and erosion, exotic species and diversity and abundance of macrophytes, macroinvertebrates and fish. The classifications were:

Good – generally no evidence of erosion, streambank degradation or excessive sedimentation; water quality excellent; riparian vegetation consists of native species; fish and macroinvertebrate habitat excellent; no exotic weeds, macroinvertebrates or fish species; no artificial barriers to upstream migration.

Moderate – some evidence of erosion, streambank degradation and sedimentation; water quality generally good; riparian vegetation consists mostly of native species; fish and macroinvertebrate habitat good; few exotic weeds, macroinvertebrates or fish species; generally no artificial barriers to upstream migration.

Poor – typically excessive erosion, streambank degradation and sedimentation; water quality poor; riparian vegetation consisting of weeds; poor fish and macroinvertebrate habitat; dominated by exotic weeds, macroinvertebrates or fish species; major artificial barriers to upstream migration.

HD3.3 WATER QUALITY

A number of water quality variables were measured at each sampling site (Figure HD-3). Measurements of physico-chemical water quality were determined using a YEOKAL 611 submersible data logger. Variables included conductivity (microsiemens per centimetre [µS/cm]), salinity (mg/L), dissolved oxygen (milligrams per litre [mg/L] and percentage saturation [%S]), pH (pH units), temperature (^{o}C) and turbidity (Neophelometric Turbidity Units [NTU]). In addition to the physico-chemical variables, waters samples were also collected at each sampling site and analysed for nutrients (nitrogen and phosphorus). The samples were stored on ice and delivered to the Hunter Water Laboratories for analysis. All water quality sampling was conducted on the 26 May 2004.

HD3.4 ASSEMBLAGES OF MACROINVERTEBRATES

At each of the 10 sampling sites (Figure HD-3), three replicate macroinvertebrate samples were collected using timed 1-minute sweeps of all habitats (edge, riffle, pools, etc.), using a 250 x 250 cm (250 µm) dip net (Plate HD-1). The contents of the net were placed into plastic trays filled with fresh water and the macroinvertebrates sorted and placed into pre-labelled plastic sample containers filled with 70% alcohol. The samples were sorted to family level and counted in the laboratory using an ISSCO M400 stereomicroscope.

HD3.5 ASSEMBLAGES OF FISH

Three replicate samples of the assemblages of fish were collected at each site using a Smith-Root 15C Electrofisher backpack unit (Plate HD-2). The Electrofisher was used to stun the fish in open water and in submerged and emergent aquatic vegetation. Three minutes of electrofishing effort per replicate was used. All stunned fish were collected using a dip net and placed into plastic trays filled with water. Fish were identified and counted in the trays and native species were released back into the water once sampling at a site was completed. All field sampling was undertaken in accordance with Section 37 of the NSW *Fisheries Management Act, 1994*, using Scientific Collection Permit Number P03/0032, and NSW Agriculture, Animal Research Authority Care and Ethics Certificate of Approval Number 03/2445.

HD3.6 ASSEMBLAGES OF MACROPHYTES

At each site, an assessment of the submerged and emergent aquatic vegetation was undertaken by estimating the relative abundance or percentage cover of aquatic macrophytes. Distribution of both instream and riparian macrophytes was also estimated along each section of Wilpinjong Creek by assigning a cover class to each species to help characterise the stream. The cover classes included: (*) one plant or small patch, (**) not common, growing in a few places, and (***) widespread (Attachment HD-D).

HD.3.7 DATA ANALYSES

Univariate and multivariate statistical procedures were used to quantify the assemblages of macroinvertebrates and fish within the study area. The univariate data were analysed using the GMAV analysis of variance statistical package (General Linear Model Analysis of Variance). Analysis of variance (ANOVA) was used to determine spatial differences in the richness and abundance of assemblages of macroinvertebrates and fish. Student Newman Kuels (SNK) tests were used to determine where differences were found in the ANOVA (Underwood, 1981). Prior to analysis of variance, the data sets were examined for homogeneity of variances using Cochran's test (Winer, 1971) and if necessary, were transformed to stabilise the variances (Underwood, 1981).

Multivariate statistical techniques were used to examine patterns in assemblages among sites, using the PRIMER (Plymouth Routines in Multivariate Ecological Research) software package (Plymouth Marine Laboratories, UK). Bray-Curtis measures of similarity were used to examine the data matrices (Clarke and Warwick, 1994). Non-metric multidimensional scaling (nMDS) ordinations were constructed to graphically illustrate relationships between samples. The significance of any apparent differences among sites was determined using one-way analysis of similarities (ANOSIM) tests. The similarity of percentages (SIMPER) procedure was used to examine the contribution of taxa to the similarities among sites (Clarke and Warwick, 1994). SIMPER identifies which taxa are good discriminators between the scales of interest. Taxa were listed in decreasing order of importance, up to where 90% of the average similarity is accounted for (Clarke and Warwick, 1994).

The SIGNAL biotic index (Chessman, 1995; Chessman *et al.*, 1997; Chessman, 2003) was used to assign average pollution sensitivity grades to each of the sites. An average SIGNAL value was calculated for each site by summing the sensitivity grades assigned to each macroinvertebrate family and dividing by the number of families at each site. The SIGNAL values range from 1 (most tolerant to pollution) to 10 (most sensitive to pollution). Average SIGNAL values greater than 6 indicate clean water, whilst values between 5 and 6 indicate the water quality is doubtful or mildly polluted. SIGNAL values between 4 and 5 indicate moderate pollution, whilst a value less than 4 indicates severe pollution (Chessman *et al.*, 1997).

HD3.8 THREATENED AQUATIC BIOTA

Searches of the literature, the Atlas of NSW Wildlife, Environment Australia and NSW Fisheries databases were conducted for threatened aquatic species, populations or ecological communities that have the potential to occur in the study area. The review was undertaken prior to the study to ensure that appropriate field methods were selected to target any threatened aquatic biota. The searches indicated that no threatened aquatic biota were likely to occur in the study area or surrounds given the known distribution of the species.

HD4 RESULTS

HD4.1 AQUATIC HABITAT

In general, the aquatic habitats within the study area were quite degraded. Vegetation/land clearance and grazing activities are the most likely cause of this degradation. Nutrients and sediments from runoff, invasions by riparian and aquatic weeds and alterations to natural stream flows have all exacerbated the problem. The creeks had very little permanent water at the time of the survey and riparian vegetation was quite sparse and limited to isolated areas with weeds. The characteristics of Planters, Spring, Cumbo, Wilpinjong and Wollar Creeks are described in Sections HD4.1.1 to HD4.1.5, respectively.

HD4.1.1 Planters Creek

Planters Creek is restricted to a series of five small farm dams which have restricted the natural flow regime. Planters Creek is a natural drainage line that generally only contains water after significant rainfall events. The dry conditions experienced over the months prior to the survey and grazing had reduced or eliminated semi-aquatic plants from the overland flow-path, however there were some scattered *Juncus* spp. and *Carex* sp. recorded (Plate HD-3). Aquatic macrophytes were generally restricted to a single dam, situated approximately 50 m to the south of the Ulan-Wollar Road (Figure HD-3). *Typha orientalis*, *Potamogeton ochreatus* and *Ottelia ovalifolia* were found in this dam (Plate HD-4). Planters Creek was given a poor rating for aquatic habitat.

HD4.1.2 Spring Creek

Spring Creek had similar attributes to Planters Creek in that it is a natural drainage line that generally only contains water after significant rainfall events. Spring Creek has also been heavily grazed and the natural flow regime modified in its catchment by farm dams (Plates HD-5 and HD-6). Macrophytes included *Juncus* spp. and *Carex* sp. Aquatic macrophytes within the dam immediately upstream of the Ulan-Wollar Road included *Typha orientalis* and *Potamogeton ochreatus* (Plate HD-6). Spring Creek was given a poor rating for aquatic habitat.

HD4.1.3 Cumbo Creek

Cumbo Creek has been heavily modified by land clearing and grazing and there is very little riparian vegetation along the creek. Aquatic macrophytes include *Typha domingensis*, *Typha orientalis*, *Phragmites australis* and *Aster subulatus*. The upper parts of the creek drain through some extensive low-lying marshes, which provide some ecological function to the creek system (Plate HD-7). The banks of the creek are not very high and are gently sloped. There was evidence of erosion caused by cattle on both the streambanks and in the streambed itself (Plate HD-8). Cumbo Creek is heavily infested in places with the introduced emergent species *Juncus acutus* (Plate HD-9) which forms monospecific stands at the expense of native species. This species has become a widespread invasive problem in wetlands in NSW. Cumbo Creek was given a poor to moderate rating, due to the occurrence of *Juncus acutus* and the extent of erosion and other weeds which reduce its ecological quality.

HD4.1.4 Wilpinjong Creek

Wilpinjong Creek had been severely impacted by the lack of rainfall in the months prior to the survey, coupled with grazing by stock and Kangaroos. Approximately 50% of the creek is in poor condition with low diversity and abundance of riparian vegetation and large infestations of weeds such as blackberries. The creek system was divided into a number of sections (sections 1 to 9, Figure HD-3). Sections 1 to 9 are described below.

Section 1

The emergent macrophytes *Typha orientalis* and *Phragmites australis* tended to dominate the bed of the creek in the upstream section (Plate HD-10). Downstream, the channel is approximately 30 m wide and 3 to 4 m deep, however there was no water, only damp soil. The substratum of the channel was comprised of sandy gravel with dense cover of semi-aquatic species which included *Typha domingensis*, *Typha orientalis*, *Phragmites australis* and *Aster subulatus* (Plate HD-11).

There was little evidence of streambank erosion, however it was apparent that this area is grazed to some extent. The main riparian species included *Cynodon dactylon*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi* and *E. moluccana.* Weeds included *Aster subulatus*, *Rubus anglocandicans* (formerly *Rubus discolor*), *Verbena incompta* and *V. bonariensis*. This section of the creek was given a poor aquatic habitat rating.

Section 2

Further downstream the banks of the creek became more heavily wooded with a range of riparian plants which included *Imperata cylindrica*, *Eragrostis australasica*, *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi*, *E. moluccana* and *Casuarina cunninghamiana* (Plate HD-12). There was some intermittent running water and the dominant instream macrophytes were *Typha domingensis*, *T. orientalis* and *Phragmites australis*. Weeds along this section of the creek included *Aster subulatus*, *Rubus anglocandicans*, *Verbena bonariensis*, *Carthamus lanatus* and *Cirsium vulgare*. This section of the creek was given a moderate aquatic habitat rating.

Section 3

The creek bed along this section was mostly dry and composed of sandy sediments with small pebbles (Plate HD-13). A single isolated pool was found which was quite turbid due to the impacts of cattle and an algal bloom (Plate HD-14). There appeared to have been some replanting done along this section of the creek, however there was still evidence of moderate grazing by cattle. The instream macrophytes included *Typha domingensis*, *T. orientalis*, *Phragmites australis* and *Potamogeton sulcatus* (in the isolated pool) whilst the streambank plants included *Imperata cylindrical*, *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi* and *E. moluccana*. Weeds included *Aster subulatus*, *Rubus anglocandicans*, *Verbena bonariensis* and *Cirsium vulgare*. This section of the creek was rated as moderate aquatic habitat.

Section 4

This section of the creek comprised a series of shallow channels (Plate HD-15) and marshy areas (Plate HD-16). Following significant rainfall, the marshes would support a diverse assemblage of plants and animals. The channel of the creek was generally shallow and the streambed was comprised of sandy sediments. There was some water found in scattered shallow depressions. There was evidence of erosion and moderate grazing by cattle. The instream vegetation included *Typha domingensis*, *T. orientalis*, *Phragmites australis*, *Schoenoplectus pungens* and *Paspalum distichum*. Bank and riparian vegetation included *Cynodon dactylon*, *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi* and *E. moluccana*, whilst weeds included *Aster subulatus*, *Rubus anglocandicans*, *Verbena incompta, V. bonariensis*, *Carthamus lanatus* and *Cirsium vulgare*. This section of the creek was rated as moderate aquatic habitat.

Section 5

The section of creek consisted of a moderately incised channel approximately 30 to 70 m wide and 3 to 4 m deep (Plates HD-17 and 18). The creek bed consisted of sediments on shale with sandstone overlay. Scattered shallow pools were found with some flowing water. Grazing by stock was evident of both the instream and riparian vegetation. The instream vegetation included *Typha domingensis*, *T. orientalis*, *Phragmites australis* and *Schoenoplectus pungens*. Streambank and riparian plants included *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp. and *Austrostipa* spp., whilst weeds included *Aster subulatus*, *Rubus anglocandicans*, *Verbena incompta*, *V. bonariensis*, *Carthamus lanatus* and *Cirsium vulgare*. This section of the creek was rated as poor aquatic habitat.

Section 6

This section of the creek also consisted of scattered shallow pools with intermittently running water with deeply incised steep banks to 3 to 4 m deep (Plates HD-19 and 20). Excessive erosion was evident due to the effects of stock repeatedly grazing the instream and bank vegetation. Instream vegetation included *Typha domingensis*, *T. orientalis*, *Phragmites australis*, *Schoenoplectus pungens*, *S. validus* and *Carex appressa*. Bank and riparian vegetation included *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi*, *Eucalyptus* sp. and *E. moluccana*. Weeds included *Alternanthera pungens*, *Xanthium spinosum*, *Aster subulatus*, *Rubus anglocandicans*, *Verbena incompta*, *V. bonariensis*, *Carthamus lanatus* and *Cirsium vulgare*. This section of the creek was rated as poor aquatic habitat.

Section 7

This section of creek was mostly dry with some damp soil in places (Plates HD-21). The banks were incised to a depth of 3 m. The impact of cattle grazing in this section appeared to be low. Instream vegetation included *Typha domingensis*, *T. orientalis*, *Phragmites australis*, *Schoenoplectus pungens* and *Lythrum hyssopifolia*. Bank and riparian vegetation included *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi*, *Eucalyptus* sp. and *E. moluccana*. The weeds included *Aster subulatus*, *Rubus anglocandicans*, *Verbena incompta*, *V. bonariensis*, *Carthamus lanatus*, *Cirsium vulgare*, *Alternanthera pungens*, *Xanthium spinosum*, *Setaria gracilis* and *Malva parviflora*. This section of the creek was rated as poor aquatic habitat.

Section 8

This section was separated from section 7 by a fence. The channel was incised with variably steep to occasional 50 m wide benched banks. The shale shelf has caused water to form shallow ponds (Plate HD-22). Erosion was low to moderate and the area appeared to have had restricted grazing for some time. However, twenty head of Hereford cattle were observed on this section grazing the instream and bank vegetation. The instream vegetation included *Typha domingensis*, *T. orientalis*, *Phragmites australis*, *Schoenoplectus pungens*, *Potamogeton pectinatus* and *Chara* sp. The streambank and riparian vegetation included *Cynodon dactylon*, *Bothriochloa* sp., *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi*, *Eucalyptus* sp. and *E. moluccana*. Weeds included *Aster subulatus*, *Rubus anglocandicans*, *Verbena incompta*, *V. bonariensis*, *Carthamus lanatus* and *Cirsium vulgare*. This section of the creek was rated as moderate aquatic habitat.

Section 9

The channel in this section was deeply incised to 4 m deep. The substratum of the creek was composed of sandy sediments and gravel and there was low to moderate erosion of the streambanks. A few scattered pools were observed. The instream vegetation was quite dense and included *Typha domingensis*, *T. orientalis* and *Phragmites australis* (Plate HD-23). Bank and riparian vegetation included *Cynodon dactylon*, *Themeda australis*, *Lomandra* sp., *Austrostipa* spp., *Angophora* sp., *Eucalyptus blakelyi*, and *E. moluccana*. Weeds included *Aster subulatus*, *Rubus anglocandicans* and *Cirsium vulgare*. This section of the creek was rated as poor aquatic habitat.

HD4.1.5 Wollar Creek

Wilpinjong Creek joins Wollar Creek before the creek enters the Goulburn River National Park (Plate HD-24). Wollar Creek is heavily modified upstream of its confluence with Wilpinjong Creek (Plate HD-25). There was significant erosion and the creek banks were heavily infested with weeds including willows. Blooms of floating algae were also observed within many places which indicated eutrophication. Instream macrophytes were dominated by *Typha domingensis*, *T. orientalis* and *Phragmites australis*. There has been some attempt to restore riparian vegetation at places along Wollar Creek as part of Natural Heritage Trust grants to local land care groups. Wollar Creek was rated as poor aquatic habitat upstream of the road crossing on Mogo Road (Plate HD-26), whilst downstream the aquatic habitat improved and was rated as moderate.

HD4.2 WATER QUALITY

The water quality data presented and discussed herein represent a snapshot in time, characterising water quality at the time of the survey. The water quality of streams within the study area have also been assessed as a component of the surface water assessment (Appendix A of the Project EIS [Gilbert and Associates, 2005), an overview of which is provided in Section 3, Volume 1 of the Project EIS. Water quality results for parameters measured *in-situ* and those analysed by the Hunter Water Laboratories for this study are presented in Attachment HD-A. In general the water quality data collected at the time of the survey suggest that most sites were experiencing some level of eutrophication and/or high salinity. The water quality results are compared to the ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems for upland rivers.

At the time of the survey, the water temperature within the creeks ranged from 10.7 to 16.5°C (Figure HD-5 and Attachment HD-A), which is typical for the time of year the samples were collected. The majority of pH values were within the recommended ANZECC (2000) guideline for the protection of aquatic ecosystems in upland rivers of pH 6.5 to 8.0. Values of pH were only slightly higher at Cumbo Creek site 1 and Wollar Creek site 1 (pH 8.1) and Wollar Creek site 2 (pH 8.2). However at the dam on Spring Creek, the pH of 9.1 was higher than the recommended guideline (Figure HD-5). The conductivity at all sites was much higher than the recommended ANZECC (2000) guideline of 350 µS/cm for the protection of aquatic ecosystems in upland rivers (Figure HD-5). Conductivities ranged from 1,458 to 6,060 µS/cm. The highest conductivities were recorded at the Spring Creek site and within both sites on Cumbo Creek (Figure HD-5). These values represent concentrations at which adverse biological effects can occur to freshwater aquatic organisms. Dissolved oxygen (DO) concentrations at the time of the survey ranged from 6.5 to 10.8 mg/L and from 55.5 to 112.0 %S and were generally considered to be acceptable levels to sustain aquatic organisms (Figure HD-5). However, five dissolved oxygen values (one on Planters Creek, three on Wilpinjong Creek and one on Wollar Creek) were below the recommended ANZECC (2000) guideline of between 90 to 110%S (Attachment HD-A). The lowest DO value was recorded in site 1 on Wilpinjong Creek, which was in an isolated pool that contained fish (Section HD4.4) and was also experiencing an algal bloom. No turbidity values were within the recommended ANZECC (2000) guideline of 2 to 25 NTU (Figure HD-5 and Attachment HD-A). The highest turbidity values were recorded at Planters Creek (460 NTU) and at Wilpinjong Creek site 3 (400 NTU). The high reading within the dam on Planters Creek may have been caused by an algal bloom and/or the disturbance associated with cattle. The high level at site 3 on Wilpinjong Creek was primarily due to the disturbance of cattle within the creek.

Total Kjeldahl Nitrogen (TKN) values ranged from 1.1 to 4.2 mg/L (Figure HD-5 and Attachment HD-A). Nitrite concentrations (Figure HD-5) for Spring Creek, Planters Creek and Wilpinjong Creek sites 1 to 4 were all above the recommended ANZECC (2000) guideline for oxides of nitrogen of 0.015 mg/L for upland rivers. Nitrate concentrations (Figure HD-5) at the abovementioned sites, as well as Cumbo Creek sites 1 and 2, were also above the recommended ANZECC (2000) guideline of 0.015 mg/L for upland rivers. Total phosphorus concentrations ranged from 0.036 to 0.190 mg/L and were above the recommended ANZECC (2000) guideline of 0.02 mg/L for upland rivers in all streams (Figure HD-5).

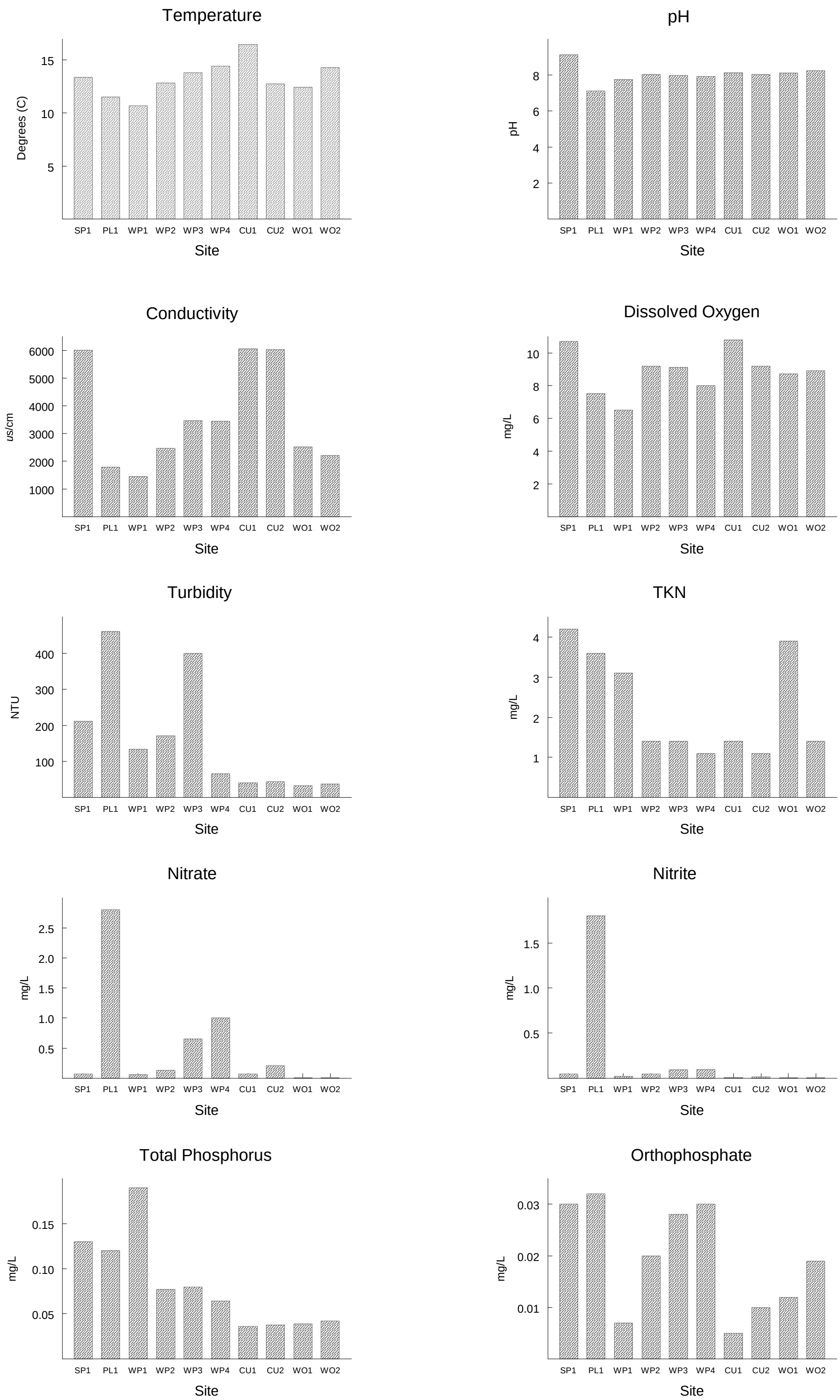


Figure HD-5 Water quality variables recorded at each site (SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek)

HD4.3 ASSEMBLAGES OF MACROINVERTEBRATES

A total of 1,065 macroinvertebrates from 31 taxa (30 macroinvertebrate taxa and 1 fish taxon) were collected from the 10 sites sampled (Attachment HD-B). The most abundant taxa of macroinvertebrates were Coleoptera beetles from the family Hydrophilidae (272 individuals). The next most abundant taxa were the freshwater shrimps from the family Atyidae (142 individuals) followed by gastropod snails from the family Physidae (140 individuals). A total of 353 Mosquito Fish (Poecillidae) were also collected within the net samples.

There were significant differences in the richness and abundance of macroinvertebrates between sites (Table HD-1; Figure HD-6). Wilpinjong Creek sites 2 and 3, Cumbo Creek sites 1 and 2 and Wollar Creek sites 1 and 2 had greater mean taxa richness than the sites in Spring Creek, Planters Creek and at sites 1 and 4 in Wilpinjong Creek (Figure HD-6). A similar pattern was also found in the mean abundance of macroinvertebrates, with the exception of site 1 in Wilpinjong Creek where abundance levels were higher (Figure HD-6). In general, there was relatively smaller mean richness and abundance of macroinvertebrates at sites that were considered to be highly disturbed.

Table HD-1 Summary of analyses of variance comparing the number of taxa (richness) and individuals (abundance) of macroinvertebrates sampled in the study area: ns = not significant (*P* > 0.05); * = significant (*P* < 0.05); ** = significant (*P* < 0.01)

		Richness		Abundance	
Source of Variation	**Degrees of Freedom (df)**	**Mean Squares (MS)**	**F-Distribution Test (F)**	**Mean Squares (MS)**	**F-Distribution Test (F)**
Site	9	28.9	2.54*	2.38	6.23**
Residual	20	11.4		0.38	
Total	29				

The non-metric multidimensional scaling (nMDS) ordination demonstrated considerable variation within the assemblages of macroinvertebrates at all sites (Figure HD-7). The stress value (0.2) associated with the ordination indicated that it gave a potentially useful 2-dimensional picture (Clarke and Warwick, 1994), which means that we can be confident that the ordination is reflecting the true position of the samples (Clarke, 1993). The ordination represents a gradation of community composition across all the samples. The smaller the distance between the samples plotted on the ordination the more similar they are in terms of species composition and relative abundance (ie. structure of the assemblage). The ANOSIM test (*R*:= 0.41**) indicated that there was a significant difference (*P* < 0.01) in the structure of the assemblages between sites, however the pairwise comparisons did not have enough permutations to be able to determine where these differences were (Clarke and Warwick, 1994).

The SIMPER procedure generally ranked the Hydrophilidae as the most important taxa that contributed to the structure of the assemblage in Spring Creek, Wilpinjong Creek sites 2 and 3, Cumbo Creek site 2 and Wollar Creek site 1 (Table HD-2). Freshwater shrimps (Atyidae) were ranked the highest at site 1 in Wilpinjong Creek and at site 2 in Wollar Creek, while Dytiscidae was ranked the highest at Planters Creek, Chironomidae at Cumbo Creek site 1 and Staphylinidae at Wilpinjong Creek site 4 (Table HD-2). Only the first four highest ranked taxa are presented for each site as these represent most of the percentage contribution to abundance. Other families which ranked in the top four include dragonflies (Aeshnidae and Corduliidae), damselflies (Coenagrionidae), beetles (Brentidae, Chrysomelidae and Scirtidae), true bugs (Corixidae and Notonectidae) and gastropods (Physidae). In general, the macroinvertebrate families that ranked high are generally more tolerant to water pollution and anthropogenic disturbance (Chessman, 2003). These included taxa such as the Hydrophilidae, Dytiscidae, Staphylinidae and Chironomidae (Table HD-2).

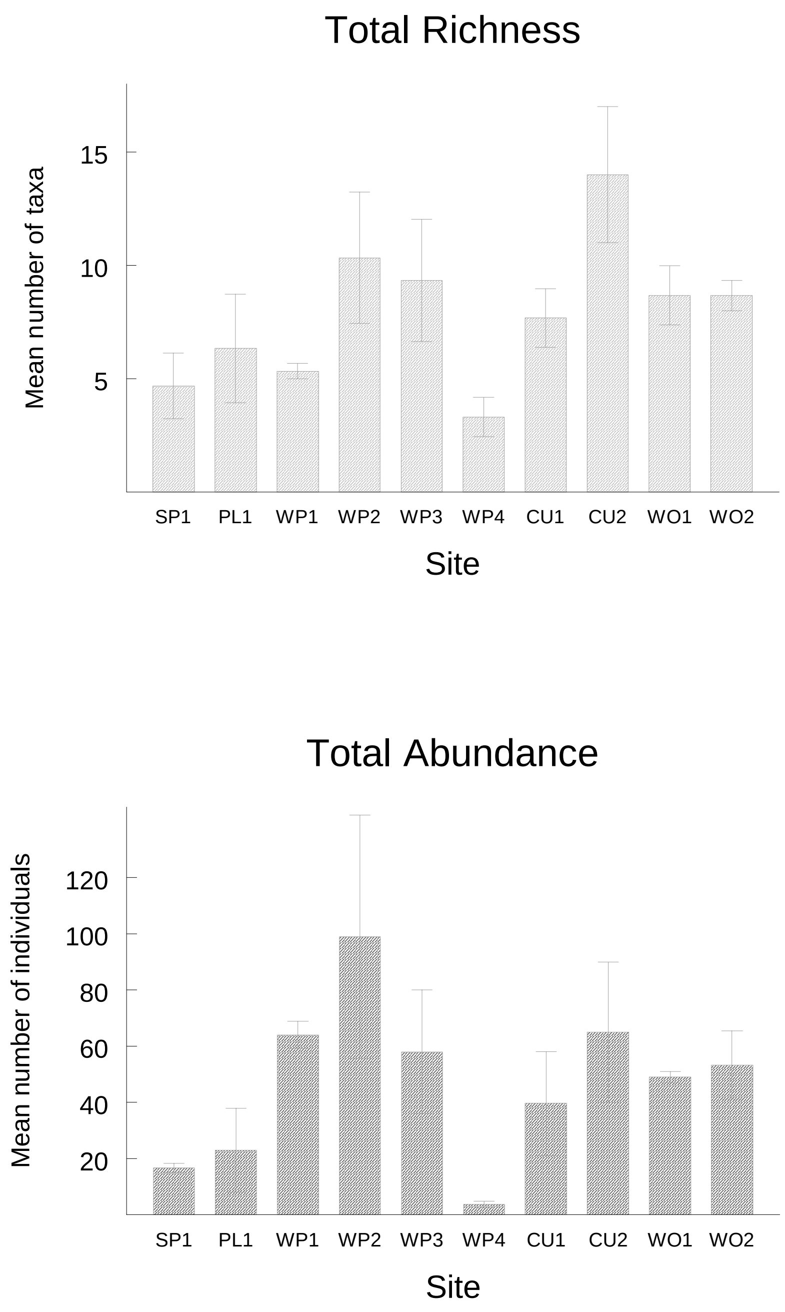


Figure HD-6 **Mean (± SE) richness and abundance of macroinvertebrates at each site (n = 3); SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek**

Figure HD-7 Plot of nMDS ordination for macroinvertebrates at each site; SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek

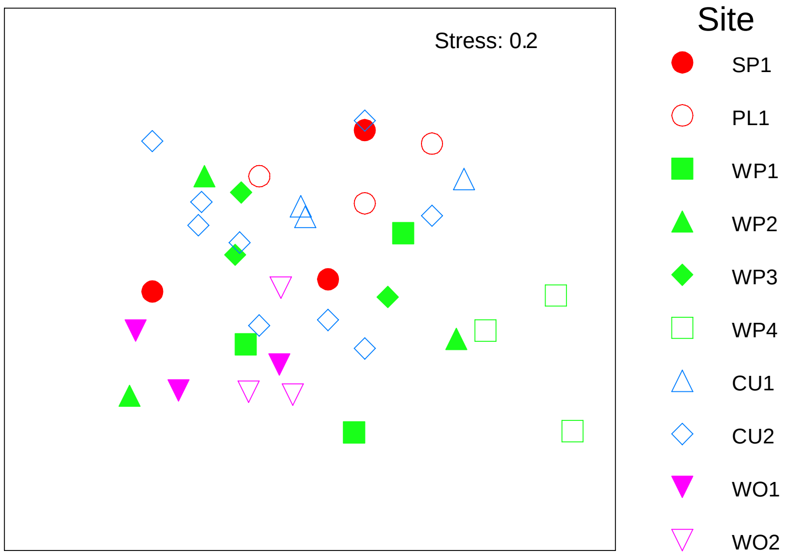


Table HD-2 Taxa ranked in order of importance that contributed to the average similarity within a location as determined using the SIMPER analysis (1-4 presented); SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek

Common Name	Taxa	Site									
		SP1	PL1	WP1	WP2	WP3	WP4	CU1	CU2	WO1	WO2
Dragonflies	Aeshnidae								2		
Shrimps	Atyidae			1						2	1
Beetles	Brentidae						3				
True Flies	Chironomidae			4				1			4
Beetles	Chrysomelidae				3						
Damselflies	Coenagrionidae	3									3
Dragonflies	Corduliidae					3					
True Bugs	Corixidae	4	3					2			
Beetles	Dytiscidae	2	1	2	4	2	2	4			
Beetles	Hydrophilidae	1	4	3	1	1	4	3	1	1	2
True Bugs	Notonectidae		2						4	3	
Gastropods	Physidae					4			3		
Beetles	Scirtidae									4	
Beetles	Staphylinidae				2		1				

The average SIGNAL values calculated for all 10 sites also supported the univariate and multivariate analyses, with values that indicated severe water pollution (Figure HD-8). The best water quality (i.e. highest index) was found in Wollar Creek site 1 at its confluence with Wilpinjong Creek (Figure HD-8). The other nine sites fell within the range of severe water pollution (Figure HD-8). The relative large number of pollution tolerant taxa at all sites suggests that the water quality is generally quite poor across the study area.

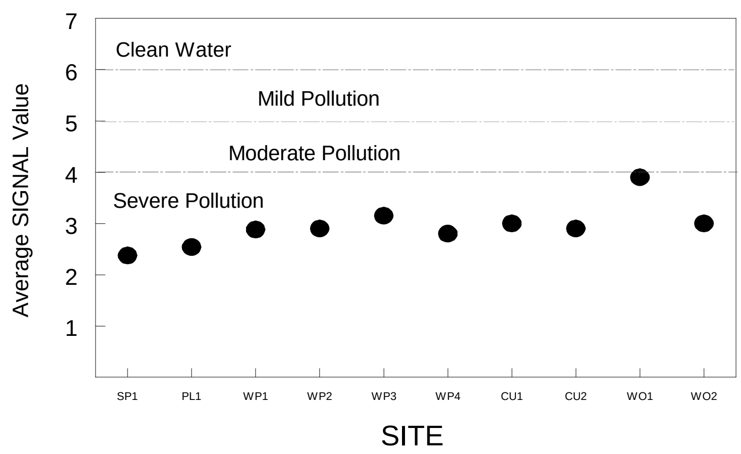


Figure HD-8 Average macroinvertebrate SIGNAL values for each site; SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek

HD4.4 ASSEMBLAGES OF FISH

A total of 1,470 individual fish and crustaceans were collected using the Electrofisher during the survey period (Attachment HD-C). These individuals were represented by five species of fish and one species of crustacean. The most numerically dominant fish was the introduced Mosquito Fish (*Gambusia holbrooki*) (1,037 individuals). Gold Fish (*Carassius auratus*) (21 individuals) were also recorded in some sites in Wilpinjong Creek and Wollar Creek. A total of three native fish species were identified, Striped Gudgeon (*Gobiomorphus australis*) (4 individuals), Long Finned Eel (*Anguila reinhardtii*) (53 individuals), and Australian Smelt (*Retropinna semoni*) (2 individuals) (Attachment HD-C). Native fish species represented less than 6% of the total abundance of fish recorded, with the remainder being the introduced Mosquito Fish and Gold Fish. The Freshwater Shrimp (*Paratya australiensis*) was also common in Wilpinjong Creek and Wollar Creek with 353 individuals recorded.

There were significant differences in the richness and abundance of fishes between sites (Table HD-3, Figure HD-9). Mean fish species richness was greatest at site 1 on Wilpinjong Creek, followed by site 3 on Wilpinjong Creek and site 2 on Wollar Creek. This was primarily due to the large number of freshwater shrimp collected at these locations. Mean abundances of fishes were greatest at site 1 on Wilpinjong Creek due to the isolated nature of the large pool at this site. This isolated pool was obviously the focal point for fish in the general vicinity as the creek was dry for a few hundred metres either side of this pool.

Table HD-3 Summary of analyses of variance comparing the number of species (richness) and individuals (abundance) of fish sampled in the study area: ns = not significant (*P* > 0.05); * = significant (*P* < 0.05); ** = significant (*P* < 0.01)

		Richness		Abundance	
Source of Variation	Degrees of Freedom (df)	Mean Squares (MS)	F-Distribution Test (F)	Mean Squares (MS)	F-Distribution Test (F)
Site	9	5.42	18.1**	8.15	30.9**
Residual	20	0.3		0.26	
Total	29				

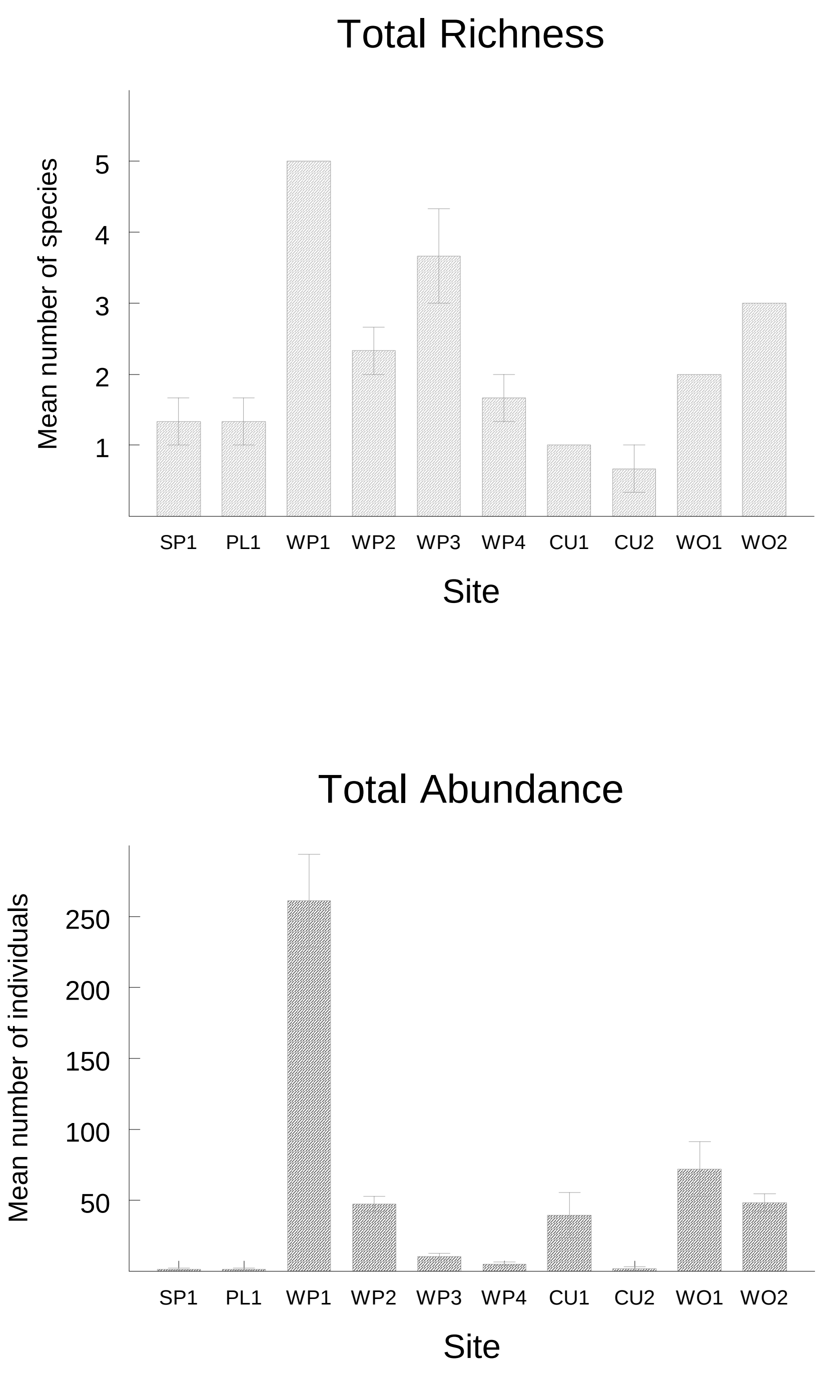


Figure HD-9 **Mean (+ SE) richness and abundance of fish at each site (n = 3); SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek**

The non-metric multidimensional scaling (nMDS) ordination showed small variation in the assemblages of fishes within a site, ie. the samples were generally plotted closer to each other (Figure HD-10). The stress value (0.09) associated with the ordination gives an excellent representation with no prospect of misinterpretation (Clarke and Warwick, 1994). The ANOSIM test (R = 0.75**) indicated that there was a significant difference in the structure of the assemblages between sites, however the pairwise comparisons could not differentiate where these differences were (Clarke and Warwick, 1994).

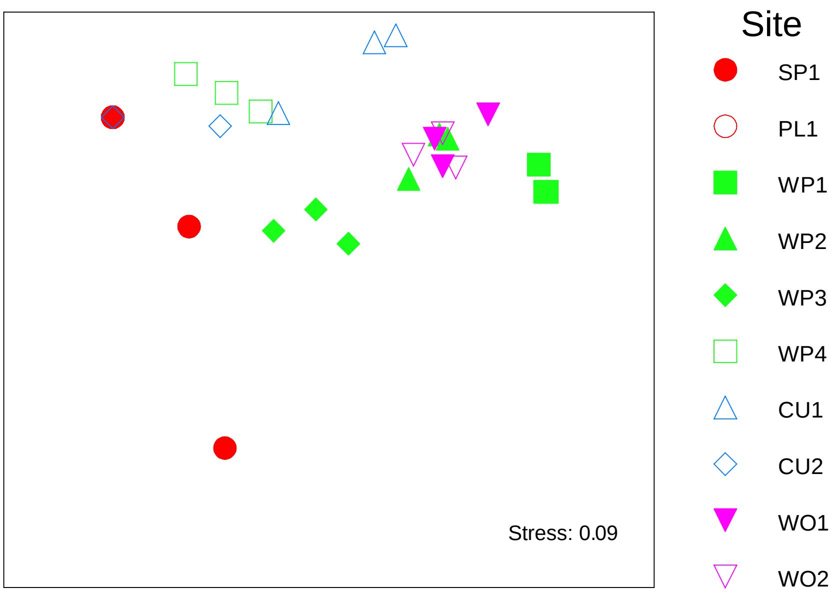


Figure HD-10 Plot of nMDS ordination for fish at each site; SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek

The SIMPER procedure ranked the Mosquito Fish (*G. holbrooki*) as the species that contributed most to the structure of the assemblages at sites SP1, PL1, WP1, WP3, WP4, CU1 and CU2 and the Freshwater Shrimp (*Paratya australiensis***)** as the species that contributed most to the structure of the assemblages at sites WP2, WO1 and WO2 (Table HD-4). The introduced Mosquito Fish (*G. holbrooki*) was ranked the next highest contributor to the structure of the fish assemblages at sites WP2, WO1 and WO2 (Table HD-4). Long Finned Eels (*Anguila reinhardtii*) were ranked as number 2 in Spring Creek and Planters Creek and Gold Fish (*Carassius auratus*) were ranked as number 2 at site 4 on Wilpinjong Creek (Plate HD-27).

Table HD-4 Species ranked in order of importance that contributed to the average similarity within a location as determined using the SIMPER analysis (1-4 presented); SP – Spring Creek, PL - Planters Creek, WP - Wilpinjong Creek, CU - Cumbo Creek, WO - Wollar Creek

	Site									
Species	**SP1**	**PL1**	**WP1**	**WP2**	**WP3**	**WP4**	**CU1**	**CU2**	**WO1**	**WO2**
Anguila reinhardtii	2	2	3	3	3					
Gobiomorphus australis			5		4					
Retropinna semoni			6		5					
Gambusia holbrooki	1	1	1	2	1	1	1	1	2	2
Carassius auratus			4			2				3
Paratya australiensis			2	1	2				1	1

HD4.5 THREATENED AQUATIC BIOTA

Given the degraded nature of the aquatic habitats, the poor water quality, the occurrence of the Mosquito Fish and barriers to fish passage, no threatened species or regionally significant species were found within the study area, nor are they considered likely to be found there in the future.

HD5 DISCUSSION

The aquatic habitats in the study area generally reflected the degraded nature of their immediate catchments, which resulted in the condition of the aquatic habitats being classified as poor to moderate. Direct disturbance to the banks of the creeks and the riparian zone has led to the intrusion of weeds and erosion. Riparian and streambank vegetation has several primary physical and biological functions, which are particularly important in maintaining the health of aquatic systems (Turak and Bickel, 1994; Pusey and Arthington, 2003). Riparian vegetation increases habitat structural complexity and provides organic matter for many aquatic organisms (Cummins *et al*., 1997). A healthy riparian zone is therefore a prerequisite for a functioning aquatic ecosystem.

The aquatic and semi-aquatic macrophytes within the study area ranged from emergent to submerged attached and floating species and tended to characterise the physical conditions at any one place. Macrophytes can modify physicochemical conditions, form structural habitats for epiphytes and fauna, trap detritus, provide shelter, compete with algae and provide detritus to food chains (Carpenter and Lodge, 1986). Where there was extensive habitat degradation and potential for increased nutrients from runoff the macrophytes tend to be dominated by those species that grow well under a high nutrient regime (Sainty and Jacobs, 2003). Aquatic and semi-aquatic weeds were common at most of the poorly rated sites.

Studies of aquatic macrophytes and the association between macroinvertebrates and fish have emphasised the role of structural complexity in determining the composition of assemblages (Cummins *et al*., 1997; Pusey and Arthington, 2003). The relatively low richness and abundance of macroinvertebrates within the study area indicated that most of these sites were disturbed or degraded in some manner. The distribution and abundance of macroinvertebrates can also be affected by changes in the flow intensity and pattern (Growns and Growns, 1997), pollution (Wright *et al*., 1995), and differences in habitat and structure (Parsons and Norris, 1996; Kay *et al*., 1999). Sewage and other toxicants within the water can also reduce the species diversity and abundance of macroinvertebrates because some families are more sensitive to these types of pollution (Chessman, 1995). The average SIGNAL index calculated for macroinvertebrates at each site and the dominance of pollution tolerant taxa indicated that the water quality was generally quite poor. Beetles (Hydrophilidae), snails (Physidae), fly larvae (Chironomidae) and freshwater shrimps (Atyidae) were common at most sites.

These groups of macroinvertebrates are all highly tolerant to various forms of water pollution and therefore their dominance is indicative of the poor quality of water in the study area (Chessman, 2003). Chessman *et al*. (1997) also described macroinvertebrate assemblages within a range of creek systems in the Hunter Region, including Wollar Creek, as having poor SIGNAL indices due to the effects of salinity, reduced riparian and instream macrophytes and the direct impacts associated with grazing cattle.

The richness and abundance of assemblages of fish within the study area was also quite poor with only three native species recorded. The composition and abundance of assemblages of fish is controlled by the flow regime, food supply, water quality, biotic interactions and habitat structure (Harris, 1995). Impoundments and structures can also create barriers that obstruct the movement of fish within river systems and greatly affect their lifecycles (Gehrke and Harris, 1996). Disturbance within aquatic systems has also tended to favour the proliferation of introduced species such as the Mosquito Fish (*G. holbrooki*), which were recorded at most sites. The Mosquito Fish can tolerate a wide range of water quality conditions (McDowall, 1996) and predation by this species is considered a threatening process in Schedule 3 of the NSW *Threatened Species Conservation Act*, *1995.* This species has also been implicated in the decline of at least 35 fish species world-wide due to competition for resources and predation (Faragher and Lintermans, 1997).

Three biological indicators were used to assess the health of the aquatic habitat within the study area. These indicators included macroinvertebrates, fish and aquatic macrophytes. Biological assemblages have been successfully used in the past as indicators of aquatic health and using a suite of biological indicators has several advantages because they are sensitive to the cumulative impacts of a wide range of disturbances (Turak and Bickel, 1994).

HD6 POTENTIAL IMPACTS AND MITIGATION MEASURES

HD6.1 POTENTIAL IMPACTS

HD6.1.1 Disturbance and Alteration of Aquatic Habitat

Aquatic habitat in the Project disturbance area would be removed or altered as a result of open cut mining. This would include the relocation of Cumbo Creek to enable flows from the south to continue through the Project area and into Wilpinjong Creek. An unsealed two-lane mine access road would also be constructed to connect the mine facilities area to Wollar Road, which would require a low level floodway crossing to be installed across Cumbo Creek and one of its tributaries. The alteration of natural flow regimes of rivers and streams is recognised as a key threatening process under the TSC Act and NSW *Fisheries Management Act, 1994*. The degradation of native riparian vegetation along NSW watercourses is also listed as a key threatening process under the NSW *Fisheries Management Act, 1994*.

Aquatic habitats in the Project disturbance area are generally in poor condition, reflecting the degraded nature of their immediate catchments. The banks of the creeks have been subject to erosion and grazing by cattle and invasion by introduced species such as Blackberry (*Rubus fruticosus*) and the Rush (*Juncus acutus*). Riparian vegetation is sparse and discontinuous. The relatively low richness and abundance of macroinvertebrates in creeks in the Project disturbance area indicates that most of these sites are disturbed or degraded in some manner. The richness and abundance of assemblages of fish was also quite poor with only one native species recorded in the Project disturbance area and three native species in the surrounds. The disturbance of the aquatic systems has also favoured the proliferation of the introduced Mosquito Fish (*G. holbrooki*).

Notwithstanding the existing degraded nature of the creeks located in the Project disturbance area, the Project would result in the loss of habitat for aquatic biota (e.g. farm dams situated on Planters and Spring Creeks) and the alteration of aquatic habitat (e.g. the relocation of Cumbo Creek), which has the potential to result in a loss of aquatic biodiversity. Ameliorative measures have been developed to minimise the potential impacts of the Project on aquatic ecosystems and are described in Section HD6.2.

HD6.1.2 Surface Water Flow and Aquatic Biota

As described in Section HD6.1.1, aquatic habitat within the Project disturbance area would be removed or altered as a result of the Project. Changes to surface water flows in creeks located outside the Project disturbance area also has the potential to impact on aquatic ecosystems. Surface water (Gilbert and Associates, 2005) and groundwater (Australasian Groundwater and Environmental Consultants [AGE], 2005) studies conducted for the Project have assessed the potential for the alteration of stream flows. The assessments indicated that the development of the Project open cuts and water supply borefield would result in a reduction in the deeper groundwater sourced (i.e. Ulan Seam) component of baseflow in Wilpinjong Creek.

The potential maximum flow reduction in Wilpinjong Creek equates to an 11% reduction of annual average flow. Whilst the predicted changes to low flows in Wilpinjong Creek would be expected to be noticeable as reduced flow persistence, the magnitude of predicted affects can be compared to those that occur due to other changes in catchment condition and landuse such as changes in stocking rates, construction of farm dams, water harvesting or bushfires which can also result in noticeable changes to low flows (Gilbert and Associates, 2005). The relative affects on the magnitude and duration of low flows would reduce significantly downstream of the confluence of Wilpinjong and Wollar Creeks due to additional unaffected inflows from Wollar Creek. As such, the effects of flow reductions further downstream in Wollar Creek (and upstream of the Goulburn River National Park) would not be discernible from other normal variations in flows resulting from the types of changes in catchment condition and landuse described above, or from the proposed 10 km of creek enhancement works (i.e. exclusion of stock and riparian revegetation) which are described in Section HD6.2.

The actual magnitude of the potential reductions in Wilpinjong Creek annual average flow would vary with time and would be less than that described above depending on the area of catchment excised by Project operations and on the level of usage of the Project water supply borefield. In periods of the Project life when catchment excision and borefield extractions are less, the reduction in flow would also be expected to be less.

The flow of rivers and creeks is often unpredictable and highly variable. Streams and creeks may flow for a large part of the year or only after heavy rainfall and floods. Fish and macroinvertebrate assemblages are influenced by the flow regime, food supply, water quality, biotic interactions and habitat structure (Harris, 1995). The distribution and abundance of aquatic organisms can be affected by significant changes in the intensity and pattern of flows (Gehrke and Harris, 1996; Growns and Growns, 1997).

A variety of aquatic habitats are present in Wilpinjong Creek which would influence the diversity and abundance of aquatic organisms. For example there are significant differences between aquatic assemblages in riffle zones compared to those found along the edges of creeks or in pools. Further sources of variability occur as a result of differences in the structural habitats provided by aquatic macrophytes and overhanging riparian vegetation (Cummins *et al*., 1997).

The predicted changes to flows in Wilpinjong Creek associated with the Project are small and would not alter the physical structure of the habitats in the creek. The small-scale predicted changes are unlikely to affect the existing aquatic ecological components and furthermore it is considered that the revegetation/enhancement initiatives described in Section HD6.2 are expected to have a positive affect on the instream ecology of Wilpinjong Creek. As the predicted changes in flow diminish downstream of the Wollar Creek confluence (Gilbert and Associates, 2005), it is considered that there would be no discernible affect on aquatic ecological components downstream of Wilpinjong Creek.

HD6.1.3 Surface Water Quality and Aquatic Biota

Surface water runoff from mine landforms and disturbed areas has the potential to contain sediments, soluble salts, process reagents, fuels, oils and grease. The potential surface water quality impacts of the Project that relate to these contaminants are described in Section 4 of the Project EIS. A range of measures would be implemented to minimise the potential for impacts on creek water quality.

The use of groundwater resources by the Project also has the potential to impact on stream water quality. Groundwater quality monitoring records in the Ulan Seam indicate EC ranges from 1,020 to 3,390 µS/cm. The Ulan Seam is a source of the total salt load that is observed in Wilpinjong Creek (Gilbert and Associates, 2005). Therefore, any reduction in the rate of contribution that groundwater from the Ulan Seam makes to the creek baseflow would have a corresponding reduction in the salt load in Wilpinjong and Wollar Creeks (Gilbert and Associates, 2005). An assessment of the potential impacts of the Project on stream water quality as a result of groundwater use and open pit mining is provided in Appendices A and B of the Project EIS (Gilbert and Associates, 2005; AGE, 2005).

High salinity concentrations can have a deleterious effect on assemblages of macroinvertebrates, fish and aquatic plants. For example, the semi-salt tolerant exotic emergent macrophyte *Juncus acutus* was found to be widespread in Cumbo Creek where it is generally thriving under conditions of elevated salinity. The effects of increased salinity on aquatic macroinvertebrates have been well documented in the Hunter region (Chessman *et al*., 1997). The potential reduction in salt load described above, combined with the Project creek enhancement works described in Section HD6.2, would be beneficial to the aquatic assemblages of Wilpinjong and Wollar Creeks.

HD6.1.4 Barriers to Fish Movement

Some Project activities have the potential to impact on the movement of fish. These include:

- the construction of a low level floodway crossing for the mine access road across Cumbo Creek and one of its tributaries;
- the burial of pipelines from the Project water supply borefield across Wilpinjong Creek to supply water to the CHPP; and
- the relocation of Cumbo Creek to enable flows from the south to continue through the Project area and into Wilpinjong Creek.

As described in the discussion of habitat disturbance/alteration above, fish would also be restricted from the creeks situated in the Project disturbance area during mining operations.

HD6.1.5 Threatened Aquatic Biota

No threatened aquatic biota listed in the schedules of the TSC Act, *Fisheries Management Act, 1994* or EPBC Act were identified by the surveys or are considered likely to occur in the Project area or surrounds given the distribution of listed species, populations or ecological communities and the degraded nature of the aquatic habitats in the Project area and surrounds.

HD6.1.6 Introduced Aquatic Biota

Disturbance within aquatic systems can favour the proliferation of introduced aquatic species which can impact on aquatic ecosystems. For example, predation by the Mosquito Fish (*G. holbrooki*) is listed as a key threatening process in Schedule 3 of the TSC Act. This species has been implicated in the decline of some 35 fish species world-wide due to competition for resources and predation (Faragher and Lintermans, 1997). Aquatic ecosystems in the vicinity of the Project have been subject to extensive disturbance as a result of past landuse practices, including a proliferation of introduced species such as the introduced Mosquito Fish and introduced emergent species, *Juncus acutus*. It is considered unlikely that the Project would have a significant affect on the occurrence of introduced aquatic biota.

HD6.1.7 Groundwater Dependent Aquatic and Riparian Ecosystems

River flow is often maintained by groundwater, which provides baseflows long after a rainfall event (DLWC, 2002). The baseflow typically emerges as springs or as diffuse flow from saturated sediments or rock underlying the stream and banks (*ibid*.). In addition, water exchange occurs between the surface and groundwater in the hyporheic zone[1], which provides habitat for aquatic invertebrates (Boulton *et. al*., 1998 in DLWC, 2002). As a result, aquatic and riparian ecosystems can be dependent on the baseflows supplied by groundwater to a stream.

Potential impacts of the Project on aquatic biota associated with changes in creek flow are discussed above. In summary, the predicted changes to flows in Wilpinjong Creek associated with the Project are small and would not alter the physical structure of the habitats in the creek. The small-scale predicted changes are considered unlikely to affect the existing aquatic ecological components.

Changes to the groundwater system also have the potential to impact on riparian vegetation by de-saturating the alluvial and colluvial deposits adjacent to streams. Results of the groundwater modelling predicted only a limited affect on alluvial and colluvial deposits adjacent to Wilpinjong Creek, with negligible affect on the shallow seepage from the adjacent elevated Goulburn River National Park to the alluvial/colluvial aquifer (AGE, 2005). As a result, it is considered that riparian vegetation would not be deleteriously affected by the Project.

[1] Hyporheic zone - the saturated interstitial sediments below streams and their banks where water exchanges between the surface and subsurface.

HD6.1.8 Cumulative Impacts on Aquatic Biota

Cumulative impacts of the Project on aquatic ecosystems predominantly relate to habitat disturbance and alteration. The assessment of cumulative impacts has taken into consideration the extent and type of habitat disturbance associated with the Project, the existing assemblages of aquatic biota, the condition of the streams and the Project ameliorative measures. A range of mitigation and ameliorative measures have been incorporated into the Project to minimise the potential impacts of the Project, including regional cumulative impacts on aquatic ecosystems.

During the progressive rehabilitation of Project landforms, a pattern of creek features (i.e. flow paths) would be formed over the rehabilitated landforms comparable to the pre-mine regime. These reconstructed creek features would convey upslope runoff across the Project area to Wilpinjong Creek. Revegetation of the permanent creek features would include the use of native riparian species. Further to riparian revegetation in the rehabilitation areas, riparian vegetation would also be established along Wilpinjong and Cumbo Creeks in the regeneration areas and the ECAs through natural regeneration/selective planting. These initiatives would increase the quantity of riparian vegetation along these watercourses and improve the condition of habitats available to aquatic biota. Some 10 km of creekline along Wilpinjong and Cumbo Creeks would be revegetated/enhanced by the Project. Measures developed to mitigate the potential cumulative impacts of the Project on aquatic ecosystems are outlined in Section HD6.2.

HD6.2 MITIGATION MEASURES

A range of mitigation measures have been developed to minimise the potential impacts of the Project on aquatic ecosystems, including measures to:

- mitigate the predicted reduction in average flows in Wilpinjong Creek;
- minimise the potential for impacts on surface water quality;
- minimise potential impacts on the movement of fish; and
- manage the Cumbo Creek relocation.

These measures are described in Section 4, Volume 1 of the Project EIS. Further to the above measures, the Project would include the rehabilitation of permanent creek features established in the rehabilitation areas and the enhancement of Wilpinjong and Cumbo Creeks.

Riparian vegetation has several primary physical and biological functions, which are particularly important in maintaining the health of aquatic systems (Turak and Bickel, 1994; Pusey and Arthington, 2003). Riparian vegetation increases habitat structural complexity and provides organic matter for many aquatic organisms (Cummins *et al*., 1997). A healthy riparian zone is therefore a prerequisite for a functioning aquatic ecosystem. The roots of trees bind and stabilise the soil, minimise siltation, provide shelter and help to retain the general channel shape, including critical habitat features such as pools, riffles and backwaters. Streams with well-developed riparian vegetation offer better habitat for fish and other aquatic fauna, than those with no trees. Leaf material falling from trees provides food for crustaceans and aquatic insects, which in turn provide food for fish. More than half of the diet of predatory fish may come from invertebrate animals falling into the stream from the bank. Overhanging trees also provide shade, which lowers water temperatures, which if allowed to rise, can be detrimental to fish and increase the rate of growth of algae. Snags consisting of trees, limbs and root masses that are partly or wholly submerged are one of the most important habitat components for fish within a creek. Many fish will lie next to the bank for shade, shelter and to avoid currents. Snags, not only provide fish with shelter and a substratum for food, but are also breeding sites for some species.

As described in this report, the creeks situated in the Project area and surrounds are highly degraded. Riparian and aquatic weeds were common in the study area and are generally a reflection of the degraded nature of the immediate catchments to the creeks. As a component of the Project, sections of Wilpinjong Creek, Cumbo Creek and creek features developed in final landforms would be revegetated with riparian vegetation. A description of the creek rehabilitation and enhancement initiatives are provided in Section 5, Volume 1 of the Project EIS.

The revegetation/enhancement initiatives are expected to have a positive affect on the in-stream ecology of Wilpinjong and Cumbo Creeks. The planned stock exclusion, weed control and establishment of vegetation in the riparian zones would lead to improved habitats for aquatic biota.

An aquatic monitoring programme would be developed to monitor the aquatic macroinvertebrate assemblages, *in-situ* water quality, characteristics and 'health' of Wilpinjong and Cumbo Creeks. The ecological integrity of the Cumbo Creek relocation would also be monitored.

HD7 SUMMARY AND CONCLUSIONS

An assessment of the aquatic habitats was conducted as part of investigations being undertaken for the Wilpinjong Coal Project. Field surveys were used to identify and assess the aquatic habitat, and included the collection of information on the condition, quality and geomorphology of the creeks as well as a description of the habitat, aquatic and riparian vegetation and associated anthropogenic disturbances. Quantitative data was also collected on the diversity and abundance of assemblages of macroinvertebrates and fish. The aquatic habitat was given a rating in terms of its "health" according to the quality of water, rates of sedimentation and erosion, streambank and aquatic plants and the presence of introduced species.

In general, the aquatic habitats were found to be in very poor condition and generally reflected the degraded nature of their immediate catchments. Water quality was found to be poor with many sites having high salinity and nutrients. The relatively low diversity and abundance of macroinvertebrates at most sites also indicated anthropogenic disturbance. The assemblages of macroinvertebrates were generally dominated by pollution tolerant taxa, indicating generally poor water quality across the study area. The SIGNAL index indicated that all sites fell within the range of severe pollution. The richness and abundance of assemblages of fish was also poor with exotic species such as the Mosquito Fish and Gold Fish dominating the assemblages.

No threatened aquatic biota were found by the survey and it is considered unlikely that any would occur in the study area given the degree of disturbance to the streams and the catchment.

Project potential impacts on aquatic ecosystems were considered in terms of habitat disturbance/alteration, changes to creek baseflows, changes to surface water quality, the occurrence of threatened aquatic biota, occurrence of introduced species, barriers to fish movement and cumulative impacts. Planned revegetation/ enhancement of sections of Wilpinjong and Cumbo Creeks are expected to have a positive affect on the in-stream ecology of Wilpinjong and Cumbo Creeks. The planned stock exclusion, weed control and establishment of vegetation in the riparian zones would lead to improved habitats for aquatic biota.

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PLATES

Plate HD-1 Sampling macroinvertebrates with a sweep net

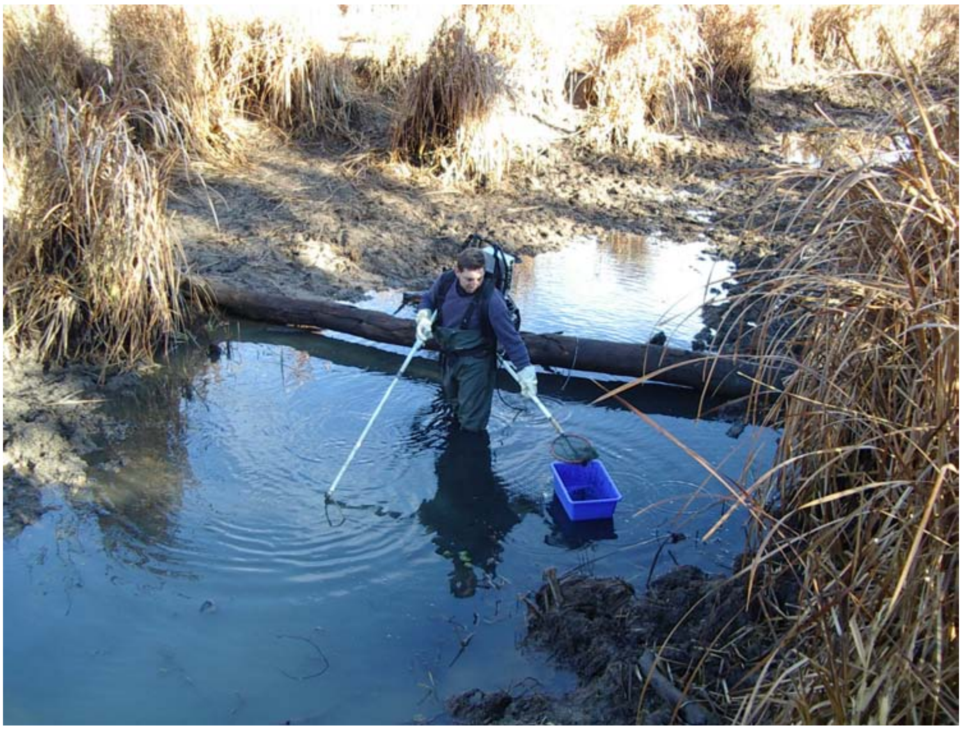

Plate HD-2 Sampling fish using the Electrofisher

Plate HD-3 Planters Creek, upstream of the Ulan-Wollar Road

Plate HD-4 Dam on Planters Creek dominated by *Typha orientalis*

Plate HD-5 Spring Creek, upstream of the Ulan-Wollar Road

Plate HD-6 Dam on Spring Creek immediately upstream of the Ulan-Wollar Road

Plate HD-7 Marsh in the upper catchment of Cumbo Creek

Plate HD-8 Disturbance to Cumbo Creek as a result of cattle

Plate HD-9 The introduced species *Juncus acutus* is widespread along Cumbo Creek

Plate HD-10 Wilpinjong Creek, upstream of the road crossing (section 1)

Plate HD-11 Wilpinjong Creek, downstream of the road crossing (section 1)

Plate HD-12 Wilpinjong Creek, extensive riparian zone with minimal erosion and grazing (section 2)

Plate HD-13 Wilpinjong Creek, some evidence of grazing and dry creek beds (section 3)

Plate HD-14 Wilpinjong Creek, small isolated pool in section 3 (site WP1)

Plate HD-15 Wilpinjong Creek, shallow channels and marshy areas (section 4)

Plate HD-16 Wilpinjong Creek, large area of marsh adjacent to the creek (section 4)

Plate HD-17 Wilpinjong Creek, upstream (section 5)

Plate HD-18 Wilpinjong Creek, downstream (section 5)

Plate HD-19 Wilpinjong Creek, deeply incised channel with evidence of erosion (section 6)

Plate HD-20 Wilpinjong Creek, large pool with *Typha* surrounding the edges (section 6 and site WP2)

Plate HD-21 Wilpinjong Creek, dry channel with deep banks (section 7)

Plate HD-22 Wilpinjong Creek, shallow pools formed over shale bedrock (section 8)

Plate HD-23 Wilpinjong Creek, dense beds of emergent macrophytes in the channel (section 9)

Plate HD-24 The confluence of Wollar Creek and Wilpinjong Creek (site WO1)

Plate HD-25 Wollar Creek, degraded habitat with floating macroalgae

Plate HD-26 Crossing over Mogo Road on Wollar Creek (site WO2)

Plate HD-27 Gold Fish collected at site 1 on Wilpinjong Creek (site WP1)

ATTACHMENT HD-A

WATER QUALITY RESULTS

Attachment HD-A
Water Quality Results

Parameter	Site										ANZECC Guidelines (2000)[1]
	PL1	SP1	WP1	WP2	WP3	WP4	CU1	CU2	WO1	WO2	
Latitude	32 18 38.0	32 19 9.7	32 19 51.7	32 19 11.3	32 18 54.3	32 18 48.6	32 20 12.6	32 20 25.7	32 19 16.2	32 19 54.5	NA
Longitude	149 50 44.0	149 51 54.4	149 51 12.1	149 54 14.7	149 55 0.0	149 55 13.5	149 53 56.6	149 53 50.6	149 56 58.6	149 57 03.3	NA
Temperature (^oC)	11.5	13.4	10.7	12.8	13.8	14.4	16.5	12.8	12.4	14.3	NA
pH (pH units)	7.1	9.1	7.7	8.0	8.0	7.9	8.1	8.0	8.1	8.2	6.5 to 8.0
Conductivity (µS/cm)	1,781	6,000	1,458	2,465	3,460	3,439	6,060	6,030	2,521	2,206	350
Conductivity (mS/cm)	-	6.7	1.6	2.7	3.8	3.7	6.7	6.6	2.8	2.4	NA
Salinity (mg/L)	0.99	3.60	0.77	1.39	2.00	1.99	3.65	3.62	1.44	1.22	NA
Dissolved Oxygen (%S)	72.1	106.7	55.5	88.8	91.0	80.9	112.0	90.7	84.0	91.5	90 to 110
Dissolved Oxygen (mg/L)	7.5	10.7	6.5	9.2	9.1	8.0	10.8	9.2	8.7	8.9	NA
Turbidity (NTU)	460.0	212.0	134.0	171.0	400.0	65.6	40.2	44.2	33.0	37.6	2-25
Total Phosphorous (mg/L)	0.120	0.130	0.190	0.077	0.080	0.064	0.036	0.038	0.039	0.042	0.02
Orthophosphate (mg/L)	0.032	0.030	0.007	0.020	0.028	0.030	0.005	0.010	0.012	0.019	NA
Total Kjeldahl Nitrogen (mg/L)	3.6	4.2	3.1	1.4	1.4	1.1	1.4	1.1	3.9	1.4	0.25
Nitrate (mg/L)	2.800	0.066	0.061	0.130	0.650	1.000	0.068	0.210	0.005	0.005	0.015
Nitrite (mg/L)	1.800	0.044	0.019	0.044	0.090	0.097	0.011	0.014	0.003	0.003	0.015

[1] ANZECC (2000) Guidelines for the protection of aquatic ecosystems for upland rivers.
NA Not applicable

ATTACHMENT HD-B

MACROINVERTEBRATE SURVEY RESULTS

Attachment HD-B
Macroinvertebrate Sampling Taxa and Abundance

MACROINVERTEBRATE TAXA	SITES														
	SP1			PL1			WP1			WP2			WP3		
	Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Glossiphoniidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lymnaeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	3	0	0	0	0	2	0	99	0	7	5	0
Arachnida	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0
Atyidae	0	0	0	0	0	0	39	6	0	0	0	0	4	0	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	2	6	0	1	0	4	0	1	0	0	7	0	1	1	0
Aeshnidae	0	0	0	0	0	0	0	0	0	0	5	0	0	2	0
Corduliidae	0	0	0	0	0	1	0	0	0	0	3	0	14	8	0
Plecoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelastocoridae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	4	0	0	0	5	0	0	1	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Notonectidae	1	0	0	3	1	19	1	0	0	0	12	0	1	29	0
Corixidae	6	0	1	0	2	4	0	0	0	0	5	0	4	16	0
Dytiscidae (L.)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Dytiscidae (A.)	4	2	0	2	3	14	3	0	2	0	4	1	1	7	5
Hydrophilidae (A.)	0	4	13	1	0	3	0	8	1	29	19	2	12	14	5
Hydrophilidae (L.)	0	0	0	0	0	0	0	0	0	2	1	0	0	0	2
Staphylinidae	0	0	0	0	0	0	0	0	0	12	0	1	0	0	0
Scirtidae (L.)	0	3	0	0	0	0	1	0	0	0	2	0	0	1	0
Brentidae (A.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	0	0	0	0	0	0	0	0	0	0	8	2	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae (L.)	0	2	0	0	0	1	0	5	1	0	6	0	4	1	0
Ceratopogonidae (L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Thaumaleidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Leptoceridae	0	0	0	0	0	1	0	0	1	0	8	0	0	0	0
Total No. Taxa	4	6	2	5	3	11	4	4	5	8	15	5	12	10	3
Total No. Individuals	13	18	14	10	6	53	44	20	7	57	182	7	52	84	12
FISH TAXA															
Poeciliidae (Mosquito Fish)	3	2	0	0	0	0	17	38	67	11	3	38	7	13	8

Attachment HD-B (Continued)
Macroinvertebrate Sampling Taxa and Abundance

MACROINVERTEBRATE TAXA	SAMPLING SITES														
	WP4			CU1			CU2			WO1			WO2		
	Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Glossiphoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lymnaeidae	0	0	0	0	0	0	0	1	1	0	2	0	0	0	1
Physidae	0	0	0	4	0	1	5	7	4	0	0	0	3	0	0
Arachnida	0	0	0	0	0	0	0	3	2	2	0	3	0	0	1
Atyidae	0	0	0	0	0	0	0	0	0	1	4	29	11	15	33
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coenagrionidae	0	0	0	1	0	1	2	2	11	0	0	0	1	1	1
Aeshnidae	0	0	0	0	0	0	6	6	13	0	0	0	0	0	0
Corduliidae	0	0	0	7	0	1	1	1	1	0	0	0	1	0	0
Plecoptera	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Gelastocoridae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	5	1	7	10	0	5	0	0	0
Corixidae	0	0	0	1	1	3	1	1	1	0	0	0	0	1	0
Dytiscidae (L.)	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Dytiscidae (A.)	1	0	1	1	1	0	0	3	3	0	0	1	5	0	0
Hydrophilidae (A.)	0	0	1	5	0	3	6	20	45	29	22	8	10	2	4
Hydrophilidae (L.)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Staphylinidae	1	1	1	0	0	1	0	1	0	0	1	0	0	0	1
Scirtidae (L.)	0	0	0	0	1	0	0	0	4	4	5	0	0	0	0
Brentidae (A.)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Tipulidae	0	0	2	0	0	0	0	1	1	1	0	0	1	0	0
Culicidae	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Chironomidae (L.)	0	0	0	1	1	1	0	2	8	0	0	0	3	0	2
Ceratopogonidae (L.)	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	0	0	0	0	0	1	3	0	1	2	0	0	2	0
Tabanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thaumaleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	2	6	0	3	0	0	2	0
Total No. Taxa	2	3	5	8	4	8	8	17	17	9	9	5	9	7	7
Total No. Individuals	2	3	6	23	4	12	27	56	112	50	42	46	36	24	43
FISH TAXA															
Poeciliidae (Mosquito Fish)	0	0	0	5	11	64	0	0	0	3	5	1	18	8	31

ATTACHMENT HD-C

FISH FAUNA SURVEY RESULTS

Attachment HD-C
Fish Sampling Results

SCIENTIFIC NAME	COMMON NAME	SITE														
		PL1			SP1			CU1			CU2			WP1		
		Replicate			Replicate			Replicate			Replicate			Replicate		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Anguila reinhardtii	Long Finned Eel	1	1	0	1	0	0	0	0	0	0	0	0	15	12	18
Gobiomorphus australis	Striped Gudgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Retropinna semoni	Australian Smelt	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Gambusia holbrooki	Mosquito Fish	0	2	1	2	1	1	45	10	64	5	0	1	150	280	210
Carassius auratus	Gold Fish	0	0	0	0	0	0	0	0	0	0	0	0	5	2	6
Paratya australiensis	Freshwater Shrimp	0	0	0		0	0	0	0	0	0	0	0	35	24	22
	Total Species	1	2	1	2	1	1	1	1	1	1	0	1	5	5	5
	Total Individuals	1	3	1	3	1	1	45	10	64	5	0	1	206	319	258

SCIENTIFIC NAME	COMMON NAME	SITE														
		WP2			WP3			WP4			WO1			WO2		
		Replicate			Replicate			Replicate			Replicate			Replicate		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Anguila reinhardtii	Long Finned Eel	1	0	0	2	1	1	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Retropinna semoni	Australian Smelt	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gambusia holbrooki	Mosquito Fish	17	25	26	4	7	6	4	2	8	80	21	15	10	25	15
Carassius auratus	Gold Fish	0	0	0	0	0	0	1	1	0	0	0	0	1	1	4
Paratya australiensis	Freshwater Shrimp	19	30	25	1	3	5	0	0	0	30	25	45	25	26	38
	Total Species	3	2	2	3	3	5	2	2	1	2	2	2	3	3	3
	Total Individuals	37	55	51	7	11	14	5	3	8	110	46	60	36	52	57

ATTACHMENT HD-D

COVER RATING OF PLANT SPECIES RECORDED ALONG EACH STREAM

Attachment HD-D
Cover Rating of Plant Species Recorded along each Stream

PLANT TAXA	CREEK												
	Planters	Spring	Cumbo	Wilpinjong									Wollar
				Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	
Alternanthera pungens									*	*			
Angophora sp.				**	**	**	**		**	**	**	**	
Aster subulatus			**	**	**	**	**	**	**	**	**	**	
Austrostipa spp.				***	***	***	***	***	***	***	***	***	
Bothriochloa sp.					**	**		**	**	**	**		
Carex appressa									**				
Carex sp.		**											
Carthamus lanatus					***		***	***	***	***	***		
Casuarina cunninghamiana					**								
Chara sp.											*		
Cirsium vulgare					**	**	**	**	**	**	**	**	
Cynodon dactylon				***	***	***	***	***	***	***	***	***	
Eucalyptus spp.				**	**	**	**		**	**	**	**	
Eragrostis austrasica					***								
Imperata cylindrica					***	**							
Juncus acutus			***										
Juncus spp.		**	*										*
Lomandra sp.				*	*	*	*	*	*	*	*	*	
Lythrum hyssopifolia										**			
Malva parviflora										*			
Ottelia ovalifolia	*												
Paspalum distichum							***						
Phragmites australis			***	***	***	***	***	***	***	***	***	**	***

Attachment HD-D (Continued)
Cover Rating of Plant Species Recorded along each Stream

PLANT TAXA	CREEK												
	Planters	Spring	Cumbo	Wilpinjong									Wollar
				Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	
Potomogeton ochreatus	**	**											*
Potomogeton pectinatus											*		
Potomogeton sulcatus						*							
Rubus anglocandicans				**	***	**	***	**	**	***	***	***	
Schoenoplectus pungens							*	***	***	***	**		*
Schoenoplectus validus									**				*
Setaria gracilis										**			
Themeda australis					**	**	**	**	**	**	**	**	
Typha domingensis			***	***	**	**	***	***	**	***	***	**	***
Typha orientalis	***	***	***	**	**	**	***	**	**	**	**	**	***
Verbena bonariensis				*	*	*	*	*	*	*	*		
Verbena incompta				**			**	**	**	**	**		
Xanthium spinosum									**	**			

Cover classes:

*	one plant or small patch
**	not common, growing in a few places
***	widespread