APPENDIX I

Aquatic ecology assessment

Cobbora Holding Company Pty Limited

EMM EMGA Mitchell McLennan

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

Cobbora Coal Project

Aquatic Ecology Environmental Assessment

Job Number: EL1112020

Prepared for EMM

September 2012

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9 The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia
Telephone: 02 9496 7700
Facsimile: 02 9493 5170
International: +61 2 9496 7700

ecologylab@cardno.com.au
www.cardno.com.au

Cover Image: Remnant waterhole (Site 3) on Sandy Creek. Photographer Bob Hunt, Cardno Ecology Lab

Document Control

Report Number	Status	Date	Author		Reviewers	
EL1112020	Draft for EMM/CHC Review	30 April 2012	Peggy O'Donnell	POD	Theresa Dye	TD
EL1112020	Draft for adequacy Review	28 June 2012	Peggy O'Donnell	POD	Marcus Lincoln Smith	MLS
EL1112020	Final	12 September 2012	Peggy O'Donnell	POD	Marcus Lincoln Smith	MLS

Summary

The Cobbora Coal Project (the Project) is an open cut coal mine proposed by Cobbora Holding Company Pty Limited (CHC). The mine will supply thermal coal, primarily to power stations in NSW. In addition, some coal will be produced for the export and spot domestic markets.

The Project is located approximately 5 km south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 60 km east of Dubbo in the central west of NSW. The footprint of the Project falls within the Warrumbungle, Wellington and the Mid Western Local Government (LGA) areas. The Project will include an open cut mine; a coal handling and preparation plant (CHPP); a train loading facility and rail spur; and a mine infrastructure area. Supporting infrastructure will include access roads, water supply and storage and electricity supply. Construction is planned to commence in mid-2013. Mine operations will start in the first half of 2015. A mine life of 21 years is proposed.

A Major Project application under Part 3A of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) was submitted to the NSW Department of Planning on 5 January 2010 (application number MP 10_0001). The Director General's environmental assessment requirements (DGRs) for the Project were issued in March 2010. In response to changes in the proposed Project and government assessment requirements, revised DGRs were issued in December 2011.

EMGA Mitchell McLennan (EMM) engaged Cardno Ecology Lab (CEL) to prepare an aquatic ecology environmental assessment (AEEA) in relation to the proposed Cobbora Coal Project (the Project). The purpose of the AEEA was to identify and describe the conservation significance of aquatic biota and habitat within the Study Area and assess the potential for the Project to impact on aquatic ecology, with particular regard to matters of National Environmental Significance listed on *the Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and state environmental significance listed on the *Fisheries Management Act 1994* (FM Act).

The Project Application Area (PAA) covers most of Sandy Creek and Laheys Creek and intersects with sections of Cudgegong River and Tallawang, Mebul, Slapdash and Tucklan Creeks. The Study Area for the AEEA incorporates the PAA and Talbragar River given its downstream proximity to the PAA.

Field investigations of aquatic habitat, biota and water quality in Talbragar River, Sandy Creek, Laheys Creeks and its unnamed tributaries were made by Cardno Ecology Lab in

October 2009, and between October and November 2011. Aquatic habitat, biota and water quality in the Cudgegong River, the Tallawang, Blackheath, Goodiman, Tucklan, Patricks, Fords, Lambing Yard and Mebul Creeks, and their unnamed tributaries were sampled in October and November 2011.

Existing Aquatic Environment

The landscape of the Study Area has been heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams have been constructed on most of the smaller watercourses in the region. There has been a considerable loss of riparian vegetation and degradation of channel banks.

Although Sandy and Laheys Creeks and the Talbragar River are periodically dry, they provide considerable aquatic habitat when in flow. In-channel habitat included macrophyte beds, submerged woody debris, deep pools, and a variety of substrata such as bedrock, sand bars, gravel beds, boulders, cobble and pebbles. Refugia in the form of persistent pools were found within all of the major watercourses within the Study Area. Some (mainly upper) sections of Laheys Creek and Tallawang Creek were extremely degraded and would be classed as containing 'unlikely' to 'minimal' fish habitat.

Water quality in Sandy Creek, Laheys Creek and the Talbragar River was very poor during both high (2011) and low (2009) flow events. Conductivity and turbidity were often above the *Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand* (ANZECC/ARMCANZ) upper limits for the protection of aquatic ecosystems, whilst dissolved oxygen was below the lower ANZECC/ARMCANZ threshold.

The aquatic biota within the Study Area (up to 500 m AHD) and adjacent reaches of the Talbragar River forms part of the endangered Lowland Darling River aquatic ecological community. The natural flow regime of this community is highly variable and many of the native taxa are adapted to these conditions.

Field assessments using the AusRivAS protocol showed the aquatic macroinvertebrate assemblages within the major creeks in the Talbragar and Cudgegong River catchments were significantly impaired, suggesting moderate pollution and/or local habitat degradation. Water quality was poor with most of the variables measured falling outside the ANZECC/ARMCANZ threshold limits. A number of taxa sensitive to low dissolved oxygen levels were absent from the remnant pools and assemblages represented a more lacustrine (lake-like) rather than riverine environment, due to the lack of surface water flow at the time of sampling even under high flow conditions.

An inventory of freshwater fish based on existing information identified 28 species that could potentially occur within the Study Area. Of these, seven are introduced and six are listed as threatened. The EPBC Act lists the Trout cod (*Maccullochella macquariensis*) as Endangered and the Murray cod (*Maccullochella peelii peelii*) as Vulnerable. Under the FM Act, Trout cod, Southern purple-spotted gudgeon (*Mogurnda adspersa*), Murray-Darling population of Freshwater catfish (*Tandanus tandanus*) and the western population of Olive perchlet (*Ambassis agassizii*) are listed as Endangered and Silver perch (*Bidyanus bidyanus*) is listed as Vulnerable.

Eight fish taxa were recorded during the field assessments. These were the introduced Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Redfin perch (*Perca fluviatilis*), Eastern gambusia (*Gambusia holbrooki*), the native Carp gudgeon (*Hypseleotris* spp.), Golden perch (*Macquaria ambigua ambigua*), Australian smelt (*Retropinna semoni*) and Freshwater catfish. One Freshwater catfish was observed in a small waterhole on Laheys Creek and a second captured in a pool downstream of the confluence of Sandy and Laheys Creeks. This species has been recorded previously in the Talbragar River. The Freshwater catfish in the Study Area are part of a remnant sub-population in the Macquarie River catchment upstream of Warren. Invasive fish species had the highest overall abundance, diversity and distribution.

None of the other threatened fish species that could potentially occur in the Study Area were observed during the field assessments nor are there records of their occurrence within the Study Area. This absence may reflect the lack of previous sampling within the region as there are local anecdotal accounts of Murray cod and Silver perch historically caught in the Talbragar River. However, given the regional degradation from extraction, upstream diversions and adjacent land practices, it is possible the waterways of the Study Area no longer support viable populations of these species. Murray cod, Silver perch and Trout cod are known to inhabit the Macquarie River downstream of the Talbragar River. As Murray cod and Silver perch migrate long distances upstream to spawn, these species may utilise waterways in the Study Area during peak flow events over spring and early summer, despite regional habitat degradation.

It is not yet known whether the stocked Trout cod population in the Macquarie River at Dubbo are self-reproducing. As this species has a small home range and does not undertake large-scale spawning migrations, it is unlikely that it has become established in the Study Area. However, the unregulated Talbragar River does represent potential, albeit marginal, habitat for Trout cod should their population increase.

Similarly, although it is unlikely that the Southern purple-spotted gudgeon inhabit the Study Area, the deep, persistent pools within the Talbragar River and its tributaries constitute potential habitat for this species. The Olive perchlet is unlikely to inhabit the region and its closest record to the Study Area is over 200 km away.

Potential Impacts Associated with the Proposed Project

The works and activities associated with the Project would take place against background ecological conditions that can be summarised as suboptimal and stressed, largely but not entirely due to past land uses. Of these uses, water abstraction represents a key stressor to aquatic ecology in waterways that are naturally ephemeral. Despite their degraded condition, the creeks adjacent to the proposed major mining areas are habitat for very small numbers of endangered Freshwater catfish, a relatively sedentary species which is adapted to turbid, saline conditions. The presence of the catfish in semi-permanent pools in Sandy and Laheys creeks demonstrates that despite the overall degraded condition of the creeks, the pools serve as valuable refuges for key aquatic species, and as such should have high priority for protection. While the invertebrate diversity within the Endangered Lowland Darling River Aquatic Ecological community was low, and no protected species within that community were collected, their presence is crucial as a supply of food resources for species such native fish.

The design and layout of mining areas have been refined through the development of the proposal to minimise impacts on the creeks. The current proposed Project avoids complete diversion of the creeks as was originally proposed and has refined the water management system to maximise return of water to the creeks. Despite this, the works and activities associated with the Project have potential to further degrade biological diversity and ecological function in the Study Area’s aquatic habitats. While some of the following processes operate to some extent in the existing system, the key processes associated with the Project that may affect aquatic ecology include:

- Altered hydrology due to drawdown of groundwater, decreases in flow volume and changes in catchment area;
- Habitat degradation from increased and/or mobilised sediment;
- Changes in frequency of riparian connectivity from predicted increase in low flow conditions; and
- Changes in water quality.

Mitigation measures have been proposed for the above potential impacts. In particular, the alteration of hydrology would be addressed by freshwater dam releases. Notwithstanding this, a potential consequence of groundwater drawdown in groundwater dependent pools and altered hydrology is the increased frequency of drying of refuge pools during dry climatic conditions, which has potential to impact directly on the protected Freshwater catfish. Given the small number of catfish present, even a small reduction in their number would cause local extirpation of the species. In summary, the assessment of significance of potential impacts on local occurrences of endangered Murray-Darling population of Freshwater catfish indicated that, given the implementation of recommended mitigation measures, there may be small residual impact on the local population of the species which needs to be carefully monitored, with adjustments to water releases if required.

The assessment of significance of the Project on other listed fish species and the endangered lowland Darling River aquatic ecological community indicated that, given the implementation of mitigation measures, there would be no significant impact on these species, or community.

Recommendations

- Ensure that discharges of water mimic natural patterns in flow, capturing seasonality in the frequency, magnitude and duration of flows, as well as the natural variability to which the native fauna are adapted, where possible;
- Minimise potential impacts from mobilised sediment by the implementation of sediment control measures, focussing on reduction of suspended sediments;
- Monitor the quality of water releases and receiving waters to inform the Water Management Strategy and minimise impacts on aquatic habitats and biota in Sandy Creek, Laheys Creek and the Talbragar River;
- Design and build the proposed bridge crossings of Sandy and Laheys Creeks in accordance with the guidelines for the design and construction of waterway crossings to maintain fish passage within identified Class 1 and Class 2 waterways. The current approach of using bridge structures to cross the creeks will meet these criteria;
- Use appropriate-sized screens on the intake structure at the Cudgegong River extraction point to minimise entrainment (trapping) of fish eggs and larvae;
    - orientate the screens in the Cudgegong River appropriately;
    - operate pumps so as to ramp water velocity up and down gradually;

   - seek to reduce the water intake velocity to below 0.12 m/s;
   - minimise impact / removal of the native riparian vegetation;

- Formulate an adaptable monitoring program for the population of Freshwater catfish in Sandy and Laheys Creek before, during and after Project commencement.
- Implement measures to compensate for the predicted drawdown of groundwater in groundwater-dependant semi-permanent pools and potential impact on Freshwater catfish populations.

Opportunities for implementation of specific compensation measures within the immediate catchment/ sub catchments are restricted due to the nature of the Project. A potential, achievable compensation measure that would address the specific residual impacts of the Project on aquatic ecology in general and Freshwater catfish in particular is the provision of funding to bring forward plans to upgrade weirs in the system that have been identified as barriers to fish passage. Removing barriers to fish passage in the greater Macquarie River system would assist the dispersion of fish larvae in the system, allowing fish larvae and adult migrating fish better access to habitats and refuges in smaller creeks. Such a compensation measure would target fish biodiversity and complement existing government programs (DPI NSW 2006).

Table of Contents

Summary i
1 Introduction 1
1.1 Project Description 1
1.1.1 Overview 1
1.1.2 Open Cut Mine 2
1.1.3 Coal Handling and Preparation Plant 2
1.1.4 Train Loading Facility and Rail Spur 3
1.1.5 Mine Infrastructure Area 3
1.1.6 Supporting Infrastructure 3
1.1.6.1 Access Roads 3
1.1.6.2 Water Supply 3
1.1.6.3 Water Management 4
1.1.6.4 Electricity Supply 4
1.2 Workforce and Operating Hours 4
2 Study Area 5
2.1 Purpose of the Report 8
3 Legislation 11
3.1 Commonwealth Legislation 11
3.1.1 Environment Protection and Biodiversity Conservation Act 1999 11
3.2 State Legislation 11
3.2.1 Environmental Planning and Assessment Act 1979 11
3.2.2 Fisheries Management Act 1994 12
3.2.3 Threatened Species Conservation Act 1995 12
3.2.4 Environmental Planning and Assessment Legislation Amendment Act 1997 13
3.3 Policies and Guidelines 13
3.3.1 NSW DPI Policy and Guidelines for Aquatic Habitat Management and Fish Conservation 13
3.3.2 NSW Office of Water Guidelines for Controlled Activities 14
3.3.3 NSW State Groundwater Dependent Ecosystems Policy 14
3.4 Review of Existing Information 15
3.5 Field Sampling Methodology 17
3.5.1 Habitat Characteristics 17
3.5.2 Water Quality 18
3.5.3 Macrophytes 18
3.5.4 Macroinvertebrates 18
3.5.5 Fish 19

3.5.5.1 Electrofishing 19
3.5.5.2 Bait Traps 20
3.5.5.3 Seine Nets 20
3.5.5.4 Plankton Nets 20
3.6 Laboratory Methods 21
3.7 Data Analysis 21
3.7.1 Water Quality 21
3.7.2 Macroinvertebrate AusRivAS Models 21
4 Results 25
4.1 Existing Information 25
4.1.1 Physical Setting 25
4.1.2 Hydrology 28
4.1.2.1 Study Area Surface Waters 29
4.1.2.2 Study Area Groundwater Dependent Ecosystems 31
4.1.2.3 Study Area Water Quality 31
4.1.3 Aquatic Habitat 32
4.1.4 Biota 33
4.2 Threatened and Protected Species, Populations, Communities and Key Threatening Processes 35
4.2.1 Listings under the EPBC Act 35
4.2.1.1 Threatened Species 35
4.2.2 Listings under the TSC Act 37
4.2.2.1 Endangered Ecological Communities 37
4.2.2.2 Key Threatening Processes 38
4.2.3 Listings under the FM Act 39
4.2.3.1 Threatened Species 39
4.2.3.2 Threatened Populations 41
4.2.3.3 Endangered Ecological Communities 44
4.2.3.4 Protected Species and Habitats 44
4.2.3.5 Key Threatening Processes 46
4.3 Field Assessment 47
4.3.1 Talbragar River Catchment 55
4.3.1.1 Talbragar River 55
4.3.1.2 Sandy Creek and Unnamed Tributaries 59
4.3.1.3 Laheys Creek and Unnamed Tributaries 61
4.3.1.4 Fords Creek and Unnamed Tributaries 62
4.3.1.5 Blackheath Creek 63
4.3.1.6 Patricks Creek 64

4.3.1.7 Tucklan Creek 64
4.3.2 Cudgegong River Catchment 65
4.3.2.1 Cudgegong River 65
4.3.2.2 Mebul Creek 67
4.3.2.3 Tallawang Creek 69
4.3.2.4 Lambing Yard Creek 70
4.3.2.5 Goodiman Creek 71
4.3.3 Summary 71
4.3.3.1 Talbragar and Cudgegong Rivers 71
4.3.3.2 Major Creeks and Tributaries 72
5 Assessment of Impacts Associated with the Proposed Works 75
5.1 Description of the Project Relevant to Aquatic Ecology 75
5.2 Management of Surface Water Groundwater, Imported and Process Water During Operation of the Project. 76
5.3 Altered Hydrology 76
5.3.1 Changes in Flow Volumes 77
5.3.2 Changes in Peak Flow 83
5.3.3 Changes to Temporal Flow Regime 83
5.4 Changes in Habitat Connectivity 84
5.4.1 Changes in Flow 84
5.4.2 Groundwater Drawdown 84
5.5 Increased Sedimentation / Sediment Mobilisation 91
5.6 Water Quality 93
5.7 Local Depletions of Endangered Murray-Darling Population of Freshwater Catfish and Endangered Lowland Darling River Aquatic Ecological Community 94
5.8 Entrainment of Fish Eggs and Larvae 94
5.9 Instream Structures and Waterway Crossings 95
5.10 Listed Key Threatening Processes 95
5.10.1 Degradation of Riparian Vegetation 95
5.10.2 Removal of Large Woody Debris 96
5.10.3 Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands 96
5.11 Threatened and Protected Species, Communities and Populations 96
5.11.1 Matters of National Environmental Significance (NES) 96
5.11.1.1 Murray Cod 97
5.11.1.2 Trout Cod 100
5.11.2 Assessments of Significance under the FM Act 103
5.11.2.1 Trout Cod (*Maccullochella macquariensis*) (Source: NSW DPI 2006a) ... 104

5.11.2.2 Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*) (Source: Fisheries Scientific Committee 2008c)........ 106

5.11.2.3 Silver Perch (*Bidyanus bidyanus*) Source (NSW DPI 2006b)........ 108

5.11.2.4 Murray River Basin Population of the Freshwater Catfish (*Tandanus tandanus*) (Source: Lintermans 2009; Fisheries Scientific Committee 2008d)........ 110

5.11.2.5 Endangered Lowland Darling River Aquatic Ecological Community........ 112

6 Mitigation of Impacts on Aquatic Ecology........ 115

6.1 Design........ 115

6.1.1 Waterway Crossings and Fish Passage........ 115

6.1.2 Dams........ 116

6.1.3 Sedimentation........ 116

6.1.4 Pollution........ 116

6.1.5 Entrainment........ 116

6.1.6 Water Abstraction........ 118

6.2 Construction........ 118

6.2.1 Mobilisation of Sediment into Waterways........ 118

6.2.2 Pollution........ 119

6.2.3 Degradation of Riparian Vegetation........ 119

6.2.4 Removal of Large Woody Debris........ 119

6.2.5 Alteration to Flow Regimes........ 119

6.3 Operation........ 119

6.3.1 Mobilisation of Sediment into Waterways........ 119

6.3.2 Pollution........ 120

6.3.3 Degradation of Riparian Vegetation........ 120

6.3.4 Removal of Large Woody Debris........ 120

6.3.5 Alteration to Flow Regimes........ 120

6.3.6 Impacts on Threatened Species, Populations and Endangered Communities 121

7 Conclusion........ 125

7.1 Existing Conditions........ 125

7.2 Context of Potential Impacts........ 127

7.3 Recommendations........ 128

8 Acknowledgements........ 130

9 References........ 131

10 Tables........ 137

11 Figures (in text)........ 136

12 Plates........ 143

13 Appendices........ 158

List of Tables

Table 1. Aquatic ecology assessment sites within the proposed Cobbora Mine Project Application Area. (In text and appended)

Table 2. Type of sampling done within the proposed Cobbora Coal Project Application Area. (In text and appended)

Table 3. Water quality measured in situ in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines.(In text and appended)

Table 4. Percent cover of macrophytes recorded within the 'wetted width' of the channel at each site. (appended)

Table 5. AusRivAS scores for macroinvertebrates from edge habitat in 2009 and 2011. (appended)

Table 6. Species of freshwater fish that have been recorded in the region of the proposed Cobbora Coal Project Area. (appended)

Table 7. Suggested crossing drainage structures based on criteria established by Fairfull and Witheridge (2003). (appended)

Table 8. Threatened and protected aquatic species which may occur within the region of the Study Area. (appended)

Table 9: Summary of changes in catchment areas for Sandy and Laheys Creek. (in text)

Table 10: Evaluation of groundwater dependency and predicted scale of groundwater drawdown on ephemeral pools in Sandy and Laheys Creeks.

List of Figures

Figure1. Study area regional overview.

Figure 2. Location of key project infrastructure within the PAA.

Figure 3. Location of the aquatic ecology survey sites.

Figure 4. Watercourse classifications.

Figure 5. Sandy and Laheys Creek subcatchment and mine pit areas.

Figure 6. Mine pit projections.

Figure 7. Predicted changes in downstream surface water flow through the lifetime of the Project, expressed as percent change from pre-mining conditions.

Figure 8: Predicted groundwater drawdown at sites with pools on Sandy and Laheys creeks.

List of Plates

Plates 1a – 1d. Talbragar River.

Plates 2a – 2d. Talbragar River.

Plates 3a – 3d. Sandy Creek.

Plates 4a – 4d. Laheys and Sandy Creeks and Cudgegong River.

Plates 5a – 5d. Laheys Creek and Sandys Creek.

Plates 6a – 6d. Laheys Creek.

Plates 7a – 7d. Mebul Creek and Tucklan Creek.

Plates 8a – 8d. Cudgegong River.

Plates 9a – 9d. Blackheath Creek and Tallawang Creek.

Plates 10a – 10d. Lambing Yard Creek and Fords Creek.

Plates 11a – 11d. Talbragar River and Laheys Creek.

Plates 12a – 12d. Goodiman Creek and Patricks Creek.

List of Appendices

Appendix 1. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman *et al*. (1997).

Appendix 2. Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003).

Appendix 3. Raw data for water quality measured in situ in the study area.

Appendix 4. Field data for fish and mobile macroinvertebrate sampling.

Appendix 5. Raw data for fish and large macroinvertebrate taxa caught by electrofisher within the study area.

Appendix 6. Raw data for fish and large macroinvertebrate taxa caught by seine net within the study area.

Appendix 7. Total number of fish and large macroinvertebrate taxa caught by bait traps at each site within the study area.

Appendix 8. Fish larvae caught by plankton net within the study area.

Glossary

assemblage	A group of organisms in one place
AusRivAS	Australian Rivers Assessment System
biota	The combined plant and animal life of a region or area
community	The recognisable association of species that regularly occur together in similar environments
critical habitat	Habitat declared to be critical in relation to that species or ecological community under the *Fisheries Management Act 1994*, *Threatened Species Conservation Act 1995* or under the *Environment Protection and Biodiversity Conservation Act 1999*
depth of cover	The depth to the roof of the coal seam from the ground
ecological community	An assemblage of native species that inhabits a particular area
endangered	A species, population or ecological community that is likely to become extinct or is in immediate danger of extinction
endangered ecological community	Ecological community specified as endangered in Schedule 4 of the *Fisheries Management Act 1994*
endangered population	Population identified as endangered in Schedule 4 of the *Fisheries Management Act 1994*
endangered species	Species identified in Schedule 4 of the *Fisheries Management Act 1994* or under the *Environment Protection and Biodiversity Conservation Act 1999*
endemic	Restricted to a particular area having originated there
exotic species	A non-indigenous species
habitat	An area or areas occupied or periodically occupied by a species, population or ecological community and includes any biotic or abiotic component necessary to sustain survival and reproduction
key threatening process	Threatening process identified as such in Schedule 6 of the *Fisheries Management Act 1994* or under the *Environment Protection and Biodiversity Conservation Act 1999*
lentic	Still waters (as in lake or pond)
life cycle	The series or stages of reproduction, growth, development, ageing and death of an organism
local population	The population that exists in the study area as well as any individuals occurring in the adjoining areas known or likely to utilise habitats in the study area
lotic	Moving or running water
macroinvertebrate	Animal with no backbone. In this instance refers predominantly to aquatic insects and aquatic larvae
macrophyte	Aquatic freshwater plant
native or indigenous	Species that existed in NSW before European settlement
compensation measure	One or more appropriate actions put in place in an appropriate location to counterbalance or offset an impact on biodiversity values

population	A group of animals or plants of the same species, potentially capable of interbreeding and sharing the same habitat in a particular area at a particular time
regeneration	Where native vegetation is allowed to return naturally to an area generally by removing existing impacts such as grazing or slashing
revegetation	Use of methods such as planting of tubestock and direct seeding to return native vegetation to an area
riparian	Associated with drainage lines / watercourses
risk of extinction	The likelihood that the local population will become extinct either in the short term or long term as a result of direct or indirect impacts on the viability of that population
taxa	Plural form of taxon: several species or types of organisms
taxon	A single species or type of organism
threatened species	A plant or animal identified in the *Fisheries Management Act 1994*, *Threatened Species Conservation Act 1995* or *Environment Protection and Biodiversity Conservation Act 1999* as extinct, critically endangered, endangered, or vulnerable. This term may be extended to encompass threatened species, populations or ecological communities
threatening process	A process that threatens, or may threaten the survival, abundance or evolutionary development of species, populations or ecological communities
viable	The capacity to successfully complete each stage of the life cycle under normal conditions
vulnerable	A species or ecological community that is rare, not presently endangered but likely to become endangered unless the circumstances and factors threatening its survival or evolutionary development cease to operate
vulnerable species	Species identified in Schedule 5 of the *Fisheries Management Act 1994* or under the *Environment Protection and Biodiversity Conservation Act 1999*

Abbreviations

AEEA	Aquatic Ecology Environmental Assessment
AHD	Australian Height Datum
BWT	Bulk water transfers
CEL	Cardno Ecology Lab
CEMP	Construction Environmental Management Plan
CHC	Cobbora Holding Company Pty Limited
CHPP	Coal handling and preparation plant
CL	Coal Lease
CMA	Catchment Management Authority
CWCMA	Central West Catchment Management Authority
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (formerly Department of Environment, Water, Heritage and the Arts)
DGRs	Director-General's Requirements
DTIRIS	Department of Trade & Investment, Regional Infrastructure & Services (formerly Industry & Investment NSW)
DoP	Department of Planning
DPI, DPI NSW, NSW DPI	Department of Primary Industries, now Industry and Investment NSW (I&I NSW)
EL	Exploration Lease
EMM	EMGA Mitchell McLennan
EMP	Environmental Management Plan
EMS	Environmental Management System
EP&A Act	*Environmental Planning and Assessment Act 1979*
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESD	Ecologically Sustainable Development
FM Act	*Fisheries Management Act 1994*
GDE	Groundwater Dependent Ecosystem
Ha	Hectares
Hrs	Hours
I&I NSW	Industry and Investment NSW (previously Department of Primary Industries (DPI))
km	kilometres
km^2	square kilometres
LGA	Local Government Area
m	metres

m^2	square metres
m^3	cubic metres
MIA	Mine Infrastructure Area
ML	Mining Lease
ML	Megalitres
mm	millimetres
MOP	Mine Operations Plan
Mt	million tonnes
Mtpa	million tonnes per annum
NES	National Environmental Significance
NOW	NSW Office of Water (previously part of DECCW)
NPAA	National Parks Association of Australia
NPWS	National Parks and Wildlife Service
NPWS Act	*National Parks and Wildlife Act 1974*
NSW	New South Wales
NV Act	*Native Vegetation Act 2003*
OEH	Office of Environment and Heritage (formerly Department of Environment, Climate Change and Water; DECCW)
O0Signal score	Observed Signal score for taxa that have a probability of occurrence greater than 0 %
OE0Signal score	Ratio of the observed to expected SIGNAL score per site for taxa that have a probability of occurrence of more than 0 %.
PAA	Project Application Area
PEA	Preliminary Environmental Assessment
POEO Act	*Protection of the Environment Operations Act 1999*
RCE	'Riparian, Channel and Environmental Inventory'
RMS	Roads and Maritime Services
ROM	run of mine coal (raw coal prior to washing)
SEMP	Sediment and Erosion Management Plan
SEPP	State Environmental Planning Policy
SIS	Species Impact Statement
sp.	species (singular)
spp.	Species (plural)
T	tonnes
TL	Total Length (measurement of fish length from snout to tip of tail)
Tpa	tonnes per annum
Tph	tonnes per hour
TSC Act	*Threatened Species Conservation Act 1995*

UJV	Unincorporated Joint Venture
V	Volts
VHMP	Vegetation and Habitat Management Plan
W	Watt
WAL	Water Access Licence
WMS	Water Management Strategy
WSP	Water Sharing Plan
yr	year

1 Introduction

EMGA Mitchell McLennan (EMM) engaged Cardno Ecology Lab (CEL) to prepare an aquatic ecology environmental assessment (AEEA) for the proposed Cobbora Coal Project (the Project).

The Project is an open cut coal mine proposed by Cobbora Holding Company Pty Limited (CHC). The mine will supply thermal coal, primarily to power stations in NSW. In addition, some coal will be produced for the export and spot domestic markets.

The Project is located approximately 5 km south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 57 km east of Dubbo in the central west of NSW. The Project will include an open cut mine, a coal handling and preparation plant (CHPP), a train loading facility and rail spur, and a mine infrastructure area. Supporting infrastructure will include access roads, water supply and storage, and electricity supply. Construction is planned to commence in mid-2013. Mine operations will start in the first half of 2015. A mine life of 21 years is proposed.

A Major Project application under Part 3A of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) was submitted to the NSW Department of Planning on 5 January 2010 (application number MP 10_0001). The Director General's environmental assessment requirements (DGRs) for the Project were issued on 4 March 2010. In response to changes in the proposed Project and government assessment requirements, revised DGRs were issued for the Project on 23 December 2011.

1.1 Project Description

1.1.1 Overview

The open cut coal mine would be developed near Dunedoo in the central west of New South Wales (NSW). The primary purpose of the Project is to provide coal for five major NSW power stations. The mine will extract around 20 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal. From this, approximately 9.5 Mtpa of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long term contract. In addition, approximately 2.5 Mtpa will be produced for export or for the spot domestic market.

The Project Application Area (PAA) is approximately 274 square kilometres (km^2). The Project's key elements are:

- An open cut mine;
- A coal handling and preparation plant;

- A train loading facility and rail spur;
- A mine infrastructure area; and
- Supporting infrastructure including access roads; water supply and storage; and electricity supply.

It is envisaged that construction activities will commence in mid-2013 and that coal will be supplied to customers from the second half of 2015. The mine life will be 21 years.

1.1.2 Open Cut Mine

Multiple open cut mining pits will be developed within three mining areas:

- Mining Area A north of the infrastructure area;
- Mining Area B south of the infrastructure area; and
- Mining Area C north-east of the infrastructure area.

There will be three out-of-pit waste rock emplacements:

- AC-OOP between mining areas A and C;
- B-OOP E adjacent to Mining Area B on the east side of Laheys Creek; and
- B-OOP W adjacent to Mining Area B on the west side of Laheys Creek.

A conventional load and haul operation is proposed using excavators, front-end loaders and trucks. Initially, trucks will haul waste rock to out-of-pit emplacements. Following this, the majority of the waste rock will be placed in the mined-out voids.

Trucks will haul excavated ROM coal to the CHPP where it will be tipped into dump hoppers above the primary crushers or onto secondary ROM stockpiles for later rehandling.

1.1.3 Coal Handling and Preparation Plant

The CHPP will treat up to 20 Mtpa of ROM coal to produce a product coal that meets the sizing and coal quality requirements of the customers. Subject to the level of impurities (rejects) in the coal and washability characteristics, the ROM will be either crushed and bypassed or treated (washed) in the preparation plant. The rejects will typically include waste rock from above and below the coal seam as well as material dispersed within the coal.

The CHPP processes will be typical of those used in the majority of CHPPs in NSW with product coal separated from rejects in a series of coal cleaning circuits. The CHPP area will also contain a truck dump station; crushing plants; coal stockpiles; and the infrastructure to move and stockpile the coal. Rejects from the CHPP will be disposed within the footprint of the mining area.

1.1.4 Train Loading Facility and Rail Spur

Coal will be transported by rail to the Project's customers, including Bayswater and Liddell power stations in the Upper Hunter Valley and Eraring, Vales Point and Munmorah power stations on Lake Macquarie on the NSW Central Coast.

Product coal will be loaded onto trains from an overhead train loading bin located on a rail spur balloon loop. Approximately five trains will be loaded each day. The rail spur will be approximately 28 km long and will join the Dunedoo-Gulgong rail line near Tallawang. A locomotive provisioning facility and a siding for fuel delivery may be located adjacent to the balloon loop.

1.1.5 Mine Infrastructure Area

The mine infrastructure area will be located adjacent to the mining areas. It will include workshops; hardstand and lay-down areas; bulk storage buildings; bulk fuel storage and a fuelling station; office buildings; an operations building and change-house; parking; an explosives magazine; and vehicle washdown bays.

1.1.6 Supporting Infrastructure

1.1.6.1 Access Roads

The main access to the mine will be from the Golden Highway to the north of the operations, via a road diversion that will replace an existing section of Spring Ridge Road. The diversion will include two bridges, one over Sandy Creek and one over Laheys Creek. There will be limited light vehicle access from the south via Spring Ridge Road.

Internal roads will connect the access road to the workshop, administration buildings and to the mine infrastructure area. Internal roads will also connect the various areas of the Project.

1.1.6.2 Water Supply

The Project will require water primarily for the CHPP and for dust suppression. Water will be sourced by intercepting surface water and by pumping groundwater that enters the mine pits in accordance with the relevant permits and licences. Water will also be sourced from the Cudgegong River and pumped approximately 26 km to the primary raw water dam south-east of the mining area. Pre-existing high security water access licences have been purchased for the Project to allow up to 3.3 gigalitres (GL) of water to be extracted from the river.

1.1.6.3 Water Management

Clean, dirty, contaminated and process water will be separated. Runoff from undisturbed areas, termed 'clean water', will be diverted around the site and into the creeks. Runoff from the out-of-pit emplacements and other disturbed areas, termed 'dirty water', is likely to contain elevated suspended solids concentrations and will be diverted to sedimentation dams to allow the solids to settle. The decant water will be re-used on site. On occasions, water may be displaced from a sedimentation dam into a creek to maintain the capacity of the dam to capture runoff from future rain events. Runoff from the open mining area, the CHPP and the MIA, as well as decant water from reject emplacements and groundwater inflows to the open mining areas, termed 'contaminated water', will be stored and re-used on site for 'makeup' process water and dust suppression. Water used in the CHPP circuit, termed 'process water', will be continuously re-used. However, makeup process water will be required to replace water that remains with fine rejects in the reject emplacement pond, coarse rejects placed in the mined out void or product coal as surface moisture. Some process water will be lost through evaporation.

Wastewater from on-site facilities such as workshops, process and administration buildings will be managed by an on-site sewage treatment system that includes on-site disposal.

1.1.6.4 Electricity Supply

The Project will require approximately 20 megawatts (MW) of electrical power and will be connected to the grid at a small switching yard adjacent to the Castlereagh Highway. A power line, generally running parallel to the rail spur, will deliver the electricity to a substation in the mine infrastructure area.

An 11 kV powerline will supply the Cudgegong River pump station from the existing grid approximately 2 km south of the pump station site.

1.2 Workforce and Operating Hours

The proposed mine construction workforce will average approximately 350 persons, peaking at approximately 550 persons over a 26 month period covering Q3 2013 to Q2 2016.

The proposed mine operation workforce is estimated to be 300 persons during the first two years of full production in 2016 and 2017. This will increase steadily over the next ten years to reach a peak level of approximately 590 persons between 2027 and 2030.

Mine construction is expected to occur up to 12 hours per day. However, construction may occur up to 24 hours per day at times (e.g. during major concrete pours).

Mine operation will occur up to 24 hours per day, 7 days per week, 52 weeks per year.

2 Study Area

The Project Application Area (PAA) covers approximately 274 km^2 within and outside the existing mining exploration lease (EL). The PAA is eight km from the village of Cobbora, 22 km southwest of Dunedoo, 23 km northwest of Gulgong and 57 km east of Dubbo (Figure 1). The PAA covers most of the Sandy Creek and Laheys Creek catchment and intersects with sections of the Cudgegong River and Tallawang, Mebul, Blackheath, Lambing Yard, Ford, Goodiman and Tucklan Creeks. The Study Area for the purposes of the AEEA is distinct from the PAA, as it also includes the reach of the Talbragar River that extends from the north east to the south west of the PAA.

The CHPP, a ROM coal stockpile, two product stockpiles, workshops, buildings and rail loop would be located within an infrastructure precinct to the east of Laheys Creek.

A pipeline is proposed from the northern side of the Cudgegong River (approximately 5 km south of Mebul), west of the Castlereagh Highway and north of Goolma Road to the infrastructure precinct. It will have the capacity to deliver up to 3,300 ML of water per year to the site. The pipeline will be buried along its entire length from the Cudgegong River to new storage dam south of the CHPP (see 1.1.6.2).

The pipeline will cross Mebul Creek and some of its unnamed tributaries as well as Blackheath Creek, Fords Creek and other unnamed tributaries of Laheys Creek (Figure. 2).

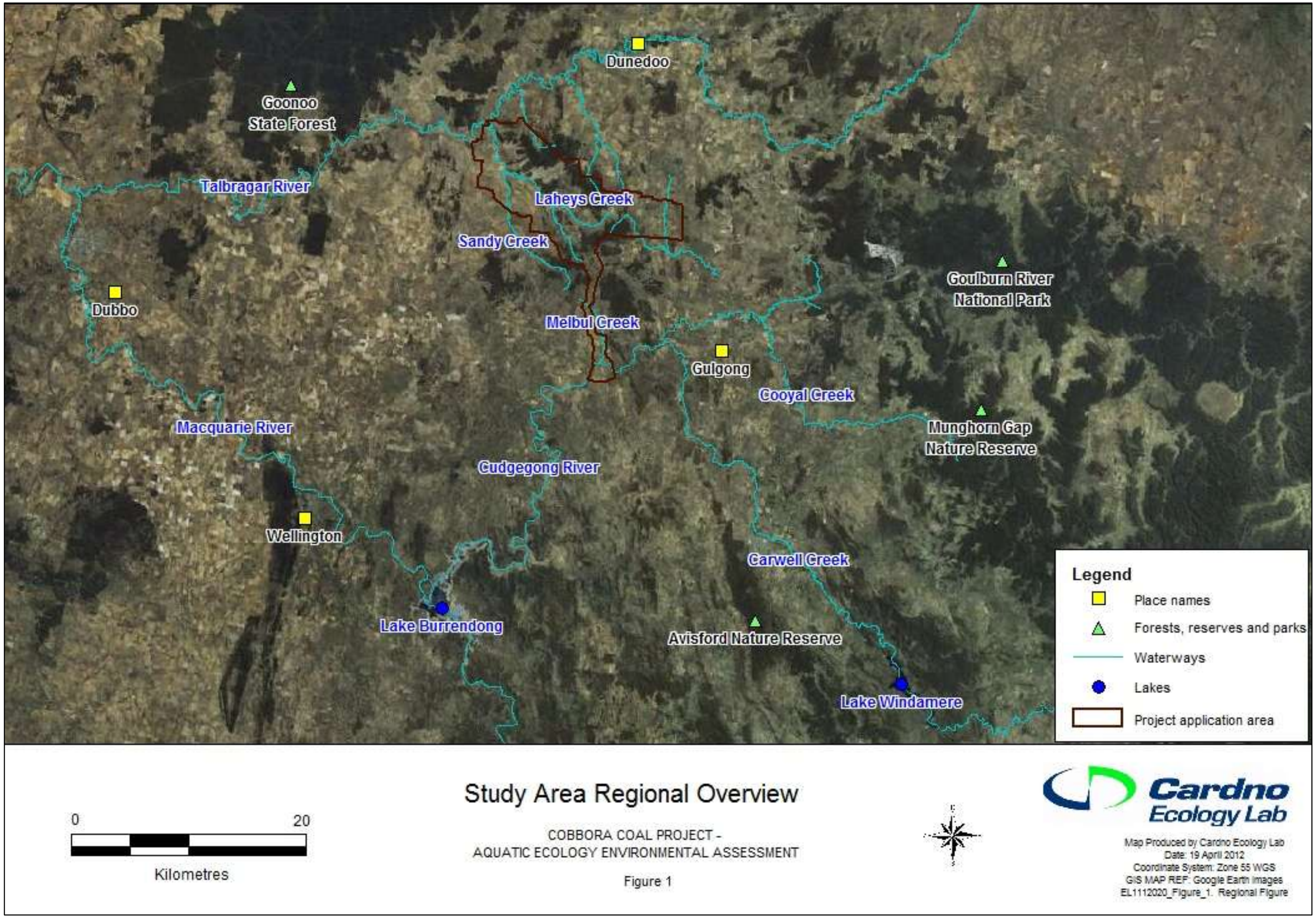

Figure 1: Study area regional overview.

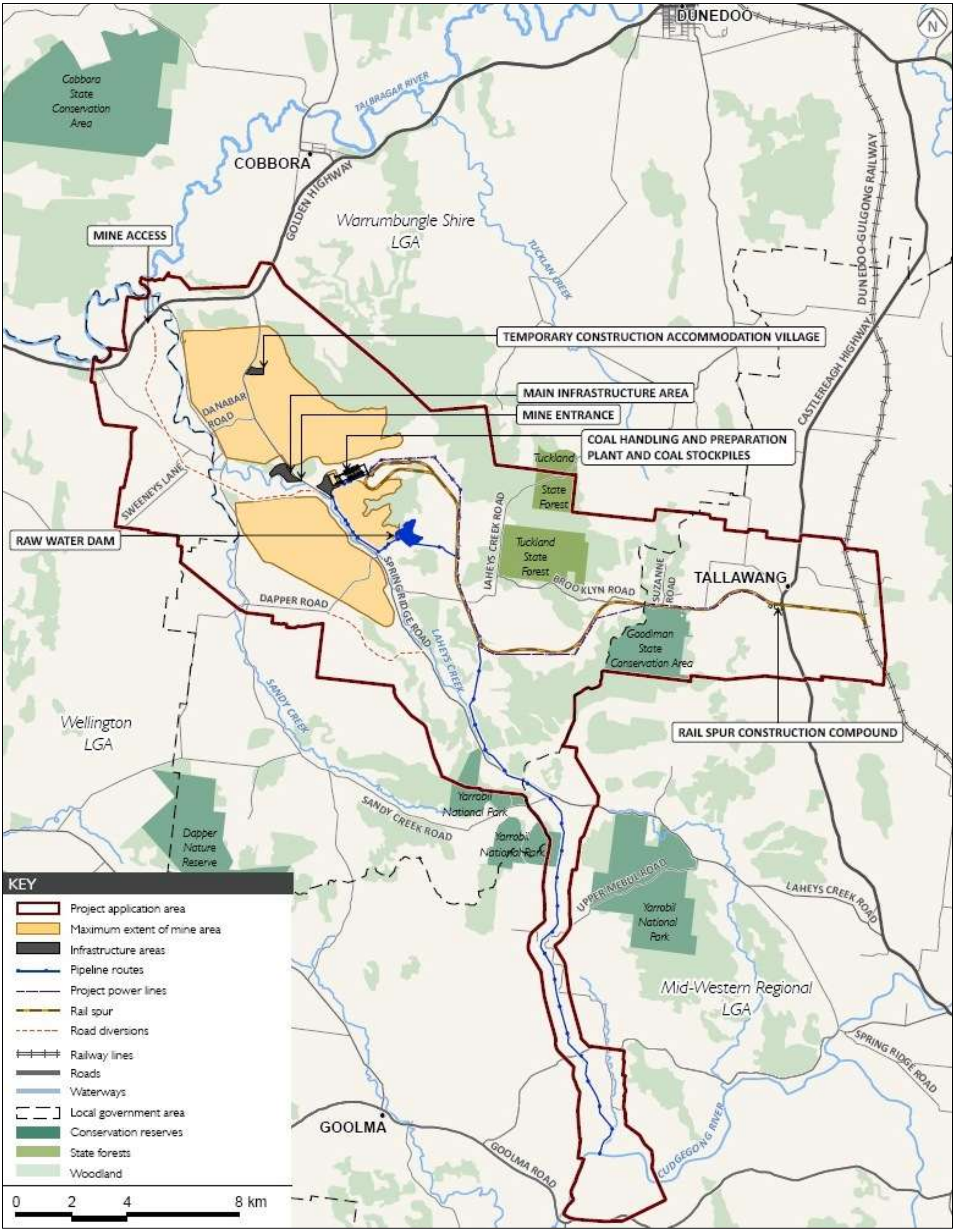

Figure 2: Project Application Area. (Figure taken from *Cobbora Coal Project (MP 10_0001) – Project Update, February 2012*).

The Project Study Area is located to the south of the Cobbora village and the Talbragar River (Figure 1). The aquatic ecology Study Area has been defined as aquatic habitats within the following watercourses and waterbodies (Figure 2):

- The reach of the Talbragar River extending from Site 1 at Cobbora downstream to Elong Elong (beyond Site 40). Talbragar River was included in the EA given its downstream proximity to the Study Area and potential hydrological impacts arising from the Project.
- The reach of the Cudgegong River extending from the Mebul Creek confluence downstream to Site 33;
- Sandy Creek and associated unnamed tributaries;
- Laheys Creek and associated unnamed tributaries;
- Mebul Creek and associated unnamed tributaries;
- The reach of Tallawang Creek extending from Site 18 downstream to Cudgegong River;
- Lambing Yard Creek and associated unnamed tributaries;
- Fords Creek and associated unnamed tributaries;
- The reach of Tucklan Creek and associated unnamed tributaries downstream to Site 25;
- The reach of Patricks Creek and associated unnamed tributaries downstream to its confluence with Tucklan Creek;
- The upper reach of Goodiman Creek at Site 65;
- Waterbodies and groundwater dependent ecosystems (GDEs) within the Project Application Area and area potentially affected by groundwater drawdown from the Project.

Sites on these waterways were assessed during field surveys in 2009 and/or 2011 (Table 1, Figure 2). Aquatic biota and habitat at each site were described (Table 2). Where appropriate, records and observations were made of water quality, macrophyte, macroinvertebrate and fish assemblages. The methods used at each site depended on water presence and depth and the likelihood of targeted taxa occurring in that area.

2.1 Purpose of the Report

This aquatic ecology assessment forms part of the Environmental Assessment Report to be submitted for determination under Part 3A of the EP&A Act.

The purpose of this AEEA is to:

- Identify and describe the conservation significance of aquatic biota and habitat within the Study Area;
- Assess the type and degree of potential impacts from the Project on native aquatic biota, threatened species, endangered populations or endangered ecological communities recorded or considered likely to occur in the Study Area; and
- Recommend mitigation measures that can be undertaken to minimise potential impacts associated with the Project.

3 Legislation

3.1 Commonwealth Legislation

3.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires approval of the Commonwealth Minister for the Environment, Heritage and the Arts for actions that may have a significant impact on matters of National Environmental Significance (NES). Matters of NES relevant to the Project include threatened species listed under the EPBC Act.

Any proposed action that is expected to have an impact on matters of NES must be referred to the Commonwealth Minister for Environment Protection, Heritage and the Arts for assessment under the EPBC Act, or assessed under the bilateral agreement between the Commonwealth and the State in which development is proposed (i.e. NSW). A referral has been prepared for the Project and the Project has been declared a controlled action under the EPBC Act.

3.2 State Legislation

3.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act provides the legislative context for environmental planning and assessment in NSW and is administered by the Department of Planning and Infrastructure (DP&I). The Project is being assessed under Part 3A as a major project under State Environmental Planning Policy (Major Projects) 2005 (SEPP MP). This part of the EP&P Act has now been repealed.

The Director-General of the NSW Department of Planning (DoP) issued requirements (DGRs) for the Project that included the following points relevant to this AEEA:

A detailed assessment of the key issues specified below, and any other significant issues identified in the risk assessment, which includes:

- A description of the existing environment, using sufficient baseline data;
- An assessment of the potential impacts of the project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions (see below);

- A description of the measures that would be implemented to avoid, minimise the potential impacts of the project, including detailed contingency plans for managing any significant risk to the environment;
- Detailed description of measures that would be implemented to avoid or mitigate impacts on aquatic threatened species, populations, ecological communities or their habitats; and
- A detailed assessment of the potential impacts on groundwater dependent ecosystems (GDEs).

3.2.2 Fisheries Management Act 1994

Projects determined by a statutory authority of the NSW State Government are required to be assessed in accordance with the EP&A Act, as amended by the FM Act. The FM Act 1994 and its Regulations are administered by Department of Trade & Investment, Regional Infrastructure & Services (DTIRIS); and are relevant to aquatic habitat and fauna that have the potential to be affected by the Project.

The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 of the FM Act lists Key Threatening Processes for species, populations and ecological communities in NSW Waters. This flora and fauna assessment has considered potential impacts to all species, populations and ecological communities listed on the FM Act that are known or considered likely to occur within the Study Area as a result of the investigations undertaken in the development of this assessment.

Other relevant sections of FM Act include:

- Section 37 – permit required to harm more fish or invertebrates than is currently allowed by restrictions on daily limits;
- Section 201 – permit required for any dredging or reclamation works; and
- Section 219 – permit required for any obstructions to fish passage.

3.2.3 Threatened Species Conservation Act 1995

Projects determined by a statutory authority of the NSW State Government are required to be assessed in accordance with the EP&A Act, as amended by the TSC Act. The TSC Act lists threatened species, populations and ecological communities under Schedules 1 and 2 of the Act, that are priorities for conservation within NSW. Schedule 3 of the TSC Act lists Key Threatening Processes for species, populations and ecological communities within NSW. This aquatic assessment has considered potential impacts to aquatic plant species and populations listed in the TSC Act that are known or considered likely to occur within the Study Area.

3.2.4 Environmental Planning and Assessment Legislation Amendment Act 1997

This Act amends the Environmental Planning and Assessment Act 1979 and the Land and Environment Court Act 1979 and relates to the validity of certain development consents.

3.3 Policies and Guidelines

3.3.1 NSW DPI Policy and Guidelines for Aquatic Habitat Management and Fish Conservation

The classification of waterways surveyed in the Study Area was done according to 'NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The assessment of impacts assumed that any waterway crossing (i.e. for temporary and permanent roads, rail, conveyor or pipeline) would be designed and built to comply with these guidelines and policies.

Section 1.2 of NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation (Smith and Pollard 1999) requires environmental compensation (creation of new habitat of the type lost) on a 2:1 basis where a significant environmental impact is unavoidable.

One of the objectives of the Fisheries Management Act 1994 is to 'conserve key fish habitats'. To determine if waterways within the Study Areas were considered to be "Key Fish Habitats", DPI NSW maps of Key Fish Habitats (http://www.dpi.nsw.gov.au/fisheries/habitat/protecting-habitats) for the mid-western and Warrumbungle regions were examined, noting that policy definition of Key Fish Habitats includes:

"Intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified."

Examination of the maps indicated that the Talbragar River, Sandy and Laheys creeks are identified on the Warrumbungle map as key fish habitats. The Cudgegong River was identified on the Mid-Western Regional map as a key fish habitat.

3.3.2 NSW Office of Water Guidelines for Controlled Activities

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

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

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

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

Part 3A projects do not require approval under the NSW Water Management Act, so the project is not considered a controlled activity under this Act. The controlled action guidelines, however, are still government policy and will be promoted by the NSW Office of Water within any Part 3A assessment process (Tim Baker, email communication 14 March 2011).

3.3.3 NSW State Groundwater Dependent Ecosystems Policy

The species composition and natural ecological processes within some ecosystems (e.g. wetlands, red gum forests, limestone caves, springs, hanging valleys and swamps) are dependent on water that has filtered down below the surface of the earth and is held in rocks, gravel and sand. The State Groundwater Dependent Ecosystems Policy (DLWC 2002) is designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of their dependent ecosystems are maintained or restored, for the benefit of present and future generations. The document provides guidance on the protection and management of groundwater-dependent ecosystems (GDEs) and includes information on:

- The location of groundwater systems in NSW;
- Different types of GDEs;
- Value of and threats to GDEs;
- The principles that underpin the management of GDEs; and
- Policies and legislation relating to management of GDEs, including how policy will be implemented and reviewed.

3.4 Review of Existing Information

Existing information on aquatic habitats and associated biota within the Study Area was obtained by searching CEL's library and undertaking searches for relevant literature using the internet.

Threatened aquatic plant, invertebrate and fish species, populations and ecological communities that occur or potentially occur within the Study Area were identified by reviewing current listings on databases maintained by NSW Government (BioNet), Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), DTIRIS and Office of Environment and Heritage (OEH; DECCW).

The BioNet database indicated species that were listed as threatened or protected under the FM Act based on records from Australian Museum and DTIRIS. BioNet database searches were made on 8 October 2009 and all other searches were made on 9 November 2011. The BioNet database has subsequently been discontinued.

The DSEWPaC Protected Matters Search Tool was used to determine relevant matters of National Environmental Significance (NES) listed under the schedules of the EPBC Act. The search area for the Protected Matters Search Tool was defined as the footprint of the Study Area, and was extended to include the adjacent reach of the Talbragar River and the Cudgegong River (between Windamere Dam and Burrendong Dam).

The DTIRIS Threatened and Protected Species Record Viewer was used to search for records of relevant threatened and protected species listed by Schedules 4, 4A and 5 of the FM Act as occurring in the Central West Catchment Management Authority (CWCMA) area.

The OEH Geographic Region Search was used to determine whether any aquatic threatened species listed under the TSC Act were present. The search was performed on the Talbragar Valley and Upper Slopes sub-regions of the CWCMA area.

Searches were also completed for the presence of significant or critical aquatic habitat within the Study Area, such as Key Fish Habitat and Ramsar wetlands.

3.5 Field Sampling Methodology

Field investigations of aquatic habitat, biota and water quality were made at Talbragar River, Sandy, Laheys, Lambing Yard Creeks and unnamed tributaries of Laheys Creek from 12 – 14 October 2009, 10 - 14 October 2011 and 31 October - 4 November 2011. Aquatic habitat, biota and water quality were sampled in the Cudgegong River, Tallawang, Blackheath, Fords, Goodiman, Tucklan, Patricks and Mebul Creeks and their unnamed tributaries from 10 – 14 October 2011 and 31 October – 4 November 2011.

3.5.1 Habitat Characteristics

At each site, a standardised description of the adjacent land and the condition of riverbanks, channel and bed was recorded using a modified version of the Riparian, Channel and Environmental Inventory (RCE) (Chessman *et al.* 1997) (Appendix 3). Habitat descriptors included:

- Geomorphological characteristics of the waterways (e.g. gully, intermittent stream, major river; deep pools or gravel beds; waterways interconnecting with other waterways or wetlands upstream or downstream);
- Flow regime of the waterways (e.g. intermittent or permanently flowing);
- Types of land use along the waterway (e.g. industries associated with the river, recreational uses);
- Riparian vegetation and instream vegetation (e.g. presence/absence, native or exotic, condition);
- Presence of instream or offstream wetlands;
- Substratum type (e.g. rock, sand, gravel, alluvial substrata);
- Presence of refuge areas (e.g. wetlands nearby that could be interlinked by the waterway during flow);
- Presence of spawning areas (e.g. gravel beds, riparian vegetation, snags); and
- Presence of natural or artificial barriers to fish passage both upstream and downstream (e.g. weirs, dams, waterfalls, causeways);

The RCE score for each site was calculated by summing the scores for each descriptor noted. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) would be assigned to a heavily channelled stream without any riparian vegetation. This methodology, developed by Peterson (1992), was modified for Australian conditions by Chessman *et al*. (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4.

3.5.2 Water Quality

Water quality was measured using a Yeo-Kal 611 probe during the surveys of 12 - 14 October 2009 and 10 - 14 October 2011. A Hydrolab probe was used during the survey of 31 October - 4 November 2011. Physical-chemical properties measured included: electrical conductivity (mS/cm and µs/cm); specific conductance (µS/cm); salinity (ppt); temperature (^{0}C); turbidity (ntu); dissolved oxygen (mg Litre^{-1} and % saturation); pH; and ORP (oxidation reduction potential: mV). Alkalinity (mg $CaCO_3$ Litre^{-1}) was measured in situ using hand-held titration cells from CHEM Metrics.

Two replicate measures of each variable were taken from just below the water surface at each site, except for alkalinity, where only one sample was taken per site.

Water quality data were collected during two field surveys: the October 2009 survey was done after a period of persistent drought, while the 2011 survey followed a period of recent high rainfall. As such, data should be considered "snapshot" in nature, and do not provide comprehensive information on changes within seasons or years.

3.5.3 Macrophytes

Percentage cover of aquatic plants (macrophytes) within the "wetted width" of the channel was estimated at Sites 1 – 13 and 15 - 40. Macrophyte species outside the wetted width were not included in percentage cover estimates but recorded as "present" only. In some cases, plants were collected, photographed and returned to the laboratory for identification.

3.5.4 Macroinvertebrates

Macroinvertebrates in pool edge habitat at 14 sites (Sites 1, 3-7, 9-10, 13, 18, 32-34 & 40) were sampled during the spring period (defined as 15 September to 15 December), in accordance with the Rapid Assessment Method (RAM) based on AusRivAS (Turak *et al.* 2004). Sites 3 and 9 were sampled during the 2009 field survey and all 14 sites were sampled in 2011.

Pool edge habitat was defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al.* 2004).

The size of sites for macroinvertebrate sampling under the AusRivAS protocol was either a distance equivalent to ten times the mode channel width or at least 100 m in length.

Samples were collected over a total length of 10 m of edge habitat usually in 1-2 m sections, ensuring that all significant sub-habitats within each site were sampled (Turak *et al*. 2004). Dip nets with a mesh size of 250 µm were used to collect invertebrates. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect suspended invertebrates and surface dwelling animals. Each AusRivAS sample was rinsed in the net with local water to minimise fine particles and placed into a white sorting tray. Animals were removed from the tray using forceps and pipettes. Trained staff removed animals for a minimum period of forty minutes. Thereafter, removals were performed in ten minute periods to a total of one hour, at which time removals would cease if no new taxa were found in a ten minute period. The animals collected were placed inside a labelled jar containing 70 % ethanol for laboratory identification.

The chemical and physical variables required for running the AusRivAS predictive model were recorded from each site.

3.5.5 Fish

3.5.5.1 Electrofishing

Electrofishing is a commonly used and effective non-destructive technique for sampling fish in freshwater habitats such as creeks, drainage ditches and streams. The technique involves discharging an electric pulse into the water which stuns fish, allowing them to be easily netted, counted, identified and released.

Electrofishing was used to sample fish and large mobile macroinvertebrates at 14 sites (Sites 1, 3-7, 9-10, 13, 18, 32-34 & 40). Sites 3 and 9 were sampled during the 2009 field survey and all 14 sites were sampled in 2011. Electrofishing was completed in appropriate habitat such as shallow pools and beneath overhanging banks and vegetation. One staff member used the electrofisher, whilst a second handled a dip net and was primarily responsible for capture of stunned fish. Two replicate electrofishing “shots” were completed at the majority of sites fished. Each replicate shot had a cumulative duration of 120 seconds of active electrofishing at 120 Hz and 100 volts. Exceptions were Site 1 shot 3, Site 32 shot 3, Site 33 shot 1 and Site 40 shot 3, where the duration of shots was much longer (approximately 1600 seconds) as the intention was not to provide a comparable (with other sites) replicate shot but to exhaustively fish a much larger reach of the river beyond the AusRivAS site boundaries. Captured native fish were placed into a fish box filled with stream water for identification and subsequent release.

All native fish were returned unharmed to the water. The introduced pest species, Eastern gambusia (*Gambusia holbrooki*), Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*) and Redfin perch (*Perca fluviatilis*)) were euthanized humanely with benzocaine.

3.5.5.2 Bait Traps

Bait traps were used to sample fish and large mobile macroinvertebrates at 14 sites (Sites 1, 3-7, 9-10, 13, 18, 32-34 & 40) during the 2011 field survey. Five traps were deployed overnight at each site for approximately 18 to 20 hours. The traps used were rectangular in shape and approximately 350 mm long and 200 mm wide with an entrance tapering to 45 mm, with 3 mm mesh size throughout. Traps were deployed in appropriate shallow water habitats such as bare substratum, macrophyte beds, overhangs and submerged snags. Traps were baited with approximately 70 mg mixture of chicken pellets and sardines.

3.5.5.3 Seine Nets

A seine net was used to sample fish and large mobile macroinvertebrates at three sites (Sites 32, 33 & 40) during the 2011 field survey. Seine netting was undertaken in pools with a water depth of less than 1 m and in broad, featureless (e.g. snags and macrophyte beds) sections of a waterway where it is easier for fish to evade a dip net or electrofisher. Seine nets were not used at Sandy Creek or Laheys Creek sites due to the lack of suitable fishing locations (e.g. narrow channel widths and numerous snags).

The seine net had 2 mm mesh, was 1 m deep and 10 m long. The net was run out from the shore in a U-shape and then hauled up on to the bank. Fish collected in the cod end in the middle of the net. The fish were quickly transferred to a fish box with minimal handling and stress. Identification, measurements and enumeration were done and the fish then released.

3.5.5.4 Plankton Nets

Plankton nets were used to sample fish eggs and larvae in the water column at Sites 32, 33 and 40 (Cudgegong River). The samples collected from Sites 32 and 33 were used to identify fish eggs and larvae that could potentially be entrained by water extraction at Cudgegong River. Many freshwater fish species spawn during spring as water temperature rises and the presence of eggs or larvae would indicate that the Study Area was used as spawning habitat by these species. Some threatened species, such as Murray cod and Silver perch, may not inhabit waterways within the Study Area, but may migrate up the unregulated Talbragar River from Macquarie River at Dubbo (where they are known to occur) and spawn on the back of spring flood flows before returning downstream.

A 600 mm diameter, 300 µm mesh plankton net was towed behind a canoe powered by a 3 hp engine. The net was deployed in the top one metre of the water column and towed for five minutes, after which the sample was removed and preserved with a 10 per cent formalin solution. Two replicate tows were done in each of the Cudgegong and Talbragar Rivers (one tow at each of the adjacent Sites 32 and 33 and two tows at Site 40).

Plankton nets were not used at Sandy Creek or Laheys Creek sites due to the lack of suitable locations where the canoe could be used effectively (e.g. small channel widths and lengths, shallow water and numerous snags).

3.6 Laboratory Methods

Animals in the AusRivAS macroinvertebrate samples were removed, identified using a binocular microscope, and a maximum of ten animals per taxa were counted as per the AusRivAS protocol. Taxa were identified to family level except for Araneae, Cladocera, Copepoda, Hydracarina, Nematoda, Nemertea, Oligochaeta and Ostracoda. Chironomidae were identified to sub-family level as required by the model. Identification of animals was validated by a second experienced scientist performing quality assurance (QA) checks on each sample. Any animal whose identity was in doubt was sent to OEH for identification.

Fish larvae and eggs were extracted from plankton samples and identified to the lowest practical taxonomic level.

3.7 Data Analysis

3.7.1 Water Quality

The water quality measurements taken during site inspections were used to assess water quality within the Study Area in terms of the health of aquatic ecosystems by comparison with the Australia, New Zealand Environment Conservation Council (ANZECC/ARMCANZ 2000) guidelines for upland rivers in south-eastern Australia.

3.7.2 Macroinvertebrate AusRivAS Models

The internet-based AusRivAS software package was used to determine the environmental condition of the waterways based on predictive models of the distribution of aquatic macroinvertebrates at undisturbed reference sites. The health of the stream was assessed by comparing the observed freshwater macroinvertebrate assemblages (i.e. those collected in the field) to macroinvertebrate assemblages expected to occur in reference (undisturbed) waterways with similar environmental characteristics. The data from this study were analysed using the NSW model for pool edge habitats sampled in spring. The AusRivAS predictive model generated the following indices.

- OE50Taxa - This is the number of macroinvertebrate families with a greater than 50 % predicted probability of occurrence that were actually observed (i.e. collected) at a site expressed as a ratio of the number of macroinvertebrate families with a greater than 50 % probability of occurrence expected to occur at undisturbed reference sites. OE50 taxa values range from 0 to slightly greater than 1 and provide a measure of the impairment of macroinvertebrate assemblages at each site. Values close to 0 indicate an impoverished assemblage while values close to 1 indicate that the condition of the assemblage is similar to that of the reference streams.

- Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. The AusRivAS bands for edge habitat in spring are graded as follows:

Band X = Richer invertebrate assemblage than reference condition (OE50 > 1.16);

Band A = Equivalent to reference condition (OE50 upper limit = 1.16);

Band B = Sites below reference condition (i.e. significantly impaired) (OE50 upper limit = 0.83);

Band C = Sites well below reference condition (i.e. severely impaired) (OE50 upper limit = 0.51); and

Band D = Impoverished (OE50 upper limit = 0.19).

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 and 10 to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat was then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

- SIGNAL > 6 = Healthy habitat;
- SIGNAL 5 – 6 = Mild pollution;
- SIGNAL 4 – 5 = Moderate pollution;
- SIGNAL < 4 = Severe pollution.

Two SIGNAL scores produced by the AusRivAS predictive model were also examined:

- O0Signal index - observed SIGNAL score for taxa that have a probability of occurrence greater than 0 %. This is calculated by averaging the SIGNAL grades for all the taxa observed and is equivalent to the SIGNAL score developed by Chessman (1995).

- OE0Signal index - the ratio of the observed to expected SIGNAL score per site for taxa that have a probability of occurrence of more than 0 %.

The AusRivAS model allows a maximum value of 220 mg $CaCO_3$ $Litre^{-1}$ for the alkalinity parameter. Alkalinity measured at Site 3 and Site 9 in 2009 and Site 34 and Site 40 in 2011 exceeded 220 mg $CaCO_3$ $Litre^{-1}$ (Appendix 3). For the AusRivAS analysis of macroinvertebrate assemblages the maximum value of 220 mg $CaCO_3$ $Litre^{-1}$ was used for these four sites. The source of the higher alkalinity readings is not known, however this substitution of data is not thought to have affected the model output.

4 Results

4.1 Existing Information

4.1.1 Physical Setting

The Study Area is located within the Central West Catchment. The catchment includes the Castlereagh, Bogan and Macquarie River valleys, covering an area of approximately 92,000 km^2 and includes the major townships of Orange, Bathurst, Dubbo, Mudgee and Nyngan (Figure 1).

The PAA lies just south of the Talbragar River (a tributary of the Macquarie River) which generally flows in an east to west direction. The PAA is dominated by the drainages of Sandy and Laheys Creeks, and to a lesser extent by Tucklan and Tallawang Creeks in the east and Mebul Creek and Cudgegong River in the south. Sandy, Laheys, Tucklan and Patricks Creeks flow from south to north, and the latter two waterways are separated from the Sandy/Laheys drainage by a low ridge that runs from Cobbora south-east to Tuckland State Forest. Patricks Creek joins Tucklan Creek south of the Cranbourne homestead (Figure 2).

The upstream reaches of Sandy and Laheys Creeks are relatively steep, dominated by bedrock, transitioning to a sand substratum ‘chain of ponds’ reach in the Talbragar flood plain (Parsons Brinckerhoff 2012a). Blackheath Creek, Fords Creek and a number of unnamed tributaries flow south-west into Laheys Creek (Figure 3). Laheys Creek flows into Sandy Creek converging between the footprint of two proposed mine areas (Mining Area A and Ming area B). Sandy Creek then discharges into the Talbragar River approximately 11.1 km downstream of the confluence of the two creeks. The Sandy Creek catchment has a total area of 169.8 km^2 (Figure 6).

The Tallawang Creek and Mebul Creek drainages are located in the eastern and southern sections of the Study Area respectively and flow from north to south. Tallawang Creek is joined by Lambing Yard Creek to the south of Goodiman State Conservation Area and is part of the Cudgegong River catchment (Figure 3). Mebul Creek originates to the west of Yarrobil National Park in the foothills of Spring Ridge and discharges directly into the Cudgegong River approximately 2.8 km upstream of the Goolma Road crossing (Figure 2).

The Talbragar and Cudgegong Rivers are both part of the Macquarie River sub-catchment. The Talbragar River has a total catchment area of approximately 4,850 km^2 and its headwaters are located at 1,130 m AHD (Australian Height Datum) at the junction of the Warrumbungle and Great Dividing ranges. For the majority of its length, the Talbragar Valley is broad and flat and predominantly used for agriculture. The Talbragar River discharges into the Macquarie River north of Dubbo, approximately 55 km to the west of the Study Area at an elevation of 258 m AHD.

The headwaters of the Cudgegong River are in the Coricudgy State Forest, to the east of Rylstone (Figure 1). The Cudgegong River flows west into Windamere Dam with the regulated river continuing north-west to the junction with Wialdra Creek, near Gulgong, a few kilometres south-east of the Study Area. From there the river turns west, then south and eventually discharges into Burrendong Dam. The Macquarie River also flows into Burrendong Dam, but from the south. Downstream of Burrendong Dam, the Macquarie River continues north-west, through the towns of Wellington and Dubbo, before being joined by the Talbragar River.

Downstream of the confluence with the Talbragar River, the Macquarie River flows west to Narromine, after which it turns north, extending to the Macquarie Marshes, located several hundred kilometres downstream of the Study Area. After emerging from the marshes, the Macquarie River converges with the Castlereagh River and then flows into the Barwon River upstream of Brewarrina.

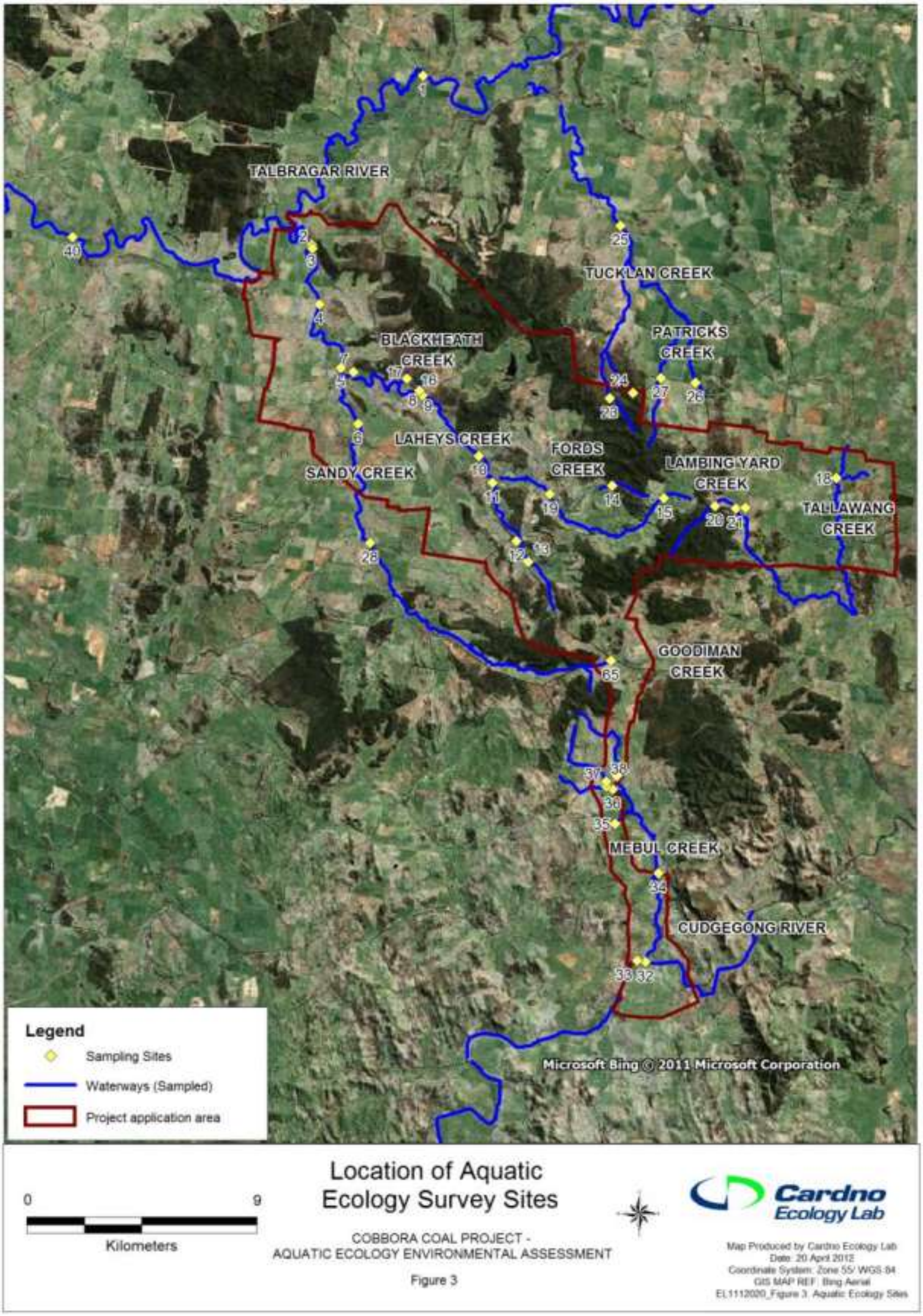

Figure 3: Location of the aquatic ecology survey sites.

4.1.2 Hydrology

River regulation and water extraction have had a substantial effect on flows within the Central West catchment (CWCMA 2007). The natural flow regime of the Macquarie River system has been heavily disrupted by the construction of weirs and the extraction of water. It is regulated along the reach extending from Burrendong Dam (south-east of Wellington) to Pillicawarrina in the Macquarie Marshes. Along this reach there are a number of weirs, including those located at Dubbo, Narromine, Gin Gin and Warren). In the upper Macquarie River catchment, above Burrendong Dam, there are a number of other storages including Windamere Dam, Winburndale Dam, Oberon Dam, Ben Chifley Dam, Suma Park Dam and Spring Creek Dam. Seasonal patterns have been altered and flow variability has been reduced with fewer large floods and long periods between inundations in the Macquarie Marshes.

The Fisheries and Aquaculture section of Industry and Investment NSW (I&I) has initiated a weir prioritisation scheme to rank structures in NSW waterways requiring remediation for the purpose of improving fish passage. Six weirs in the Central West CMA have been identified with most being on the Macquarie River downstream of the Talbragar River confluence (NSW Department of Primary Industries 2006). The weirs are the Marebone Weir, Gin Gin Weir, Narromine Weir, Warren Shire Council Weir, Dubbo City Council Weir and the Dubbo Weir. An upgrade to the Marebone Weir was completed in September 2011, while the others have planned upgrades to improve functionality and facilitate the passage of fish.

The Cudgegong River also has a severely disrupted hydrology. It is heavily regulated and supports two major dams; Windamere Dam has a 368,000 ML capacity and Burrendong Dam 1,189,000 ML. Twenty seven per cent of its surface waters are used which is at the region’s developmental limit and current groundwater extraction in the Cudgegong Valley Alluvium is several times the rainfall recharge volume (CSIRO 2008).

The regulated sections of the Macquarie and Cudgegong Rivers are subject to a Water Sharing Plan (WSP) developed by the Macquarie-Cudgegong River Management Committee in 2004. The plan contains provisions for the environmental release of a portion of inflows to Windamere Dam to attain (in combination with any downstream tributary inflows) flows between 150 and 1,500 ML/day at Rocky Water Hole on the Cudgegong River. These flows are protected from extraction until they enter the Burrendong Dam storage and are distinct from bulk water transfers (BWT) made between Windamere Dam and Burrendong Dam. Preece (2004) reported that BWTs from Windamere to Burrendong had the potential to cause severe cold water pollution in the Cudgegong River. The potential effects of the BWT on the ecological health of the Cudgegong River are the subject of a current environmental assessment. At the start of the 2007 – 2008 water year, the WSP was suspended due to extremely dry conditions when the Windamere Dam storage fell below the trigger volume of 110,000 ML, below which environmental releases cease (CSIRO 2008). During this time, high security licence holders in the Cudgegong River were allowed 80 % of their allocations.

The Talbragar River is regarded as an unregulated river. Extractive demand and the construction of town water supply schemes along unregulated rivers within the catchment impact on natural flow regimes of this watercourse (CWCMA 2007). Flow in many of the tributaries of the Talbragar River has been heavily disrupted by groundwater and surface water abstraction and the construction of private dams, intercepting flow for use on surrounding agricultural lands. These changes result in an increase in zero and low flow periods and alter natural patterns of connection and disconnection and persistence of waterholes that serve as refuges (Sheldon *et al*. 2010).

4.1.2.1 Study Area Surface Waters

Average annual rainfall in the Study Area is approximately 644 mm/year (S.D. ± 192 mm) and mean annual evaporation is 1,776 mm/year (S.D. ± 89 mm) (Parsons Brinckerhoff 2012a). The Talbragar River, and Sandy and Laheys Creeks are naturally ephemeral waterways and cease to flow during dry periods. There are no headwater storages to regulate flows and therefore all flows are a direct reflection of rain events, groundwater baseflows and evapotranspiration processes (Parsons Brinckerhoff 2012a). Flows in the Talbragar River are characterised by a seasonal pattern with lower flows over summer and autumn, and flood events throughout winter and spring (Parsons Brinckerhoff 2012a). The Talbragar River has zero daily flow 35 % of the time, a median daily flow (50^{th} percentile exceedance) of approximately 6 ML/day and a median annual discharge of 21,509 ML/year (Elong Elong gauging station, 20 km downstream of the Sandy Creek confluence with the Talbragar River) (Parsons Brinckerhoff 2012a). Sixteen per cent of daily flows in the Talbragar River exceed 100 ML/day (Parsons Brinckerhoff 2012a).

Modelling by Parsons Brinckerhoff (2010a) estimated a median (i.e. median rainfall year) baseline flow of 1,104 ML/yr in Sandy Creek at the Golden Highway crossing. The 10^{th} percentile rainfall year (dry) results in an annual flow of 198 ML/year at the same location. Over the period 1966 – 1985, Sandy Creek had zero flow 45 % of the time and a median daily flow (50^{th} percentile exceedance) of approximately 0.05 ML/day (Parsons Brinckerhoff 2012a). Two per cent of daily flows in Sandy Creek exceed 100 ML/day (Parsons Brinckerhoff 2012a). Sandy Creek is wider and has a higher flow capacity than Laheys Creek.

Two irrigation-supply dams have been constructed on Blackheath Creek, a tributary of Laheys Creek (Parsons Brinckerhoff 2010a) (“Farm Dams”, Figure 4). The larger dam has a capacity of approximately 1,500 ML and the smaller upstream dam receives flow from groundwater springs (Parsons Brinckerhoff 2010a).

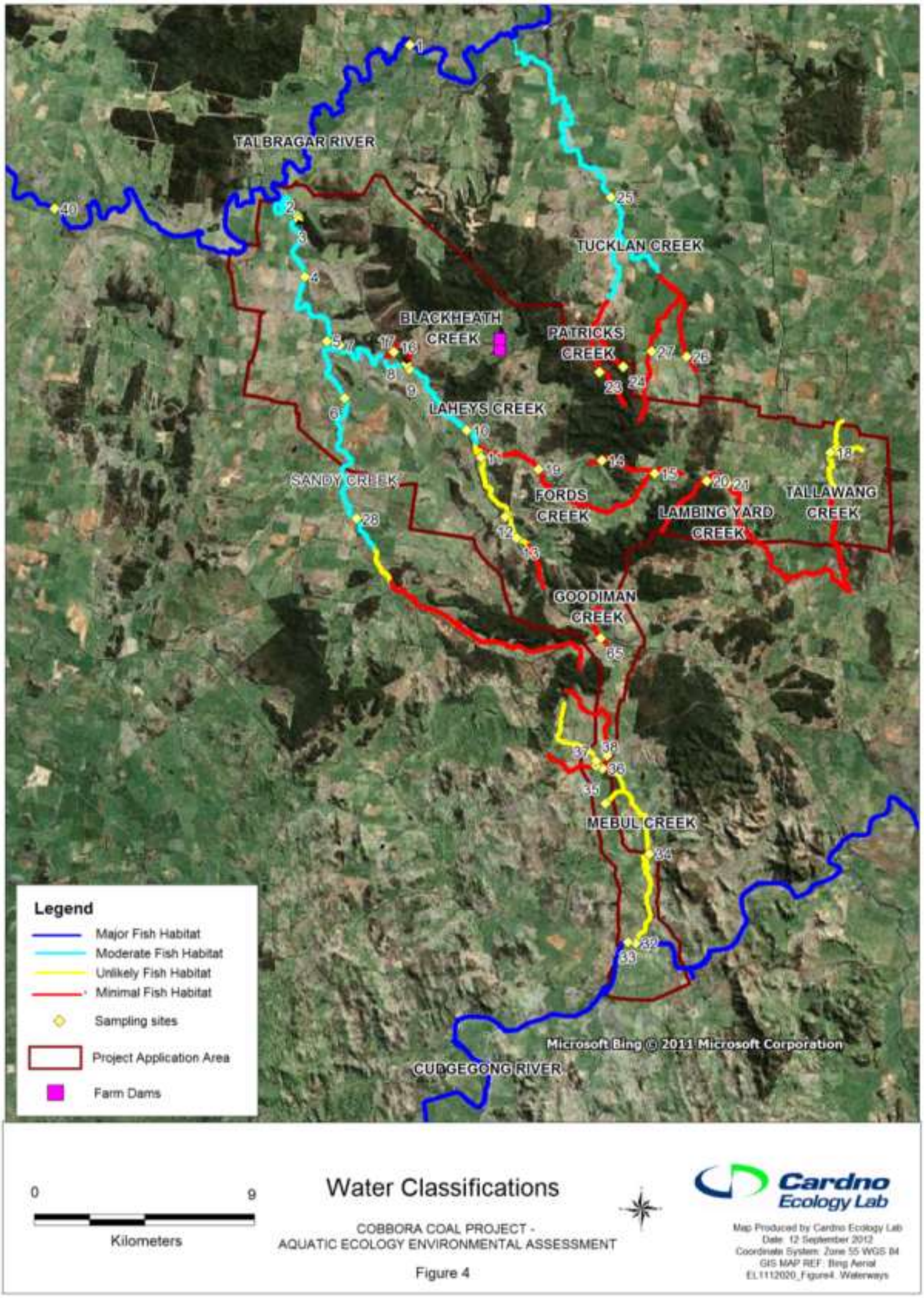

Figure 4: Watercourse classifications.

4.1.2.2 Study Area Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are ecosystems that have their species composition and natural ecological processes determined by groundwater (DLWC 2002). A GDE may either be entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water. GDEs include base flow in streams, wetlands, terrestrial vegetation and aquifer and cave ecosystems (DLWC 2002).

The Study Area contains differentiated aquifers with a range of groundwater permeability, storage and flow characteristics (Parsons Brinckerhoff 2012b). Surface water and potentially some minor groundwater connectivity occurs across the region in a variety of forms, such as springs or seeps, flood flow recharge to groundwater and groundwater contribution to river baseflow and permanent pools (Parsons Brinckerhoff 2012b). Therefore, the groundwater system in the region may support GDEs such as pool refugia, hyporheic ecosystems and, emergent macrophyte stands. The hyporheic zone is a fluctuating region where water exchanges between the surface and groundwater (in alluviums) and is an important habitat for many aquatic invertebrates and a refuge during droughts and floods.

Groundwater contributions to base flow typically emerge as springs or diffuse flow from saturated sediments. It can be an important component of instream flow and can be critical to the persistence of discontinuous pools during droughts which function as refugia for aquatic biota that are unable to utilise the hyporheic zone. Groundwater from shallow alluvia contributes to baseflow in Sandy Creek, Laheys Creek and the Talbragar River. The Talbragar River is a “gaining river” and groundwater from the Study Area flows towards it, contributing to baseflow (Parsons Brinckerhoff 2012b). The amount of baseflow to these waterways under typical conditions is quite low and insufficient to create a continuously flowing river (Parsons Brinckerhoff 2012b). However, the groundwater contribution may be important to the persistence of pool refugia in unregulated waterways (such as Talbragar River and Sandy and Laheys Creeks) during periods of low rainfall.

During periods of no flow, groundwater can be important for the persistence of aquatic macrophytes stands, such as cumbungi (*Typha orientalis*), which has roots and rhizomes that penetrate beneath creek beds into the saturated alluvial sediments. Cumbungi stands were common in many of the ephemeral waterways within the Study Area.

4.1.2.3 Study Area Water Quality

The Talbragar River and Sandy and Laheys Creeks have been classified as ‘slightly to moderately disturbed systems’ as land use in the catchment is dominated by agriculture and pastoralism. Water from tributary inflows and groundwater base flows are generally brackish to saline (Parsons Brinckerhoff 2012a).

Water quality surveys indicated that Sandy and Laheys Creeks had elevated salinity and nutrient levels, reflecting local land use (Parsons Brinckerhoff 2012a). Some metals were above the threshold for the protection of species in aquatic systems but these levels were natural and reflect the local geology and brackish groundwater (Parsons Brinckerhoff 2012a).

Salinity hazard mapping (water) for the Central West identified the Study Area as being located within a very high hazard rating for water salinity (CWCMA 2007).

4.1.3 Aquatic Habitat

Waterways within the Study Area are considered as "Key Fish Habitat" under DPI NSW guidelines for aquatic habitats (DPI NSW 2012).

The Study Area forms part of the Lowland Darling River aquatic ecological community which is listed as endangered in NSW (DPI NSW 2007). The NSW Fisheries Scientific Committee (FSC) determined that the Lowland Darling River aquatic ecological community included north-western slope rivers, including the Macquarie River upstream to Burrendong Dam (which includes the Talbragar River and its tributaries up to 500 m AHD) and the Cudgegong River from Windamere Dam downstream to Burrendong Dam (DPI NSW 2005a). Excluded from the listing are waterways above 500 m AHD not specifically named in the FSC Determination, farm dams and artificial canals. The majority of aquatic habitat within the Study Area occupies an altitude between 360 m and 500 m AHD, and as part of the Macquarie River catchment, the aquatic biota present would be considered part of the listed ecological community.

The Lowland Darling River aquatic ecological community is characterised by meandering rivers, wetlands, backwaters and billabongs and provides a variety of aquatic habitats, such as; deep channels, pools, runs and riffles, instream woody debris, gravel beds and aquatic plant beds (NSW DPI 2007). The natural flow regime in dryland river areas is highly variable and persistent waterholes are critically important aquatic habitat. For organisms with desiccation-resistant life stages, the larger river waterholes represent the only permanent aquatic habitat during extended periods of low or no flow. These waterholes act as aquatic refugia in an otherwise terrestrial landscape which fuels productivity that sustains higher trophic levels (Sheldon *et al*. 2010).

Several hundred kilometres downstream of the Study Area, the Macquarie Marshes are a series of non-terminal braided swamps, wetlands, lagoons, channels and floodplain inundated by flooding from the lower Macquarie River and its distributary streams. The northern and southern section of the Macquarie Marshes Nature Reserve and the Wilgara Wetland are listed together as a Wetland of International Importance under the Ramsar Convention. The Macquarie Marshes is one of the largest semi-permanent wetlands in south-eastern Australia. It includes extensive areas of reed swamp, river red gum woodland and water couch grasslands. The marshes are important habitat for many species of flora and fauna, particularly colonial waterbirds and migratory bird species listed under the JAMBA (Japan-Australia Migratory Bird Agreement) and CAMBA (China-Australia Migratory Bird Agreement) agreements.

4.1.4 Biota

The Lowland Darling River aquatic ecological community includes all native fish and aquatic invertebrates within all natural creeks, rivers, billabongs, lakes, anabranches and floodplains of the Darling River within NSW (DPI NSW 2007). It is characterised by a diverse biotic assemblage, including 21 native fish species and hundreds of native invertebrates (including insects, crustaceans, molluscs, sponges and worms) (DPI NSW 2007). Many of these taxa are adapted to the highly variable environmental flows of the system's natural state. For example, the threatened Murray cod *(Maccullochella peelii)* and Silver perch (*Bidyanus bidyanus*) rely on seasonal flow patterns to trigger spawning and create suitable breeding habitat (DPI NSW 2007). Freshwater mussels (Family Hyriidae) are adapted to prolonged dry periods and bury themselves in sediment and seal their shells (Gooderham and Tsyrlin 2002). Large adult yabbies (*Cherax destructor*) burrow deep below the surface where they "can survive for seven years until a drought breaks and then re-emerge to rapidly breed and repopulate" (McCormack 2008, p11).

All species listed by the Fisheries Scientific Committee as characterising the Lowland Darling River aquatic ecological community may not necessarily be present at any one location within the range of the community. This is true for the Study Area (Cudgegong River, Talbragar River and their tributaries) which has particular subsets of the biotic assemblage reflecting their particular altitude, habitat composition and anthropogenic impacts (i.e. river regulation). Previous surveys and the published distribution of native fish suggest that up to 28 species of freshwater fish may inhabit the greater region of the Study Area, which includes the Talbragar River, reaches of the Macquarie River immediately upstream and downstream of the Talbragar confluence and the Cudgegong River (from Windamere Dam to Burrendong Dam) (McDowall 1996, Lintermans 2007, NSW Government BioNet Database). Of these, 21 species are native and 7 species are introduced.

Six fish species are listed as threatened. The *EPBC Act* lists the Trout cod (*Maccullochella macquariensis*) as endangered and the Murray cod as vulnerable. Under the *FM Act*, Trout cod, Southern purple-spotted gudgeon (*Mogurnda adspersa*), Murray-Darling population of Freshwater catfish (*Tandanus tandanus*) and western population of the Olive perchlet (*Ambassis agassizii*) are listed as endangered and the Silver perch is listed as vulnerable.

BioNet has records of Freshwater catfish from the Talbragar and Cudgegong Rivers. Although there are no records on BioNet of the remaining threatened species from the Talbragar River sub-catchment, this could reflect a lack of historical sampling in the region. These taxa have previously been recorded from similar altitudes and/or habitat further upstream in the Macquarie River catchment and CEL field investigators heard anecdotal accounts of the presence of Murray cod and Silver perch from residents on the Talbragar River (Table 6). Murray cod, Freshwater catfish and Silver perch have been sampled from the Cudgegong River catchment, including the Windamere and Burrendong dam storages and from the Macquarie River near Dubbo.

Concern exists for the conservation of other native species that occur within the Talbragar River and Cudgegong River sub-catchments. There have been substantial regional declines in abundance of Golden perch (*Macquaria ambigua ambigua*) and Northern river blackfish (*Gadopsis marmoratus)* and these species are now subject to fishing restrictions in NSW (see Section 4.2.3.4). It is unlikely that all 28 species identified in Table 6 occur within either the Talbragar River or Cudgegong River subsections of the Study Area. The estimate was obtained by including surveys from a wider region, including adjacent reaches of the larger Macquarie River system, which provides greater and more permanent aquatic habitat in its reaches at similar altitudes. Aquatic habitats within sections of the Study Area (such as the upper reaches of Sandy and Laheys Creeks) are more ephemeral and therefore it is possible that some species, particularly the larger taxa, may not be present. Other species have not been recorded in the region for decades and it is possible that their distribution has contracted and they have become locally extinct.

A number of the native fish species listed in Table 6 are targeted by recreational fishers. Historical, commercial and recreational fishing has contributed to the decline of species such as Murray cod, Trout cod, Golden perch, Silver perch, Northern river blackfish and Freshwater catfish, and fishing restrictions now exist for these species in NSW. Stocking of NSW rivers and dams with hatchery-reared native species has occurred for conservation and/or to enhance recreational fishing. The native Silver perch, Golden perch, Murray cod, Trout cod, Freshwater catfish and the introduced Rainbow trout (*Oncorhynchus mykiss*) and Brown trout (*Salmo trutta*) have all been stocked within the region of the Study Area (DPI NSW 2003). However, many stocked native fish have failed to establish breeding populations and recent records of these species may represent stocked individuals and not wild fish from self-sustaining populations.

4.2 Threatened and Protected Species, Populations, Communities and Key Threatening Processes

4.2.1 Listings under the EPBC Act

4.2.1.1 Threatened Species

The DSEWPaC Protected Matters Search Tool indicated that one Vulnerable fish species, Murray cod, and one Endangered fish species, Trout cod, may either occur in the Study Area or suitable habitat may occur in the Study Area.

Murray cod

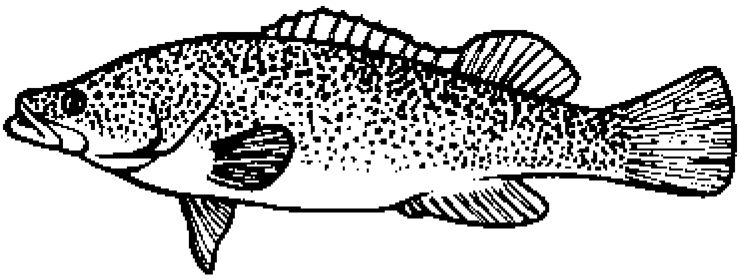

Illustration 1: Murray cod (Source: Murray Darling Basin Commission 2001)

The natural range of the Murray cod includes most of the Murray-Darling River system in NSW. Murray cod are currently patchily distributed and there are few areas in NSW where they can be considered common. It is difficult to determine whether recent records of Murray cod represent natural populations or are stocked fish reared in hatcheries (Morris *et al*. 2001). The DTIRIS Threatened and Protected Species Record Viewer has records of Murray cod from the Cudgegong River as recently as 2009 and from the Macquarie River at Dubbo in 2008.

Murray cod are found in a range of habitats, from small, clear, rocky streams in the upper-western slopes of NSW to turbid, slow-flowing lowland rivers of the western plains (Morris *et al*. 2001). The species prefers deeper holes near cover such as fallen trees, rocks and overhanging vegetation. Larvae and juvenile Murray cod feed on zooplankton and aquatic insects whereas adults feed on other fishes, crustaceans and molluscs (Koehn and O'Connor 1990).

The species is relatively sedentary during late summer, autumn and winter but during spring and early summer, when waters reach temperatures between 16 – 21 ^{0}C, the Murray cod migrates large distances (up to 120 km) upstream to spawn. Seasonal floods are important in stimulating these spawning migrations (McDowall 1996, Koehn and Harrington 2006).

Overfishing by a commercial fishery between mid-1800 and the 1930s contributed to the decline of the Murray cod. Other threats to Murray cod include:

- River regulation resulting in barriers to passage and/or loss of flood flows;
- Removal of large woody debris from NSW waterways;
- Competition with introduced fish species; and
- Pollution.

Trout cod

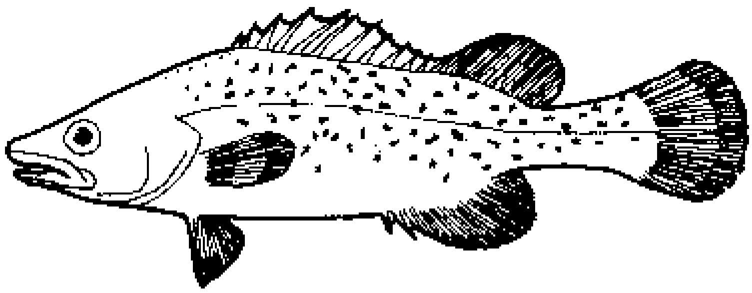

Illustration 2: Trout cod (Source: Murray Darling Basin Commission 2001)

The natural range of the Trout cod was historically throughout much of the upper reaches of the Murray-Darling drainage although now it is restricted to a few sites in south-eastern Australia (Morris *et al*. 2001). In NSW, stocked populations exist in the Macquarie River at Dubbo but it is yet to be determined if these fish have established reproducing populations. Trout cod have been recorded in the Macquarie River on the DTIRIS Threatened and Protected Species Record Viewer as recently as 2007.

Trout cod are often found in streams with a high abundance of submerged woody debris, in water that is deep and relatively close to riverbanks. The species feeds on aquatic insects, crustaceans, tadpoles and other fish (McDowall 1996).

Trout cod have small home ranges and do not undertake large-scale spawning migrations, although they can disperse larger distances during flood events. Following day length and water temperature cues during spring and early summer, mature Trout cod form pairs and spawn (NSW DPI 2002a, Koehn and Harrington 2006)

The effects of fishing, construction of dams, weirs and modifications to rivers (i.e. de-snagging) are considered the major factors responsible for the historical decline of the Trout cod. Current threats to Trout cod include:

- River regulation that modifies natural river flows and temperatures;

- Removal of large woody debris;
- Interactions with introduced species (competition and predation); and
- Reduced opportunities for dispersal.

4.2.2 Listings under the TSC Act

The DECCW Geographic Region Search identified no aquatic threatened species or communities listed under the TSC Act that might be present within the Study Area.

4.2.2.1 Endangered Ecological Communities

Artesian Springs Ecological Community

The Artesian springs ecological community is restricted to the artesian springs of the Great Artesian Basin in north-western NSW (OEH2011a). The springs occur where artesian water emerges at the surface through fault-lines in the overlying rock and produce mounds from the salts and sediments as the water evaporates (OEH 2011a). The vegetation within the community frequently consists of sedges or similar vegetation, however, trees and shrubs may also occur adjacent or nearby.

Variations in flow rates, water depth, water temperature and chemistry within and between springs results in a variety of habitat types. Vegetation structure and composition may be influenced by grazing pressure, with the persistence of some species being dependent upon grazing by native herbivores to control competitors.

Threats to the Artesian springs ecological community include:

- Trampling by livestock;
- Reduced flows resulting from a decrease in pressure in the Great Artesian Basin;
- Weed invasion;
- Disturbance by feral pigs;
- Grazing; and
- Flooding of springs for long periods may negatively impact some plant species.

The Artesian springs ecological community is predicted to occur in the Upper Slopes sub-region of the Central West CMA. However, whilst springs occur in the region, no springs were observed within the proposed mine footprint or in the area affected by groundwater drawdown. As such, this endangered ecological community (EEC) will not be considered further in this AEEA.

4.2.2.2 Key Threatening Processes

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is listed as a Key Threatening Process on Schedule 3 of the TSC Act (DECC 2005). Human activities that reduce or increase flows, change the seasonality of flows, change the frequency, duration, magnitude, timing, predictability and variability of flow events, alter surface and subsurface water levels and change the rate of rise or fall of water levels can all alter the natural flow regimes of water courses. Despite the ephemeral nature of Sandy and Laheys creeks and sometimes poor water quality, the works associated with the Project could potentially change the natural flow regime of waterways within and downstream of the Study Area.

The flow regime is a key driver of river ecology. Changes to flow can alter the geomorphological process of sediment erosion, transport and deposition that structure a variety of important channel habitat forms. This process modifies macrophyte communities, influences water properties important to biological assemblages and alters in-stream connectivity, isolating or connecting habitats and populations.

Examples of impacts on aquatic biota associated with altering natural flow regimes include:

- Restricted access to habitat for foraging, refuge or reproduction (e.g. reduced fish passage);
- Disruption of natural environmental cues necessary for reproductive cycles;
- Reductions in flow can decrease the amount of organic matter on which invertebrates and vertebrates depend on;
- Changes in flow can increase erosion and lead to sedimentation impacts on aquatic communities and degradation of the riparian zone;
- Deeper and more permanent standing water can facilitate the establishment and spread of exotic species; and
- Changes to water quality parameters such as dissolved oxygen and concomitant effects on sensitive fauna.

These alterations can pose a threat to species, populations or ecological communities which rely on natural flow regimes for their short term and long term survival and thereby contribute to loss of biological diversity and ecological function in aquatic ecosystems.

4.2.3 Listings under the FM Act

4.2.3.1 Threatened Species

Three species listed as threatened under the FM Act could potentially occur within the region of the Project Area. These are the endangered Trout cod, Southern purple-spotted gudgeon and the vulnerable Silver perch.

The historical distribution of the endangered River snail (*Notopala sublineata*) included the lower reaches of the Macquarie River but did not extend as far upstream as the Talbragar River or Cudgegong River confluences (NSW DPI 2007). Therefore this species will not be considered further.

Trout cod

See Section 4.2.1.1.

Southern purple-spotted gudgeon

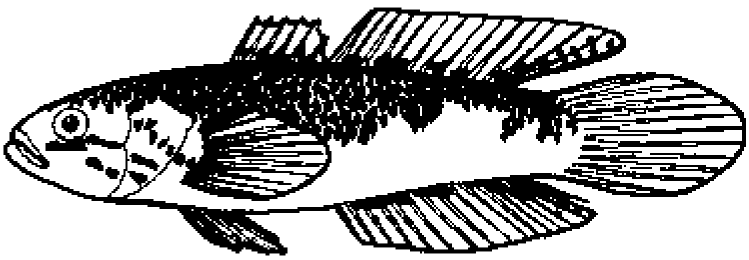

Illustration 3: Southern purple-spotted gudgeon (Source: Murray Darling Basin Commission 2001)

The Southern purple-spotted gudgeon was historically distributed throughout the entire Murray-Darling drainage but has experienced a considerable reduction in distribution and abundance (Morris *et al*. 2001). The species is now extremely rare in inland NSW and has been recorded only once from this area since 1983, when a new population was discovered in 2005 at Wuuluman Creek (~ 320 m AHD), which joins the Macquarie River approximately 8 km downstream of the Burrendong Dam wall.

Southern purple-spotted gudgeon are found in slow-moving or still waters of creeks and billabongs, often amongst benthic structures such as aquatic macrophytes, rocks or large woody debris. They feed mainly on insect larvae but also consume worms, tadpoles, small fish and some plant matter. The species can reach 120 mm but is more commonly found at 70 mm and reaches maturity at 45 – 50 mm (NSW DPI 2002b).

Southern purple-spotted gudgeon spawn during summer when water temperatures exceed 20 ^{0}C and food is abundant. Adhesive eggs are attached to hard structures.

Threats to the Southern purple-spotted gudgeon include:

- Predation by introduced fish such as Eastern gambusia and Redfin perch;
- Habitat degradation, particularly the loss of aquatic plants; and
- Fluctuation in water levels as a result of river regulation, causing impacts on reproduction and recruitment.

Silver perch

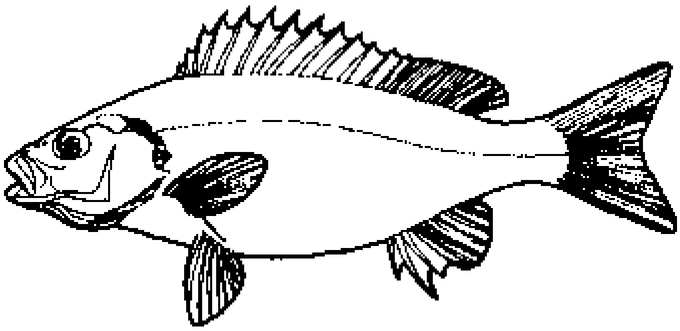

Illustration 4: Silver perch (Source: Murray Darling Basin Commission 2001

The historical distribution of Silver perch included most of the Murray-Darling drainage in NSW excluding the cool, high, upper reaches of tributary streams (Morris *et al*. 2001). Silver perch have subsequently disappeared from most of their former range and declined to low numbers. Only nine individuals were recorded from all of NSW during the NSW Rivers Survey (Harris and Gehrke 1997). Stocking of the species now occurs in NSW although in many cases this has not resulted in the establishment of reproducing populations and they remain threatened in the wild. The DTIRIS Threatened and Protected Species Record Viewer has records of Silver perch from the Macquarie River near Dubbo in 2006.

Silver perch prefer fast-flowing water but also inhabit warm, standing waters with cover provided by submerged woody debris and reeds (*Phragmites.* spp). The species is omnivorous, feeding on aquatic insects, molluscs, worms and green algae.

Silver perch is a schooling fish. Adults migrate upstream in spring and summer to spawn. Juveniles also sometimes move upstream in response to rising water temperature and water levels (DPI NSW 2005b).

Threats to Silver perch include:

- Modification of natural river flow and temperature regimes from river regulation causing reduced dispersal and spawning migrations;
- Cold-water releases resulting in spawning failures;
- Degradation of habitat, including loss of riparian vegetation and water quality decline;
- Barriers to passage;
- Competition from introduced species such as Eastern gambusia, Carp and Redfin perch;
- Diseases such as EHN (epizootic haematopoietic necrosis), which is carried by Redfin perch; and
- Stocking of inappropriate genetic strains.

4.2.3.2 Threatened Populations

The Murray-Darling population of Freshwater (eel-tailed) catfish and the western population of the Olive perchlet are listed as endangered.

Freshwater catfish

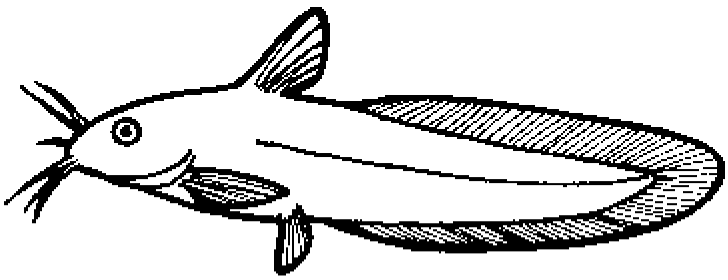

Illustration 5: Freshwater catfish (Source: Murray Darling Basin Commission 2001

The western population of Freshwater catfish was originally widely distributed throughout the Murray-Darling River System in NSW, although it was relatively uncommon upstream of Wagga Wagga on the Murrumbidgee River (Morris *et al*. 2001). Most riverine populations have declined significantly, and it is now rare or absent from all rivers and creeks in Victoria as well as the Murray, Darling and Lachlan Rivers in NSW. Moderate remnant populations occur in the Macquarie River catchment upstream of Warren. The DTIRIS Threatened and Protected Species Record Viewer has records of Freshwater catfish from the Talbragar River (close to the Study Area) in 1995.

The species is found in a variety of habitats, including rivers, creeks, lakes and billabongs. Although it inhabits flowing streams, the Freshwater catfish prefers sluggish or still waters. It has been stocked in farm dams and lakes where it has established breeding populations

(Lintermans 2007). It is found in clear or turbid waters and over substrata such as mud, gravel and rock. The catfish are bottom feeding carnivores with a diet consisting mainly of shrimps, yabbies, insects, snails and small fish.

Freshwater catfish are relatively sedentary and non-migratory with most individuals moving less than five km in a lifetime. Spawning occurs when temperatures rise during late spring to mid-summer. The species has an elaborate courtship display and lay eggs in a nest of up to 2 m in diameter built out of pebbles and/or gravel. The eggs are guarded by the male.

Historically, Freshwater catfish formed part of the inland commercial fishery in NSW from the early to mid-1900s. There was a significant and rapid decline in numbers in the late 1970s/early 1980s and the species was absent from the commercial catch in the late 1980s. Current threats to the catfish include:

- Interaction with introduced species, such as Carp and Redfin perch;
- Loss of habitat through river regulation;
- Loss of habitat and spawning sites through siltation;
- Reduced spawning success and loss of spawning sites due to flow alteration and flooding regimes;
- Loss of temperature spawning cues due to cold-water discharge;
- Loss of aquatic plants; and
- Chemical pollution, including agricultural pesticides.

Relevant to potential impacts of the Project, adult Freshwater catfish are believed to have relatively high salinity tolerance (Clunie and Koehn 2001). Catfish that were slowly acclimated to increased salinity tolerated salinity of 19 ppt (LC50), and altered behaviour responses such as reduced movement and, increased gill ventilation rates and decreased feeding were observed in salinity greater than 8 ppt (McNeil *et al*. 2010). Maximum salinity recorded during field surveys was 2.4 ppt at Site 9 in 2009, where one Freshwater catfish was caught and released. Salinity tolerances of juvenile catfish are less well known, but they are assumed to be less tolerant to elevated salinity (Clunie and Koehn 2001).

Olive perchlet

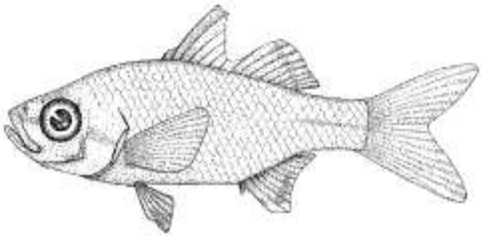

Illustration 6: Olive Perchlet (Source: McDowall 1996)

Historically, the natural range of the Olive perchlet included tributaries of the Murray-Darling drainage in western NSW. The species has experienced a serious decline and is now only found at a few sites in the Darling River drainage. Inclusion of the Olive perchlet in the assessment was requested by DPI NSW input into the DGRs but it is uncertain whether the species historically occupied the region of the Study Area and it has never been observed in the Macquarie River catchment. The closest record is over 200 km away, from the lower Bogan River, near the town of Nyngan.

Olive perchlets inhabit the vegetated margins of rivers, lakes, creeks and swamps. The species is usually found in waters approximately one metre deep, with little or no flow, near overhanging vegetation and especially in backwaters (Morris *et al*. 2001). The species often form large aggregations during the day around shelter provided by large woody debris and boulders but disperse during the night to feed on micro-crustaceans and insect larvae. (Morris *et al*. 2001)

Olive perchlets spawn in November and December when water temperatures reach 23 ^{0}C. Females release adhesive eggs amongst aquatic vegetation.

Threats to the western population of the Olive perchlet include:

- Predation by introduced fish such as Eastern gambusia and Redfin perch;
- Habitat degradation, including the removal of large woody debris;
- Rapid fluctuations in water levels as a result of river regulation impacting on reproduction and recruitment; and
- Cold-water releases resulting in spawning failures.

As it is considered highly unlikely that Olive perchlets are present in the Study Area, no assessment of significance of the potential impacts of the Project on this species was undertaken.

4.2.3.3 Endangered Ecological Communities

Aquatic biota in the Study Area (below 500 m AHD) form part of the endangered Lowland Darling River aquatic ecological community (See Section 4.1.3 and 4.1.4). The NSW Fisheries Scientific Committee (FSC) determined that the Lowland Darling River aquatic ecological community included north-western slope rivers, including the Macquarie River upstream to Burrendong Dam and the Cudgegong River from Windamere Dam downstream to Burrendong Dam (DPI NSW 2005a). Five native finfish species in this community are listed as threatened in NSW: Olive perchlet, Southern purple-spotted gudgeon, Silver perch, Trout cod and Southern pygmy perch (the latter does not occur in the Macquarie River catchment). Serious declines in other community fish species has been documented, such as Freshwater catfish and Northern river blackfish.

Threats to the Lowland Darling River aquatic ecological community include:

- Modification of natural flows as a result of river regulation;
- Cold water releases from dams;
- Degradation of riparian habitat;
- Removal of instream large woody debris;
- Predation, competition, diseases and habitat modification associated with introduced species such as Carp, Goldfish, Redfin perch, Eastern gambusia and the Tadpole snail (*Physa acuta*);
- Agricultural practices that affect water quality such as irrigation, clearing, grazing and the use of pesticides and fertilizers; and
- Overfishing.

4.2.3.4 Protected Species and Habitats

Aquatic Habitat

Aquatic habitat protected in NSW under the Fish Habitat Protection Plan No.1 that may be present in the Study Area or in downstream areas includes: wetlands, sand and gravel substrata, reed beds and other aquatic plants, large woody debris and rocks.

Fishing Restrictions

A number of species that potentially occur in the Study Area are subject to fishing restrictions in NSW:

- River blackfish: fishing is prohibited in all NSW waters;

- Trout cod: fishing is prohibited in all NSW waters;
- Olive perchlet: fishing is prohibited but anglers are unlikely to encounter the species;
- Southern purple-spotted gudgeon: fishing is prohibited but are unlikely to encounter the species;
- Freshwater catfish:
    - fishing prohibited in all western rivers and unlisted western dams;
    - bag limit of 5 in listed western dams; and
    - minimum length of 30 cm in listed western dams.
- Silver perch:
    - fishing prohibited in all western rivers and unlisted western dams;
    - bag limit of 5 and possession limit of 10 in listed western dams; and
    - minimum length of 25 cm in listed western dams.
- Golden perch:
    - bag limit of 5 and possession limit of 10; and
    - minimum length of 30 cm.
- Murray cod:
    - fishing prohibited in all inland waters September to November inclusive;
    - minimum length of 60 cm;
    - bag limit of 2 (only one over 100 cm); and
    - possession limit of 4 (only one over 100 cm).
- Yabby:
    - bag limit of 200; and
    - possession limit of 200.

Burrendong Dam and Windamere Dam are listed western dams and therefore fishing for Silver perch and Freshwater catfish is permitted in both. However, Burrendong Dam waters within 185 m upstream and downstream of the weir face and the spillway channel are closed to fishing.

4.2.3.5 Key Threatening Processes

Three of the key threatening processes listed under the FM Act: *Degradation of Riparian Vegetation*, *The Removal of Large Woody Debris from NSW Rivers and Streams;* and *Instream Structures and Mechanisms that Alter Natural Flow* are relevant to the Project (DPI NSW 2005c, 2005d).

Degradation of Riparian Vegetation

The term "riparian vegetation" refers to the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains. Riparian vegetation is important ecologically because it provides a source of organic matter; shade and a source of large woody debris. Riparian vegetation stabilises river beds and banks, protecting the channel against erosion and acts as a filter for sediments and nutrients entering watercourses.

Removal of Large Woody Debris

Instream woody debris provides complex habitat for macroinvertebrates and particularly fish, including refuge from predation, habitat for prey and as damming structures that create pools.

Instream Structures and Mechanisms that Alter Natural Flow

Instream structures, such as floodgates, bridges, culverts, flow regulators, erosion control structures and causeways, can all modify natural flow regimes of waterways (See Section 4.2.2.1 above). Of particular concern are the impacts these structures have on the passage of fish. Construction in the vicinity of a watercourse or crossings would minimize potential impacts on aquatic habitat and biota if they complied with the NSW Fisheries *Guidelines and Policies for Aquatic Habitat Management and Fish Conservation* and *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003).

4.3 Field Assessment

The field assessment of aquatic habitat within the Study Area was completed over three field trips from October 2009 to November 2011 (12 – 14 October 2009, 10 - 14 October 2011 and 31 October - 4 November 2011, Table 1). Data on water quality, aquatic habitat and biota in Talbragar River, Sandy, Laheys Creek and its unnamed tributaries were collected on all three occasions. Cudgegong River, Tallawang, Blackheath, Goodiman, Tucklan, Patricks, Lambing Yard, Fords and Mebul Creeks and their unnamed tributaries were sampled for the parameters listed in Table 2 on 10 – 14 October 2011 and 31 October – 4 November.

The 2009 survey took place following a period of extended drought although 5 mm of rainfall occurred on the first day of sampling (12 October 2009). Sites 1 to 15 were established during this survey and standing water was present only at Sites 1, 3, 6 and 9.

Water levels were much higher during the 2011 surveys as these took place during the end of a La Nina cycle and following 115 mm of rainfall over the preceding month (8 September – 8 October 2011). Site 1 to 14 and Sites 16 – 65 were sampled during these two surveys. Sampling at Site 15 was not repeated due to its proximity to a property with no access permission.

Fish habitat at each site was classified according to NSW Fisheries Guidelines (Table 1) (guidelines for the criteria are contained in Appendix 2). Table 1 contains RCE scores for each site (Riparian, Channel and Environmental inventory). Appendix 1 details the categories and descriptors used to calculate RCE scores (after Chessman *et al*., 1997). Where appropriate, recordings were made of water quality, macrophyte, macroinvertebrate and fish assemblages. Table 2 lists type of sampling completed at each site.

Table 1. Aquatic ecology assessment sites within the Cobbora Study Area.

Site	Easting	Northing	Altitude (m)	Drainage	Watercourse	Fish Habitat Classification	RCE Score
1	712319	6452373	357	Talbragar River	Talbragar River	1	31
2	707396	6445239	441	Talbragar River	Sandy Creek	2	30
3	707419	6445085	357	Talbragar River	Sandy Creek	2	30
4	707660	6442670	359	Talbragar River	Sandy Creek	2	29
5	708542	6439931	373	Talbragar River	Sandy Creek	2	32
6	709237	6437522	373	Talbragar River	Sandy Creek	2/3	27
7	709071	6439734	378	Talbragar River	Laheys Creek	2	32
8	711922	6438799	395	Talbragar River	Laheys Creek	2	32
9	712009	6438685	393	Talbragar River	Laheys Creek	2	35
10	714386	6436042	407	Talbragar River	Laheys Creek	2	31
11	714960	6434887	460	Talbragar River	Laheys Creek	3	26
12	715939	6432354	458	Talbragar River	Unnamed tributary of Laheys Creek	3/4	24
13	716415	6431455	441	Talbragar River	Laheys Creek	3/4	33
14	720100	6434653	485	Talbragar River	Unnamed tributary of Fords Creek	4	26
15	722331	6434056	518	Talbragar River	Unnamed tributary of Fords Creek	4	22
16	711883	6438901	385	Talbragar River	Blackheath Creek	4	28
17	711358	6439419	388	Talbragar River	Unnamed tributary of Laheys Creek	4	23
18	729769	6434768	489	Cudgegong River	Tallawang Creek	3	32
19	717407	6434338	435	Talbragar River	Fords Creek	4	23

Site	Easting	Northing	Altitude (m)	Drainage	Watercourse	Fish Habitat Classification	RCE Score
20	724521	6433691	536	Cudgegong River	Lambing Yard Creek	4	37
21	725399	6433559	517	Cudgegong River	Lambing Yard Creek	4	31
22	725823	6433561	517	Cudgegong River	Lambing Yard Creek	4	23
23	720086	6438392	480	Talbragar River	Patricks Creek	4	35
24	721074	6438588	495	Talbragar River	Unnamed tributary of Patricks Creek	4	33
25	720711	6445767	391	Talbragar River	Tucklan Creek	2	30
26	723792	6438959	481	Talbragar River	Tucklan Creek	4	24
27	722314	6439207	470	Talbragar River	Unnamed tributary of Tucklan Creek	4	27
28	709637	6432411	403	Talbragar River	Sandy Creek	2/3	32
32	721080	6414260	390	Cudgegong River	Cudgegong River	1	32
33	720745	6414314	387	Cudgegong River	Cudgegong River	1	32
34	721739	6418020	419	Cudgegong River	Mebul Creek	3	26
35	719984	6420155	456	Cudgegong River	Unnamed tributary of Mebul Creek	3/4	20
36	719842	6421653	464	Cudgegong River	Unnamed tributary of Mebul Creek	4	21
37	719572	6421784	467	Cudgegong River	Unnamed tributary of Mebul Creek	4	29
38	719578	6421983	478	Cudgegong River	Mebul Creek	3	30

Site	Easting	Northing	Altitude (m)	Drainage	Watercourse	Fish Habitat Classification	RCE Score
39	720038	6422204	467	Cudgegong River	Unnamed tributary of Mebul Creek	4	21
40	697099	6445760	301	Talbragar River	Talbragar River	1	31
65	719889	6427151	533	Cudgegong River	Goodiman Creek	4	33

GPS Datum: WGS 84, Grid: UTM, Position: 55

Data recorded 12/10/09 - 14/10/09 , 10/10/11 - 14/10/11 & 31/10/11 - 4/11/11.

Table 2: Type of sampling done within the Cobbora Study Area.

Site	Water Quality	RCE	Fish Habitat Classification	Macrophyte	AusRivAS	Fish and Large Mobile Macroinvertebrates		
						Bait Trap & Electrofishing	**Seine Net**	**Plankton Net**
1	•	•	•	•	•	•		
2	•	•	•	•				
3	•	•	•	•	•	•		
4	•	•	•	•	•	•		
5	•	•	•	•	•	•		
6	•	•	•	•	•	•		
7	•	•	•	•	•	•		
8	•	•	•	•				
9	•	•	•	•	•	•		
10	•	•	•	•	•	•		
11	•	•	•	•				
12		`	•	•				
13	•	•	•	•	•	•		
14*		•	•					
15		•	•					
16	•	•	•	•				
17		•	•	•				

Site	Water Quality	RCE	Fish Habitat Classification	Macrophyte	AusRivAS	Fish and Large Mobile Macroinvertebrates		
						Bait Trap & Electrofishing	**Seine Net**	**Plankton Net**
18	•	•	•	•	•	•		
19	•	•	•	•				
20		•	•					
21		•	•					
22		•	•					
23		•	•					
24		•	•					
25	•	•	•	•				
26		•	•					
27		•	•	•				
28		•	•	•				
32	•	•	•	•	•	•	•	•
33	•	•	•	•	•	•	•	•
34	•	•	•	•	•	•		
35		•	•	•				
36		•	•	•				
37		•	•	•				
38		•	•	•				
39		•	•	•				

Site	Water Quality	RCE	Fish Habitat Classification	Macrophyte	AusRivAS	Fish and Large Mobile Macroinvertebrates		
						Bait Trap & Electrofishing	**Seine Net**	**Plankton Net**
40	•	•	•	•	•	•	•	•
65		•	•					

* RCE and Fish Habitat assessment not repeated at Site 14 in 2011 due to its proximity to a property with no access permission

4.3.1 Talbragar River Catchment

4.3.1.1 Talbragar River

The Talbragar River flows through a floodplain heavily modified by agriculture. The surrounding land had been cleared for grazing or crop production. Although the Talbragar River is unregulated by dams, the natural flow regime has been significantly altered by water abstraction and overland flow interception as a number of private dams and bores occur throughout the catchment.

The sites surveyed on Talbragar River (Site 1 and Site 40) are shown in Figure 2 and Plates 1a - d and 2c - d respectively. Site 1 was located 400 m downstream of the Cobbora Road bridge crossing and Site 40 was located upstream of the Boomley Road bridge crossing of the Talbragar River.

The RCE score for the river was moderate, suggesting the channel was degraded but still provided reasonable aquatic habitat (Table 1). Tall woody riparian vegetation was characterised by the native River red gum (*E. camaldulensis*), River she-oak (*Casuarina cunninghamiana*) and the introduced Weeping willow (*Salix babylonica*). Riparian forest was narrow and incomplete. Channel banks were loose, partly consolidated by pasture grasses and bank collapses were common. Livestock had access to the channel in many sections.

The channel substratum was composed of bedrock, boulder, cobble, sand bars, gravel beds and finer sediments had accumulated in the deeper pool sections. The waterway contained a variety of habitats, such as deep pools, runs, backwater channels or anabranches, large woody debris, gravel beds, sand bars, riffles and occasional stands of macrophytes. The 2009 survey followed a prolonged dry period and surface waters within the Talbragar River had contracted to a series of discontinuous pools and the majority of the surveyed reach was dry (Plate 1c) in contrast to high flows in 2011 (Plate 1d). Standing water at Site 1 (2009) had constricted to a very small turbid pool that contained two freshwater turtles and 23 Carp (Plate 11a, b) (Appendix 5), ranging in size from 13 cm TL to 40 cm TL. The Carp were removed and euthanized.

In situ water quality was very poor during both high and low flow events sampled. Dissolved oxygen, conductivity and turbidity were outside the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems on all occasions (Table 3 and Appendix 3). pH was outside threshold limits at Site 1 in 2009 and again in 2011. Conductivity, pH and turbidity levels were above the upper limits while dissolved oxygen was below the lower thresholds. Low dissolved oxygen and high turbidity were expected in the small residual waterholes dominated by large numbers of Carp observed in 2009. Carp are a bottom feeding species known to degrade water quality by resuspending fine sediments. The high turbidity in 2011 was most likely a result of high recent rainfall and the degraded nature of Talbragar River banks and riparian vegetation. High conductivity values recorded were also expected as the Study Area occurs in a region with a high risk of water salinity (Parsons Brinckerhoff 2012a).

The habitat was relatively poor for macrophytes at both sites; temporal flows are highly variable with high turbidity and a significant sediment load and pool slopes and banks were often steep. Macrophytes within the wetted width of the channel were absent at Site 1 and occupied only 1 % of Site 40 (Table 4). At Site 40, Marsh club-rush (*Bolboschoenus fluviatilis*) was present in the shallows and on exposed mudflats, with small submerged stands of Stonewort (*Nitella* sp.) and Watermilfoil (*Myriophylum* sp.) located in the faster shallow flows upstream of the Boomley Bridge.

A total of 26 macroinvertebrate taxa were recorded from the pool edge habitat at the sites on the Talbragar River, with numbers ranging from 11 at Site 1 to 22 at Site 40 (Appendix 4). The composition of the aquatic macroinvertebrate assemblages indicated that the Talbragar River was significantly impaired due to pollution and/or local habitat degradation (AusRivAS Band B) at Site 1 and equal to the reference condition at Site 40 (AusRivAS Band A; Table 5). O0Signal scores of 4.1 at Site 1 and 3.86 at Site 40, with an overall SIGNAL2 score of 3.8, suggest that the Talbragar River was moderately to severely polluted or degraded and the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0Signal scores of close to 1.0 indicate that the macroinvertebrate assemblage had a similar proportion of pollution-tolerant taxa to equivalent reference sites (Table 5). The Talbragar River was poor habitat for macroinvertebrates; macrophyte density was low and water quality poor, with high siltation and low dissolved oxygen. Freshwater shrimp (Family Atyiidae) were abundant within the Talbragar River and Freshwater prawns (*Macrobrachium* sp.) and Yabbies (*Cherax destructor*) were common (Appendices 5 – 7; Plate2a). Macroinvertebrates with drought-resistant adaptations were observed in the dry river bed during the 2009 survey. Yabbies were found alive in burrows in the cooler and damp conditions under woody debris and boulders. Dead and desiccated Freshwater mussels were also commonly observed partially buried in the channel bed (Plate 2b).

The Talbragar River was considered major fish habitat (Class 1 Waterway, Figure 4) although it had suffered significant degradation from regional agriculture. The reach had deep pools, undercut banks and ledges and a significant amount of submerged large woody debris along the reaches that were surveyed. Waterhole refugia were observed in the 2009 survey during a sustained dry period. Five fish species were observed during the high and low flow surveys and all were relatively common: the native Carp gudgeon (*Hypseleotris* spp.) and Australian smelt (*Retropinna semoni*) and the introduced Carp, Goldfish and

Eastern gambusia (Appendix 5). Carp gudgeon were commonly associated with macrophytes, snags or boulders and cobble substrata whereas the smelt inhabited the open channel waters, often in faster currents and were only caught with the seine net. Fish eggs were entrained in the plankton net at Site 40 but the species could not be identified (Appendix 8).

Whilst a Class 1 waterway, the Talbragar River has been significantly degraded and this is reflected in the composition and relative abundance of the fish assemblage. Threatened species such as Freshwater catfish, Silver perch and Murray cod were not recorded in the Talbragar as part of this survey (although they may still be present) and the assemblage was dominated by introduced species, such as Carp and Eastern gambusia, which are tolerant of pollution and habitat degradation. Carp made up the majority of fish biomass in the Talbragar River and was the only fish species recorded in the waterhole 'refugia' at Site 1 in 2009 (Plate 11a).

Although the Talbragar River is unregulated by dams, several potential barriers to fish passage were observed. Large woody flood debris had accumulated against the piers of the Boomley Road Bridge downstream of Site 40 creating a significant barrier across the entire channel (Plate 2d) and it is possible that similar barriers have formed elsewhere along the river naturally and against artificial structures following flood flows. 'Flood gates' (within channel fencing) were also commonly observed on the Talbragar River. Given that the river experiences zero or low flows for a considerable portion of the year, landowners have fenced across the river, down to the channel bed, to prevent the escape of livestock. The bottom of within-channel fences were often secured by heavy, hanging objects (not embedded in the channel) intended to permit flood debris to pass downstream but also serve as a continuous and effective barrier to livestock during zero or low flows (Plate 11c). These structures would pose a barrier to fish moving up or downstream, particularly larger individuals (such as mature Murray cod on spawning migrations) and were not always successful at preventing the build-up of flood debris.

Table 3. Water quality measured in situ in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines for upland watercourses in south-east Australia (see Appendix 3 for raw data).

Table 3a. Water quality measured in situ in the study area in October 2009.

Site Waterway	**Conductivity (us/cm)**	**pH**	**Dissolved Oxygen (% sat.)**	**Turbidity (NTU)**
Guideline Range	*30 - 35*	*6.50 - 8.00*	*90 - 110*	*2 - 25*
1 Talbragar	↑	↑	↓	↑
3 Sandy Ck d/s confluence with Laheys Ck	↑	✓	↓	✓
6 Sandy Ck u/s confluence with Laheys Ck	↑	✓	↓	✓
9 Laheys Ck u/s confluence with Sandy Ck	↑	✓	↓	↑

Recorded by Cardno Ecology Lab 12/10/09 - 14/10/09.

↓ = below guidelines, ↑ = above guidelines, ✓ = within guidelines

Table 3b. Water quality measured in situ in the study area in October - November 2011.

Site Waterway	**Conductivity (us/cm)**	**pH**	**Dissolved Oxygen (% sat.)**	**Turbidity NTU)**
Guideline Range	*30 - 350*	*6.50 - 8.00*	*90 - 110*	*2 - 25*
1 Talbragar	↑	↑	↓	↑
2 Sandy Ck d/s confluence with Laheys Ck	↑	✓	↓	↑
3 Sandy Ck d/s confluence with Laheys Ck	↑	✓	↓	↑
4 Sandy Ck d/s confluence with Laheys Ck	↑	✓	✓	↑
5 Sandy Ck near confluence with Laheys Ck	↑	✓	↓	↑
6 Sandy Ck u/s confluence with Laheys Ck	↑	↑	↑	↑
7 Laheys Ck u/s confluence with Sandy Ck	↑	✓	✓	↑
8 Laheys Ck	↑	✓	↑	↑
9 Laheys Ck	↑	✓	✓	↑
10 Laheys Ck	↑	↑	✓	↑
11 Laheys Ck	↑	✓	↓	↑
13 Laheys Ck	↑	✓	↑	↑
16 Blackheath Ck	✓	✓	↓	↑
18 Tallawang Creek	✓	✓	↓	↑
19 Fords Creek	↑	✓	✓	↑
25 Tucklan Creek	✓	✓	↓	↑

Table 3b. Water quality measured in situ in the study area in October - November 2011.

32 Cudgegong River	↑	✓	↓	na
33 Cudgegong River	↑	✓	✓	na
34 Mebul Creek	↑	✓	↓	na
40 Talbragar River	↑	✓	↓	na

Recorded by Cardno Ecology Lab 10/10/11 - 14/10/11 & 31/10/11 - 04/11/11.
↓ = below guidelines, ↑ = above guidelines, ✓ = within guidelines ns = not sampled
na: faulty water quality probe: reading not available or unreliable

4.3.1.2 Sandy Creek and Unnamed Tributaries

Sandy Creek flows through a landscape heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams are common on many of its tributaries,

Six sites on Sandy Creek were surveyed (Table 1, Figure 3, Plates 3 a – d and 5 c – d).

The RCE scores for Sandy Creek were moderate suggesting it was degraded but still provided reasonable aquatic habitat (Table 1). Large woody riparian vegetation was sparse and absent along some reaches. Channel banks were generally consolidated by pasture grasses and bank collapses were common. Channel substratum in deep low velocity pool sections were characterised by fine silts and sands and the shallower sections that experience higher velocity flows were dominated by gravels, pebbles and cobbles. Outcrops of bedrock and rock shelves were observed at more upstream locations such as Site 5 (Plate 5c, d) and Site 6 (Plate 3a, b). The waterway contained a variety of habitats, such as macrophyte stands (e.g. cumbungi and common reed), deep pools (Plate 3a), runs, large woody debris, gravel beds, sand bars and occasional riffles. During the low flow survey of 2009, surface water was only observed at Site 3 and Site 6 where it had contracted into discontinuous pools. The waterhole at Site 3 represented a significant aquatic refuge as it was still approximately 1.2 m deep (Plate 3a), contained snags and was fringed by macrophytes and overhanging riparian vegetation. Pasture grasses had colonised the creek bed in the dry reaches. In situ water quality was poor during the high and low flow events sampled in 2011 and 2009 respectively. Conductivity was above the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems at all sites and on all occasions (Table 3 and Appendix 3). Dissolved oxygen was outside the threshold limits on all occasions with the exception of Site 4 in 2011 and turbidity was above the threshold limits at all Sandy Creek sites in 2011 (Table 3 and Appendix 3).

Six macrophyte species were identified in Sandy Creek and tributary sites where macrophyte surveys were undertaken (Table 4). The two most widespread species, Cumbungi (*Typha* *orientalis*) and Common reed (*Phragmites australis*) were present at six of the nine sites surveyed, although percentage cover was variable ranging from 0 – 90 % for Cumbungi (average % cover = 15 ± 33 S.D.) and 0 – 80 % for Common reed (average % cover = 12 ± 29 S.D.). Two species of Stonewort (*Nitella* sp. and *Chara* sp.), Tussock sedge (*Carex appressa*) and Curled dock (*Rumex crispus*) where usually present at densities, but at percentage covers of lower than 1 % or were only observed outside the channel wetted width. Cumbungi and Common reed were observed at a number of Sandy Creek sites in 2009 in the absence of surface water. Common reed is able to persist in terrestrial habitats such as creek banks and Cumbungi stands are considered potential GDE's as their rhizomes are able to penetrate beneath creek beds accessing alluvial groundwater where it is available.

A total of 37 macroinvertebrate taxa was recorded from the pool edge habitat at Sandy Creek, with numbers ranging from 17 at Site 3 in 2009 to 25 at each of Site 3 and Site 4 in 2011 (Appendix 4). Macroinvertebrate species richness was greater at Site 3 during the high flow survey. Hydraenid beetles were the only aquatic macroinvertebrates from 2009 that were not recorded again in 2011. The composition of the aquatic macroinvertebrate assemblages indicated that at Site 3 (2009), Sandy Creek was significantly impaired due to pollution and/or local habitat degradation (AusRivAS Band B), but was equal to the reference condition at Site 3 during higher flows (2011) (AusRivAS Band A; Table 5). O0Signal scores ranging from 3.71 (Site 3, 2009) to 3.36 (Site 6, 2011) and the overall SIGNAL2 score of 3.8 suggest that Sandy Creek was severely polluted or degraded as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0 Signal scores of less than one indicate that the macroinvertebrate assemblages had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (Table 5). Freshwater shrimp (Family Atyiidae) were abundant at all sites within Sandy Creek. Yabbies were recorded at the furthest upstream (Site 6) and downstream (Site 3) sites where bait traps and electrofishers were used suggesting a distribution along the entire reach of Sandy Creek. Freshwater prawns were recorded at Site 5.

The lower reach of Sandy Creek (Sites 2 – 5) is considered moderate fish habitat (Class 2 Waterways) although it had suffered significant degradation from local agriculture (Table 1). The reach had deep pools, undercut banks and ledges and a significant amount of submerged large woody debris along the reaches that were surveyed. The waterhole at Site 3 represented a significant dry period aquatic refuge. Further upstream the fish habitat became more marginal as flow diminished and modal depths decreased. Five fish species were observed during the high and low flow surveys, four of which are common; the native Carp gudgeon, the introduced Carp, Goldfish and Eastern gambusia. The threatened

Freshwater catfish was observed at Site 5 in 2011 (Appendix 5); this waterhole was dry in the 2009 survey (Plate 5c - d).

A causeway crossing was present at the upper reach of Sandy Creek at Site 28 which would represent a barrier to upstream fish passage during moderate to low flows. There were also numerous natural barriers or obstructions along Sandy Creek which would be barriers to upstream passage during moderate or low flows, such as dense macrophyte stands in shallow water and channel bed accumulations where the waterway becomes effectively a chain of ponds. The road crossing at Sandy Creek Road was a causeway and would present a barrier to fish passage during low flows (Site 7).

4.3.1.3 Laheys Creek and Unnamed Tributaries

Laheys Creek flows through a landscape heavily modified by agriculture. The adjacent landscape supports sections of eucalypt woodland although the majority has been cleared for grazing or crop production. Private dams are common on many of its tributaries (such as the large private dam in the upper Blackheath Creek catchment). Flow in Laheys Creek is impeded by a number of causeways.

Eight sites along Laheys Creek and its unnamed tributaries were surveyed; Sites 7 – 13 and Site 17 (Table 1, Figure 2, and Plates 6a - d).

The RCE scores for Laheys Creek were moderate suggesting it was degraded but provided reasonable aquatic habitat (Table 1). Large woody riparian vegetation was sparse and often incomplete. Channel banks were generally consolidated by pasture grasses and bank collapses were common. Channel substratum in deep low velocity pool sections were characterised by fine silts and sands. Shallower sections that experience higher velocity flows were dominated by gravels, pebbles and cobbles. Outcrops of bedrock and rock shelves were more common at upstream locations, such as the downstream end of Site 13 (Plate 5a). The waterway contained a variety of habitats, such as macrophyte stands (e.g. Cumbungi and Common reed), deep pools (Plate 6d), runs, large woody debris, gravel beds, sand bars and occasional riffles. During the low flow survey of 2009 surface water was only observed at Site 9. The waterhole at Site 9 represented an aquatic refugia and although it was approximately 0.5 m deep in 2009 (Plate 6c), a threatened Freshwater catfish was caught during electrofishing (Plate 4b). During periods of low flow, large sections of Laheys Creek dry out and are colonised by pasture grasses (Plates 6a, b). The unnamed Laheys Creek tributaries assessed during the high flow survey of 2011 (Sites 12 and 17) were dry indicating that they only flow during and immediately after a significant rainfall event. Water quality was poor for the physical parameters measured during the high and low flow events sampled in 2011 and 2009 respectively. Conductivity and turbidity were above the

ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems at all sites and on all occasions (Table 3 and Appendix 3). Dissolved oxygen was outside the threshold limits on four out of seven sampling events.

Six macrophyte species were identified in Laheys Creek and its tributaries (Table 4). All were relatively common and abundant throughout the region. Cumbungi was the most widespread and was present at half of the eight sites, although percentage cover was highly variable ranging from 0 – 40 % (average % cover = 8.4 ± 18 S.D.). Site 13, located in the upper reach of the creek, was the most diverse supporting four species (Table 4).

A total of 39 macroinvertebrate taxa was recorded from the pool edge habitat at Laheys Creek, with numbers ranging from 15 at Site 9 in 2011 to 28 at Site 13 in 2011 (Appendix 4). Macroinvertebrate species richness was lower at Site 9 following the high flows. The composition of the aquatic macroinvertebrate assemblages indicated that diversity at Laheys Creek had increased between studies, likely the result of increased water availability. AusRivAS Band scores ranged from B (indicating severe impairment due to pollution and/or local habitat degradation) at Site 9 (2009) to X (indicative of enhanced species richness) at Site 13 (Table 5). O0Signal scores ranging from 4.00 (Site 9, 2009) to 3.27 at Site 7 and an overall SIGNAL2 score of 3.6 suggest that Laheys Creek was moderately to severely polluted or degraded and the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0 Signal scores of less than one indicate that the macroinvertebrate assemblages had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (Table 5). Freshwater shrimp (Family Atyiidae) were abundant at all sites within Laheys Creek. Whilst yabbies were recorded at the majority of Laheys Creek sites, no freshwater prawns were observed. This is typical of smaller creeks with relatively low natural flows.

Fish, macroinvertebrates and water quality were surveyed at a small waterhole (Site 9) found in a section of Laheys Creek outside the mine footprint (Plate 6c). Introduced Carp were recorded, as well as native Carp gudgeon and a Freshwater catfish (36 cm TL, Plate 4b), (Appendix 4). Freshwater shrimp and yabbies were also relatively common. Further upstream, the single pipe culvert crossings of Spring Ridge Road (Site 10) and Laheys Creek Road (Site 11) represents barriers to fish passage

4.3.1.4 Fords Creek and Unnamed Tributaries

Fords Creek flows through a broad valley heavily modified by agriculture. The surrounding land had been cleared for grazing and private dams were common.

Fords Creek (a tributary of Laheys Creek) and its unnamed tributaries are located at the junction of Laheys Creek Road and Brooklyn Road along the route of the proposed pipeline structure; Site 19 (Table 1, Figure 2, Plates 10c - d).

The RCE scores for the three sites sampled on Fords Creek were low suggesting it was highly degraded and would provide poor aquatic habitat (Table 1). Large woody riparian vegetation was absent. The channel was indistinct and colonised by pasture grasses. Channel banks were consolidated by pasture grasses and tramping by livestock was evident. The channel substratum in pool sections was composed entirely of fine silts and sand with no instream retention devices. Site 19, 14 and 15 represented poor aquatic refuge, consisting of a series of disconnected pools with no observable macrophytes. Pasture grasses that had colonised dry reaches of the creek bed prior to the high flow event of 2011 were submerged, indicating that Fords Creek only flows during and immediately after a significant rainfall.

Fords Creek and its unnamed tributaries were considered minimal fish habitat (Class 4 Waterway), likely the consequence of significant degradation from local agriculture and other anthropogenic influences (Table 1). No fish species were observed. A box culvert and flood gates represented a barrier to upstream fish passage at the site.

4.3.1.5 Blackheath Creek

Blackheath Creek flows through a broad valley heavily modified by agriculture. The surrounding land has been cleared for grazing and there are two large private dams approximately 4 km upstream of the creek. Farm dams have altered natural flow regimes and habitat of surrounding watercourses in this area. The location of each dam was recorded using a GPS (E 715730, N 6439592; E 715928, N 6440343), however, no sampling was undertaken (Figure 4). It is possible that the two dams are habitat for invasive fish species such as Carp and Eastern gambusia.

Site 16 on Blackheath Creek (a tributary of Laheys Creek) was located approximately 2 km south of the confluence of Sandy Creek and Laheys Creek (Table 1, Figure 2, Plates 9a - b).

The RCE score for Blackheath Creek was low suggesting it is highly degraded and would provide poor aquatic habitat (Table 1). Large woody riparian vegetation was sparse and incomplete. The channel was indistinct and colonised by pasture grasses and its substratum was composed of fine silts, sand and clay. Site 16 represented poor aquatic habitat containing a single stagnant pool with the macrophyte species Tussock sedge (*Carex appressa*) covering approximately 10 % of the reach.

Blackheath Creek was considered minimal fish habitat (Class 4 Waterway), likely the consequence of significant degradation from local agriculture and other anthropogenic influences including dams (Table 1). No fish species were observed. A quadruple pipe culvert represented a potential barrier to upstream fish passage at the study site; however, migration would not be possible due to the lack of surface water.

4.3.1.6 Patricks Creek

Patricks Creek flows through a broad valley heavily modified by agriculture. The adjacent landscape supports sections of eucalypt woodland (Site 23) that have been historically cleared for grazing or crop production and a pine plantation (Site 24).

Patricks Creek (a tributary of Tucklan Creek) and its unnamed tributary are located upstream of Site 25, but the creek's upper reaches fall inside the PAA; Site 23 and 24 (Table 1, Figure 2, Plate 12c - d).

The RCE scores for Patricks Creek and its tributary were moderate, suggesting it was degraded but still provided reasonable aquatic habitat (Table 1). Large woody riparian vegetation was present but incomplete. The channel was indistinct and colonised by pasture grasses in sections. Channel banks were consolidated by pasture grasses and eucalypt forest. Channel substratum was composed of sand with cobble and pebble stone and course woody debris. Patricks Creek and its tributary represented poor aquatic refuge due to the absence of surface water or macrophytes.

Patricks Creek was considered minimal fish habitat (Class 4 Waterway), likely the consequence of significant degradation from local agriculture and other anthropogenic influences (Table 1). No fish species were observed. A single pipe culvert represented a barrier to upstream fish passage at the study site.

4.3.1.7 Tucklan Creek

Tucklan Creek flows through a landscape heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams and road crossings are common on many of its tributaries.

Three sites on Tucklan Creek and its unnamed tributary south of the Avonside North Road creek crossing were surveyed; Sites 25 – 27 (Table 1, Figure 2, Plates 7c - d). The RCE scores for Tucklan Creek were moderate suggesting it was degraded but still provided reasonable aquatic habitat in sections (Table 1). Large woody riparian vegetation was sparse and often incomplete. Channel banks were generally consolidated by pasture grasses and bank collapses were common. The channel substratum in deep low velocity pool sections was characterised by fine silts and sands. Surface water was only observed at Site 25 and was classified as predominantly pool habitat with small stands of macrophytes and few snags. Pasture grasses had colonised the creek bed in the dry reaches. During the high flow survey of 2011, Sites 26 and 27 were dry, indicating that they flow only during and immediately after a significant rainfall event.

Two macrophyte species were identified from the Tucklan Creek sites (Table 4). Curled dock (*Rumex crispus*), the most widespread species was present only outside the wetted width (Table 4). Site 25 in the lower reach supported small stands of Common rush with approximately 1 % cover.

In situ water quality at Site 25 was moderate during the high flow event in 2011. Conductivity and pH was within the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems but dissolved oxygen and turbidity were outside the threshold limits (Table 3 and Appendix 3). The high turbidity was likely the result of recent high rainfall and the degraded nature of Tucklan Creek banks and riparian vegetation.

The upper reaches of Tucklan Creek (Sites 26 and 27) and its unnamed tributary were considered minimal fish habitat (Class 4 Waterways). The lower reaches of the creek (Site 25) was unlikely fish habitat (Class 3 Waterway). This is probably due to degradation from local agriculture and other anthropogenic influences (Table 1). The reach had semi-permanent pools and dry gullies with no permanent aquatic flora. No fish species were observed during the high flow survey in 2011.

A causeway crossing presented a barrier to upstream fish passage at Site 25, even under moderate flow conditions. Flood gates also posed a barrier to fish passage upstream of the creek crossing. Dry gullies at Sites 26 and 27 prevented any potential for upstream migration.

4.3.2 Cudgegong River Catchment

4.3.2.1 Cudgegong River

The Cudgegong River flows through a broad valley heavily modified by agriculture. The adjacent landscape supports sections of eucalypt woodland although the majority has been cleared for grazing or crop production. The natural flow regime of the Cudgegong River has been significantly altered by regulated releases from Windamere Dam. The proliferation of private dams and bores throughout the catchment also alter flow by means of water abstraction and interception of overland flows.

Two sites on the Cudgegong River were surveyed (Table 1, Figure 2, Plates 8a - d). Site 32 was located upstream of the confluence of the Cudgegong River and Mebul Creek and Site 33 was located 0.5 km further upstream.

The RCE score for the river was moderate, suggesting the channel was degraded but still provided reasonable aquatic habitat (Table 1). Tall woody riparian vegetation was characterised by the native River red gum, River she-oak and the introduced Weeping willow. Riparian forest was sparse and incomplete. Channel banks were steep in sections, partly consolidated by pasture grasses and bank collapses were common. Tramping by livestock was common along the edge of the channel.

The channel substratum was composed of boulder, cobble, pebble, sand bars, gravel beds and finer sediments had accumulated in the deeper pool sections. The waterway contained a variety of habitats, including deep pools, runs, backwater channels or anabranches, large woody debris, gravel beds, sand bars, riffles and occasional stands of macrophytes.

In situ water quality was poor during the high flow event in 2011. Conductivity was outside and pH was within the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems at both Sites 32 and 33 (Table 3 and Appendix 3). Dissolved oxygen was outside threshold limits at Site 32 but within limits at Site 33. Turbidity could not be recorded due to equipment failure, however, given the poor water clarity and highly turbid readings obtained from surrounding water bodies, is likely to have been outside the ANZECC/ARMCANZ threshold limits. The turbid water was likely the result of recent high rainfall and the degraded nature of Cudgegong River banks and riparian vegetation.

The habitat was relatively poor for macrophytes at both sites; temporal flows were highly variable with high turbidity and a significant sediment load and pool slopes and banks were often steep. Macrophytes were absent within the wetted width of the channel at Site 32 and occupied approximately 1 % of Site 33 (Table 4). At Site 32, Common reed was restricted to the steep surrounding banks outside the wetted width. At Site 33, Bog bulrush (*Schoenoplectus mucronatus*) and Ribbonweed (*Vallisneria americana*) were present in a shallow section near the banks edge.

A total of 31 macroinvertebrate taxa were recorded from pool edge habitat in the Cudgegong River, with numbers of taxa ranging from 21 at Site 32 to 27 at Site 33 (Appendix 4). The aquatic macroinvertebrate assemblages at both sites in the Cudgegong River were equivalent to the AusRivAS reference collection (Band A, Table5). O0Signal scores ranging from 3.79 at Site 32 to 3.76 at Site 33 and an overall SIGNAL2 score of 3.8 suggest that the Cudgegong River was severely polluted or degraded and the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0 Signal scores of approximately one indicate that the macroinvertebrate assemblages had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (Table 5). Freshwater shrimp (Family Atyiidae) and freshwater prawns were abundant at all sites within the Cudgegong River. No yabbies were observed.

The Cudgegong River was considered major fish habitat (Class 1 Waterway, Figure 4), although it has suffered significant degradation from regional agriculture. The reaches surveyed had deep pools, overhanging vegetation, undercut banks and ledges and a significant amount of submerged large woody debris. Six fish species were observed during the high flow survey: the native Carp gudgeon and Australian smelt and the introduced Carp, Goldfish, Eastern gambusia and Redfin perch (*Perca fluviatilis*). Carp gudgeon and Eastern gambusia were commonly associated with macrophytes, snags and cobble substrata, whereas smelt inhabited the open channel waters, often in areas with faster currents and were caught only with the seine net.

Although it is a Class 1 waterway, the Cudgegong River has been significantly degraded. This is reflected in the composition and abundance of the fish assemblage. Threatened species such as Freshwater catfish, Silver perch and Murray cod were not recorded in the Cudgegong as part of this survey, but may still be present). The assemblage was dominated by introduced species which are tolerant of pollution and habitat degradation. Carp was the most abundant species in the Cudgegong River and native Golden perch the least abundant.

The Cudgegong River contains several potential barriers to fish passage as a result of anthropogenic influences. Several dams on the Cudgegong River block the passage of the majority of fish species, including Windamere Dam (upstream of Site 32). No dam sites were included in the site investigations. Other structures such as road bridges supported by instream structures can trap woody debris following high flows creating a barrier to fish passage.

4.3.2.2 Mebul Creek

Mebul Creek flows through a broad valley heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams and culvert crossings are common on many of its tributaries.

Six sites on Mebul Creek and its unnamed tributaries were surveyed (Table 1, Figure 2, Plates 7a - b). Site 34 was located at the southernmost creek crossing on Upper Mebul Creek road, while Sites 35 - 39 were located at creek crossings to the north of Site 34 on Upper Mebul Creek road.

The RCE scores for Mebul Creek and its unnamed tributaries were low, suggesting they were highly degraded and would provide poor aquatic habitat (Table 1). Large woody riparian vegetation was sparse and incomplete throughout. Channel banks were generally consolidated by pasture grasses and bank collapses were common. Channel substratum in deep low velocity pool sections and shallow runs had a similar composition of fine silts and sands with cobble and pebble stones. Site 34, having deep pools upstream of the culvert road crossing and various fringing macrophytes and few snags downstream, contained the only significant aquatic refuge. The habitat at Sites 34 and 38 was limited to discontinuous pools. Pasture grasses had colonised the creek bed in the dry reaches. Sites 36, 37 and 39 were dry during the high flow survey of 2011, indicating that they flow only during and immediately after a significant rainfall event.

During the high flow event in 2011, in situ water quality was poor at Site 34. Conductivity and dissolved oxygen were outside but pH was within the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems (Table 3 and Appendix 3). Turbidity readings were not recorded due to equipment failure, however, given the poor water clarity and high turbidity of the surrounding waterways, would probably have been outside the ANZECC/ARMCANZ threshold limits. The turbid water was the result of recent high rainfall and the degraded nature of Mebul Creek banks and lack of riparian vegetation.

Seven macrophyte species were identified in Mebul Creek and its tributaries (Table 4). The most widespread species, Stonewort (*Chara* sp.) was present at two of the six sites surveyed, although its percentage cover was variable ranging from 2 – 40 %. Two emergent macrophyte species, Tussock sedge (*Carex appressa*) and Curled dock (*Rumex crispus*) were observed outside the channel wetted width. Small patches of Cumbungi, Bog bulrush and Stonewort (*Nitella* sp.) were observed at Site 34. Floating pondweed (*Potamogeton tricarinatus*) was observed in a shallow pool upstream of a culvert crossing at Site 35.

Eighteen macroinvertebrate taxa were recorded from the pool edge habitat at Mebul Creek, (Appendix 4). The aquatic macroinvertebrate assemblage in Mebul Creek was equivalent to the AusRivAS reference condition (Band A, Table 5). An O0Signal score of 3.67 and an overall SIGNAL2 score of 3.8 suggest that Mebul Creek was severely polluted or degraded as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0 Signal scores of less than one indicate that the macroinvertebrate assemblage had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (Table 5). Freshwater shrimp (Family Atyiidae) and yabby were abundant at the site. No Freshwater prawns were observed.

Sites 34 and 38 were considered unlikely fish habitat (Class 3 Waterways) due to significant degradation from local agriculture and other anthropogenic influences (Table 1). The reach had deep pools, undercut banks and ledges with little large woody debris. Sites 35-37 and 39 on the tributaries of Mebul Creek were considered minimal fish habitat (Class 4 Waterways) due to the absence of surface water following a high rainfall event. During the high flow survey in 2011, two common fish species were observed; native Carp gudgeon and the introduced Eastern gambusia.

Box culvert crossings were present at the upstream and downstream reaches of Mebul Creek and its tributaries (Sites 34 - 39) and represent a barrier to upstream fish passage during moderate to low flows. Flood gates upstream of the creek crossing (Site 34) also pose a barrier to fish passage. There were also numerous natural barriers along Mebul Creek tributaries which would be barriers to upstream passage during moderate or low flows. These included dense macrophyte stands in shallow water and channel bed accumulations where the waterway becomes effectively a disconnected chain of pools.

4.3.2.3 Tallawang Creek

Tallawang Creek flows through a broad valley heavily modified by agriculture, residential structures and a causeway creek crossing. The surrounding land has been cleared for grazing or crop production and private dams were common.

Site 18 on Tallawang Creek was located on the eastern side of Castlereagh Highway along the route of the proposed railway line (Table 1, Figure 2, Plates 9c - d).

The RCE score for Tallawang Creek was moderate, suggesting the channel was degraded but still provided reasonable aquatic habitat (Table 1). Large woody debris was absent throughout. Channel banks were generally consolidated by pasture grasses and riparian vegetation was sparse and incomplete. Trampling by livestock was evident throughout the reach and bank collapses were common. The channel substratum in shallow pool sections was composed of fine silts, sand and gravel. Sand bars were frequent throughout the reach, with boulder and cobble stones accumulating upstream of the causeway. Site 18 consisted of a series of shallow, disconnected pools with no observed macrophytes and thus represented poor aquatic refuge. Pasture grasses had colonised sections of the creek bed in the dry reaches. During the high flow survey of 2011, Tallawang Creek was dry, indicating that flows occur only during and immediately after a significant rainfall event (Plate 9 c and d).

During the high flow event in 2011, in situ water quality was poor. Conductivity and pH was within the ANZECC/ARMCANZ threshold limits for the protection of aquatic ecosystems but dissolved oxygen and turbidity were outside the threshold (Table 3 and Appendix 3). The highly turbid water was the result of recent high rainfall and the degraded nature of Tallawang Creek banks and the lack of riparian vegetation.

A green filamentous alga (Chlorophyta) was the only aquatic plant observed at the study site with approximately 5 % cover (Table 4). Native and exotic pasture grasses comprised the remainder of the vegetation.

A total of 13 macroinvertebrate taxa were recorded from the pool edge habitat at Tallawang Creek (Appendix 4). The aquatic macroinvertebrate fauna in Tallawang Creek was significantly impaired relative to the AusRivAS reference condition (Band B, Table 5). The O0Signal score of 2.8, the lowest score of all sites sampled, and an overall SIGNAL2 score of 3.8 suggest that Tallawang Creek was severely polluted or degraded and the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (Table 5 and Appendix 4). The OE0 Signal score of less than one indicates that the macroinvertebrate assemblage had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (Table 5). Freshwater shrimp (Family Atyiidae) and yabby were abundant at the site, but no freshwater prawns were observed.

Tallawang Creek was considered unlikely fish habitat (Class 3 Waterway) as a consequence of significant degradation from local agriculture and other anthropogenic influences (Table 1). The reach had shallow, disconnected pools, undercut banks and ledges with no snags. A single native fish species, Carp gudgeon, was observed during the high flow survey in 2011.

A causeway crossing presented a barrier to upstream fish passage at the study site, even under high flow conditions in 2011. Flood gates also posed a barrier to fish passage upstream of the creek crossing. Sand bars act as natural barriers to upstream passage during moderate or low flows where the waterway becomes effectively a disconnected chain of pools.

4.3.2.4 Lambing Yard Creek

Lambing Yard Creek flows through a broad valley heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams were common.

Sites 20 – 22 on Lambing Yard Creek were located west of Castlereagh Highway along the route of the proposed rail line (Table 1, Figure 2, Plates 10a - b).

The RCE scores for Lambing Yard Creek varied from moderate to low, suggesting the channel was highly degraded and would provide poor aquatic habitat (Table 1). Although large woody debris was present it was outside the wetted width. In most instances the channel was indistinct and was colonised by pasture grasses and the occasional eucalypt. Livestock had access to sections of the creek, but the banks were generally firm. The substratum in pool sections was composed entirely of fine silts and sand. Site 22 consisted of a single stagnant pool with no observed macrophytes and represented poor aquatic habitat. During the high flow survey of 2011, surface water was absent at Sites 20 and 21. The colonisation of sections of the creek bed by pasture grasses suggests that flows occur only during and immediately after significant rainfall events.

Lambing Yard Creek was considered minimal fish habitat (Class 4 Waterway) due to significant degradation from local agriculture and other anthropogenic influences (Table 1). No fish species were observed.

Farm dams, flood gates and artificial crossings on this creek represent potential barriers to upstream fish passage. Fish migration would also be limited by lack of water. During the high flow survey of 2011, the surface water in Lambing Yard Creek was limited to a single pool at Site 22.

4.3.2.5 Goodiman Creek

Goodiman Creek flows through a broad valley heavily modified by agriculture. The surrounding land has been cleared for grazing or crop production and private dams were common.

Site 65 on Goodiman Creek was located at the junction of Sandy Creek Road and Laheys Creek Road along the route of the proposed pipeline (Table 1, Figure 2, Plate 12a - b).

The RCE score for Goodiman Creek was moderate, suggesting the channel was degraded but still provided reasonable aquatic habitat (Table 1). Large woody debris was present but outside the wetted width. The channel was indistinct and colonised by pasture grasses. There was a thin riparian strip of eucalypt forest. During the high flow survey of 2011, surface water was absent at the study site. The presence of pasture grasses in sections of the creek bed suggests that flows occur only during and immediately after significant rainfall events (Plate 13 a and b).

Goodiman Creek was considered minimal fish habitat (Class 4 Waterway) due to significant degradation from local agriculture and other anthropogenic influences (Table 1). No fish species were observed. A triple pipe culvert represented a barrier to upstream fish passage at the study site. The absence of surface water would also prevent potential fish migration.

4.3.3 Summary

4.3.3.1 Talbragar and Cudgegong Rivers

The Talbragar and Cudgegong River are the two main waterways within the Study Area (Figure 2). Despite having suffered significant degradation from regional agriculture and anthropogenic impacts, both are classified as major fish habitat (Class 1 Waterway, Figure 4). While the Talbragar is unregulated by dams, the natural flow regime of the Cudgegong River has been significantly altered by regulated releases from Windamere Dam. The private dams and bores located on these waterways have also altered flows.

The physical characteristics of the two rivers were similar, with a distinct channel being present, banks predominantly consolidated with pasture grasses and a thin strip of riparian vegetation. The waterways contained a variety of habitats including; deep pools, runs, backwater channels or anabranches, large woody debris, gravel beds, sand bars, riffles and occasional stands of macrophytes. Channel substratum was generally composed of boulder, cobble, pebble, sand bars, and gravel beds with finer sediments accumulating in deeper pool sections.

Water quality was poor with the majority of the variables measured falling outside the ANZECC/ARMCANZ threshold limits (Table 3). The aquatic macroinvertebrate assemblages indicated that the waterways had suffered severe pollution and/or habitat degradation (Table 5). Invertebrate diversity within the Endangered Lowland Darling River Aquatic Ecological community was low, and no protected species within that community were collected. Invasive fish species had the highest abundance, diversity and distribution in these waterways (Appendix 5). No threatened fish species were caught or observed.

4.3.3.2 Major Creeks and Tributaries

Six creeks and their tributaries which drain into the Talbragar River (Sandy, Laheys, Fords, Blackheath, Patricks and Tucklan creeks) and four creeks and their tributaries that drain into the Cudgegong River (Mebul, Tallawang, Lambing Yard and Goodiman creeks) were sampled.

All sites had been heavily modified by regional agriculture and anthropogenic impacts. The surrounding land use was generally characterised by open grazing pasture with artificial structures including creek crossings. Private dams and bores were common throughout the catchment and have altered natural flow by abstracting water and interrupting overland flow. Waterway classifications varied from moderate (Class 2 Waterway, Figure 4) to minimal fish habitat (Class 4 Waterway, Figure 4). The majority of waterways lacked surface water and aquatic macrophytes and were classified as minimal fish habitat.

The creek's physical characteristics were similar; a marginal or indistinct channel, banks predominantly consolidated with pasture grasses and incomplete riparian vegetation with few macrophytes. Large pool habitat without riffles was common in low altitude, downstream locations. High altitude, upstream creeks were often ephemeral, characterised by shallow, disconnected pools and dry gullies (Plate 12a – d). Channel substratum was generally composed of cobble, pebble and sand bars with finer sediments accumulating in pool sections.

Water quality was poor with the majority of the variables measured falling outside the ANZECC/ARMCANZ threshold limits (Table 3). The aquatic macroinvertebrate assemblages indicated that the waterways had suffered severe pollution and/or habitat degradation (Table 5). Invasive fish species had the highest abundance, diversity and distribution (Appendix 5). Two individuals of the endangered western population of Freshwater catfish were observed or caught, one in each of two refuge pools in Sandy Creek (Site 5 in 2011) and Laheys Creek (Site 9 in 2009, Appendix 5).

5 Assessment of Impacts Associated with the Proposed Works

5.1 Description of the Project Relevant to Aquatic Ecology

A comprehensive description of the Project is given in Section 1.2. The Project's key elements with respect to potential impacts on aquatic ecology are:

- Open cut mining areas adjacent to Sandy and Laheys Creeks;
- Coal handling and preparation plant (CHPP);
- Train loading facility and rail spur;
- Mine infrastructure area;
- Access roads;
- Water storage in sediment, raw water and highwall dams;
- Import of water via pipeline from the Cudgegong River; and
- Infrastructure for electricity supply.

Key potential impacts on aquatic ecology from the Project relate to:

- Alteration to natural flow regimes due to volume and timing of water releases from dams, drawdown of groundwater and reduction of Laheys and Sandy Creek catchment size;
- Changes in connectivity due to predicted changes in frequency of no, very low, low and high flows;
- Habitat degradation due to increased and/or mobilised sediment;
- Changes in water quality;
- Local depletions of (i) endangered Murray-Darling population of Freshwater catfish and (ii) endangered Lowland Darling River aquatic ecological community;
- Entrainment and/or impingement of fish, fish larvae and eggs of native fish species as water is abstracted from the Cudgegong River; and
- Instream structures related to road and electricity infrastructure.

5.2 Management of Surface Water Groundwater, Imported and Process Water During Operation of the Project.

The water management system for the Project has been designed to minimise external water uses and avoid impacts on aquatic habitats, water quality and ecology. The design of the proposed water management system includes:

- segregation of clean, dirty and contaminated water types;
- diversion of clean water from undisturbed catchments around the mine to Sandy and Laheys Creeks;
- direction of dirty water runoff from disturbed areas, such as overburden emplacement areas, into a number of sedimentation dams strategically placed throughout the mine to encourage settling;
- reuse of captured water on-site to supplement a site water deficit, or;
- discharge of water to Sandy and Laheys creeks when water quality discharge criteria have been met;
- capture of contaminated runoff and groundwater seepage in-pit and transfer via pumps to mine water dams;
- capture of contaminated runoff from the CHPP, mine infrastructure area, coal stockpiles and rail loading facilities in contaminated water storage dams;
- no discharge of contaminated water to the creek system (Parsons Brinckerhoff 2102a).

5.3 Altered Hydrology

The disturbance regime that is likely to be most relevant to endangered fish species is the natural variation in flow regimes. Bunn and Arthrington (2002) identified four key principles that highlight the linkage between flows and aquatic biota:

1. Flow is a major determinant of physical habitat in streams, which in turn has a major effect on the presence and abundance of flora and fauna.

2. The life history strategies of aquatic species have evolved in response to natural flow regimes.

3. Flows are important in maintaining natural patterns of longitudinal and lateral connectivity that are essential to the viability of populations of many riverine species;

4. Changes in the flow regime have facilitated the invasion and success of exotic and introduced species.

Disturbances in the natural flow regime that have potential to directly or indirectly impact on aquatic habitats, endangered fish and the Lowland Darling River aquatic ecological community include changes in flow volume, changes in magnitude of peak flows and changes in the seasonal distribution of flows. Potential indirect impacts associated with altered hydrology include habitat degradation due to mobilisation and redistribution of sediment, changes in water quality and decrease in connectivity between larger creek and river habitats and pool habitats.

5.3.1 Changes in Flow Volumes

In general, a reduction in flow volume can lead to a concomitant reduction in water velocity, depth, channel 'wetted width' and potentially the magnitude and/or frequency of elevated seasonal flows. This can in turn lead to:

- Reduction in amount of aquatic habitat (e.g. shallow riffles, bars and pools) and associated biota;
- Reduction in longitudinal connectivity, reducing access to foraging, spawning and refuge habitat;
- Lower water quality, resulting in a less diverse macroinvertebrate assemblage dominated by pollution-tolerant taxa;
- Encroachment of macrophytes and other plants into the channel;
- Shift towards an assemblage dominated by taxa that prefer stable low-flow environments; and
- Reduction in flow-related life-history cues.

Increases in flow volume also have potential impacts on aquatic ecology. Sustained increases in flow volume can alter aquatic habitats by:

- Reduction in habitat diversity and food supply by drowning out productive habitats such as shallow riffles and pools;
- Alteration of creek bed and bank morphology by changing focus of erosion and deposition patterns;
- Alteration in sediment transport regimes, with flow-on changes in water quality;
- Reduction in abundance and diversity of fish, dominance by non-native species and low reproductive success due to loss of suitable spawning sites and changes in food supply;

- Changes in diversity and community composition in aquatic invertebrate and macrophyte communities;
- Alteration in natural distribution of riparian vegetation due to changed flow behaviour (Lloyd *et al*. 2003).

Predicted alterations in flow volume indicate an overall decrease in the Sandy Creek system during average and dry years of up to 5%, but an increase in water volume during wet years (Parsons Brinckerhoff 2012a). Hence, the impacts on aquatic ecology of altered flow volumes during the operation of the Project are likely to depend on the interaction of the mine water balance with climatic conditions occurring at the time. Ecological changes in Sandy and Laheys Creeks, and to a lesser extent in the Talbragar River, may include none, or some combination or intensities of alterations to habitats, geomorphology, individual species or communities listed above. Overall, the magnitude of change in flow volume predicted is at the lower end of hydrological changes and is likely to result in an overall relatively small ecological response when the existing condition of the system is factored in. If however, the changes in flow volume exceed some critical threshold condition, then the ecological response observed may be greater in magnitude than anticipated. Of particular concern for Sandy Creek, Laheys Creek and the Talbragar River is the potential impact of changed flow volume on the connectivity and duration of pools that provide habitat for the endangered population of Freshwater catfish, as well as the endangered Lowland Darling River aquatic ecological community (consisting mainly of macroinvertebrates).

Reductions in flows associated with abstraction of water from the Cudgegong River are not expected to have significant impacts on aquatic ecology given that the flow of the river is regulated by the release of water from Windamere Dam by State Water. These flows (and the effects of abstraction) are managed by State Water to meet a range of objectives including minimising environmental impacts.

5.3.1.1 Changes in Catchment Area

In the long-term, flow volume in Sandy and Laheys creeks will be reduced in small part by the reduction in catchment area and therefore runoff of rainwater to the creeks caused by the mine voids. Two of Sandy Creek's five subcatchments will have reduced catchment surface area due to mine voids, with the reduction in effective catchment area increasing as the mine areas are worked. By the end of the mine's lifetime the total catchment area for Sandy Creek will have been reduced by 20 km^2 or by 11.8 % of the pre-mining catchment area (Figure 5, Table 9, Figure 6). Reductions in catchment areas that provide run off into Laheys Creek will be concentrated in one of Laheys Creek three sub catchments where runoff patterns will change due to Project infrastructure. By the end of the mine's life time the total catchment area for Laheys Creek will have reduced by 20.1 km^2 (17.9 %) (Figure 5, Table 9, Figure 6).

Table 9: Summary of changes in catchment areas for Sandy and Laheys Creek.

Year	Total Coal Pit area (km^2)	Sandy Creek Catchment Reduction (km^2)	% of pre-mining size	Laheys Creek Catchment Reduction (km^2)	% of pre-mining size
1	7.7	2.9	1.7	4.8	4.3
2	12.7	4.4	2.6	8.3	7.3
4	16.5	7.3	4.3	9.1	8.1
8	26.5	12.9	7.6	13.6	12.1
12	30.8	16.2	9.5	14.6	13.0
16	36.3	18.6	11.0	17.7	15.7
20	39.2	19.4	11.4	19.8	17.6
21	40.2	20.0	11.8	20.1	17.9

After Year 21 rehabilitation of the landform will result in all runoff again flowing into creeks in a similar pattern to pre-mining conditions.

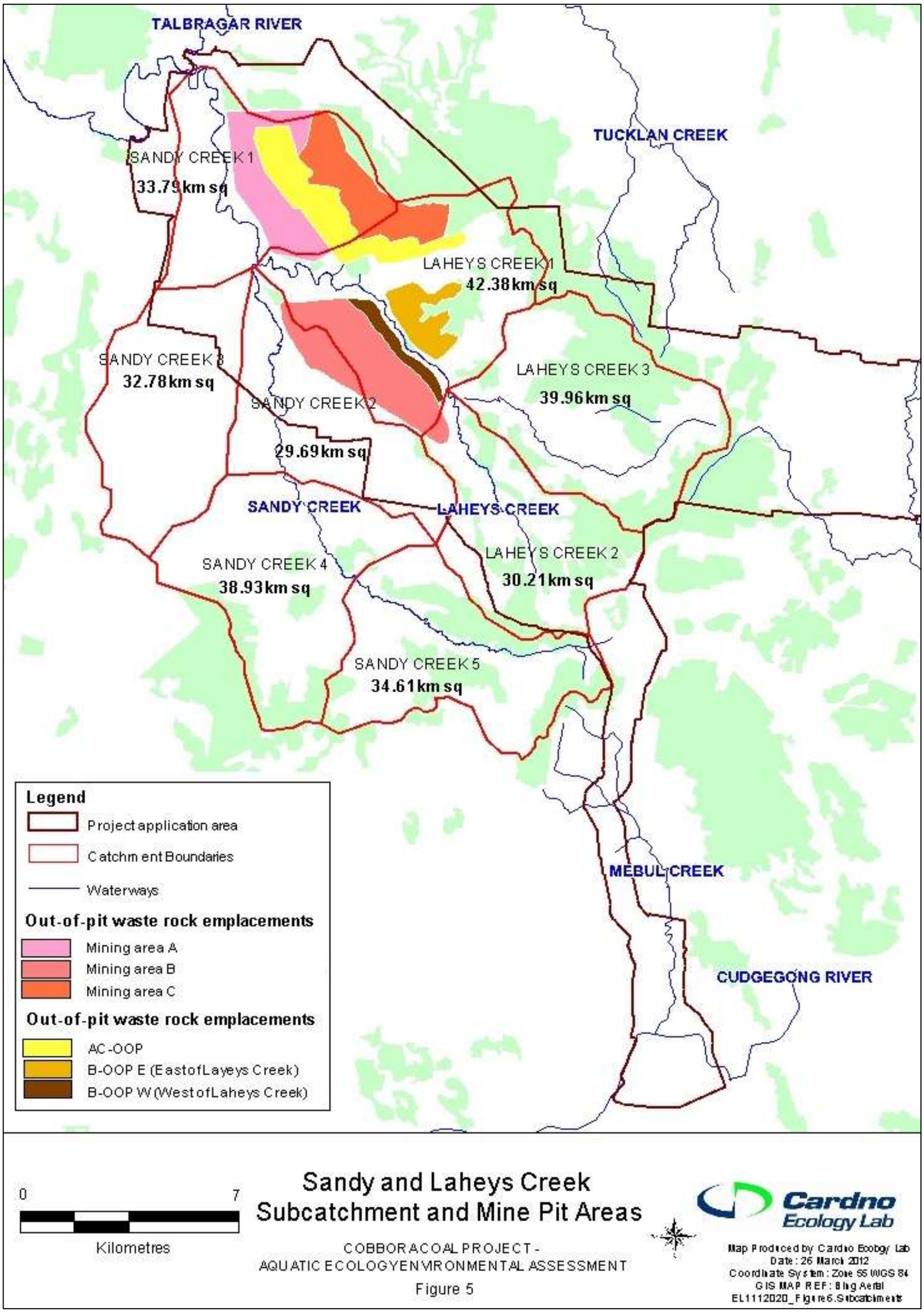

Figure 5: Sandy and Laheys Creek subcatchment and mining areas.

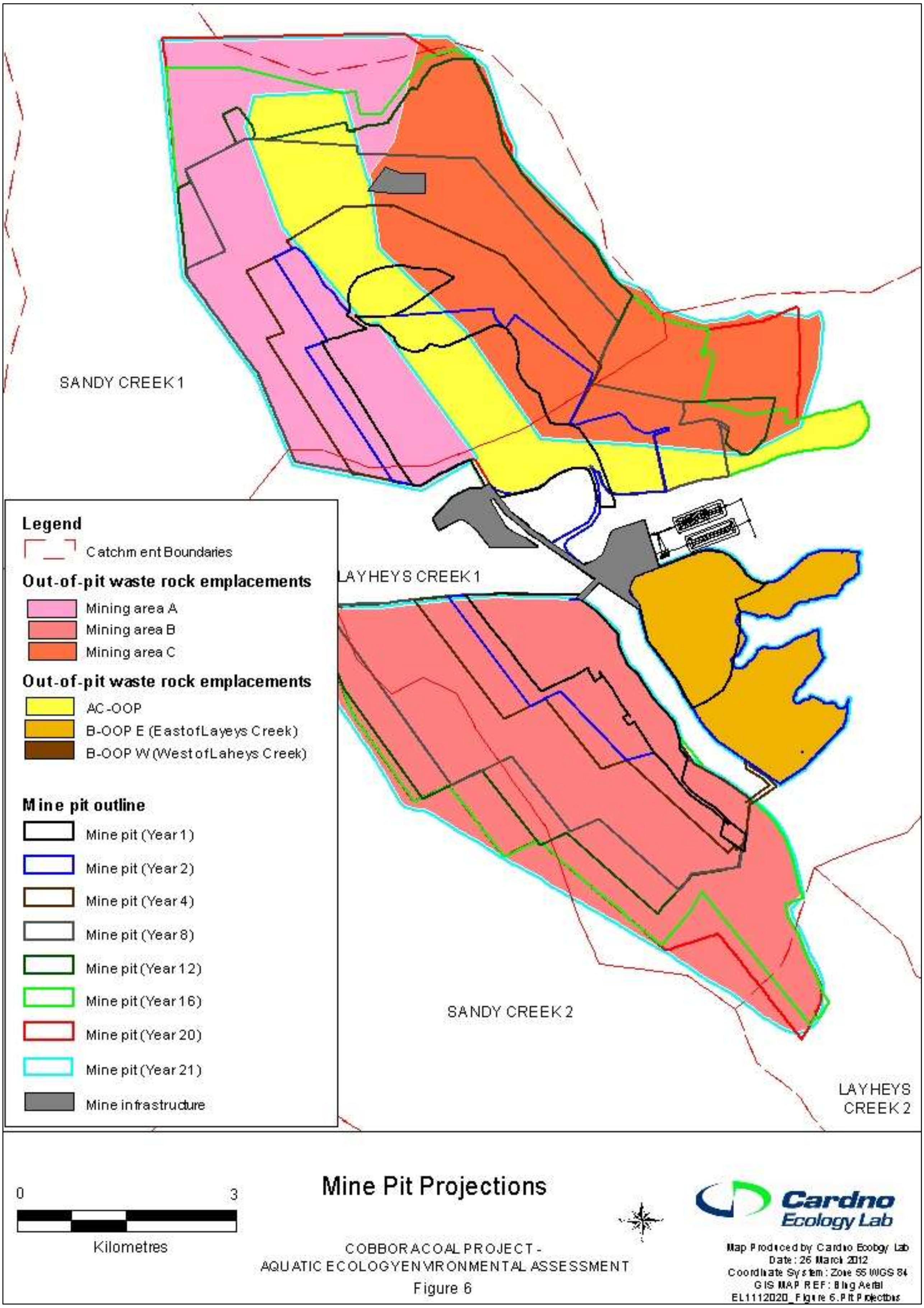

Figure 6: Mining area projections.

5.3.1.2 Changes in Average Surface Water Flow

The net pattern of predicted change in annual surface water flow during the lifespan of the Project is summarised in **Figure 7** below, based on Parsons Brinckerhoff 2102a, Appendix E: *Water Balance and Surface Water Management System Report,* and is expressed as predicted change compared to pre-mining flow conditions.

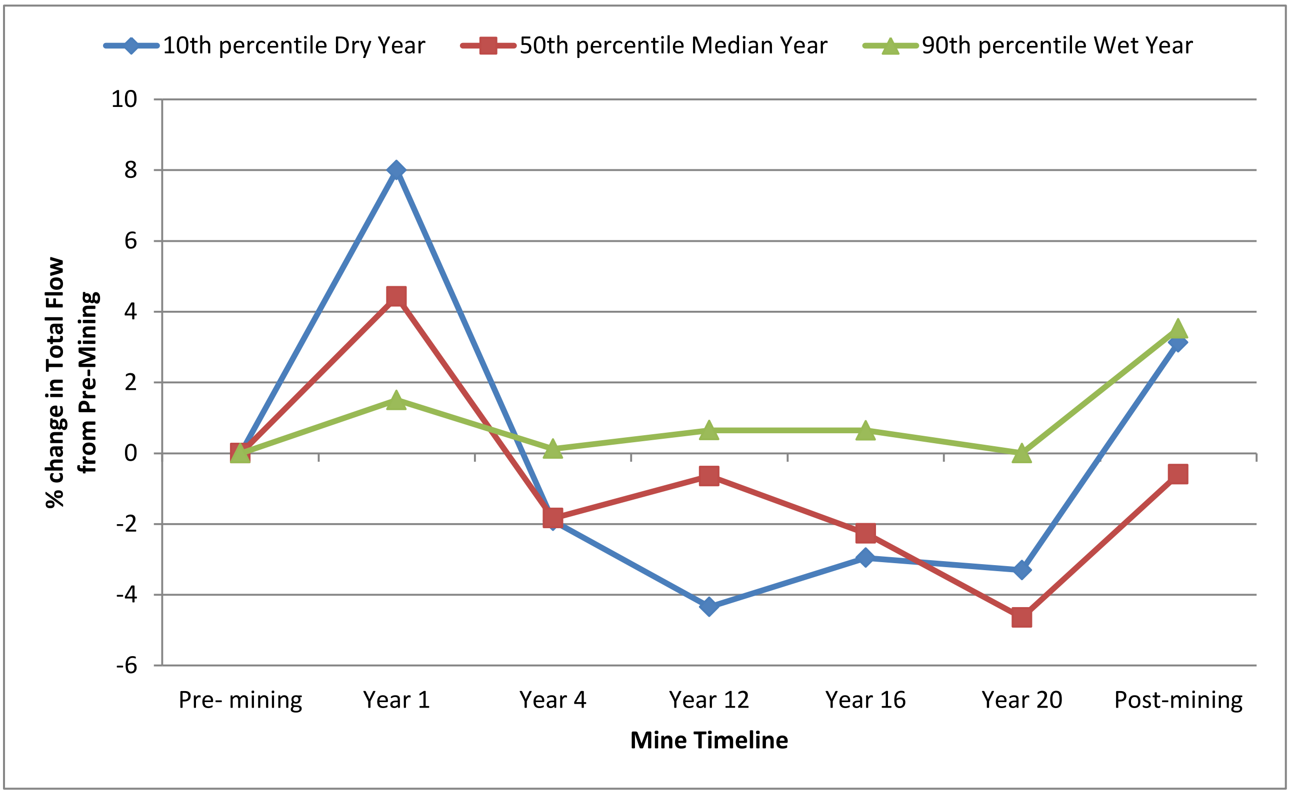

Figure 7. Predicted changes in downstream surface water flow through the lifetime of the Project, expressed as percent change from pre-mining conditions. Data source: Parsons Brinckerhoff 2012a, Appendix E, Tables 6-1, 6-2 and 6-3: Annual site water balance, "Total flow at study catchment outlet".

The water balance modelling predicted that, following an initial period (Years 1 to 4) the annual surface water flow regime downstream of the site will generally decrease for dry and median years, but generally increase for wet years (Parsons Brinckerhoff 2012a). **Figure 7** demonstrates this change compared to pre-mining baseline for the Year 4 to Post-mining period, and indicates that the average magnitude of decreased flow for dry and median conditions will be twice that of the predicted increase in wet conditions over the same time period (Year 4 to Post-mining). The increase in wet years may be attributed to water captured in dams being discharged to the creek in wet years when it is not required to supplement a mine water deficit (Parsons Brinckerhoff 2012a). Such releases could be managed to have beneficial effects on the ecology of receiving waters and to minimise potential impacts on the receiving waters (e.g. potential changes in water quality and flow rates).

Periodic release of water from the mine will increase mean daily flow, but the increases will be within the ranges defined by NOW flow objectives (Parsons Brinckerhoff 2012a, Appendix C). On average this will make pool refuges, particularly in Sandy Creek, less ephemeral, despite the overall decrease in annual flow volume in the system (Parsons Brinckerhoff 2012a). However decreases in flow are predicted to be greater than increases in flow in dry and median climate conditions, therefore the periods in which refuge pools are connected, facilitating passage of fish and fish larvae may decrease compared to the current conditions after the initial four years of mine operation (Figure 7). The reduction in connectivity between pools in dry and median climate conditions is estimated to be in the order of 5% compared to the baseline condition, and the impact of the small reduction in the time available for fish to access refuge pools is difficult to estimate, particularly given the existing ephemeral nature of the creeks.

5.3.2 Changes in Peak Flow

Flood modelling indicated that the pattern of peak water flows in Sandy Creek would alter under the Project. The velocity of peak flows in 2 year ARI events would increase by 2 %, while velocities in 5 year ARI events are predicted to decrease by 1 %. There are no predicted increases in peak velocities for less frequent 100 ARI and 2000 ARI events. The predictions are similar for peak flows in Laheys, with a slightly larger 8 % increase in peak velocities of 2 year ARI events, and no changes for less frequent events (Parsons Brinckerhoff 2012a).

Potential impacts associated with increases in peak flow velocities relate to the potential for higher velocities to erode creek banks and mobilise bottom sediments, changing aquatic habitat structure and increasing turbidity. Increased peak flow velocities can result in habitat alteration as mobilised sediments settle out in downstream habitats such as pools. The magnitude of the predicted increases in peak flow velocity for frequent events is small, and is likely to be insignificant. The erosive potential of less frequent events is predicted to be unchanged from the current condition and hence changes in peak flows due to the Project overall are unlikely to differ from the current conditions.

5.3.3 Changes to Temporal Flow Regime

The life history attributes of many aquatic organisms are adapted to temporal patterns (i.e. seasonal) and variability in natural flow regimes. The temporal flow pattern can be important for providing spawning cues, stable spawning and nursery environments, facilitating the passage of migrating fish, dispersing fish larvae and structuring prey assemblages. Two threatened fish species, Murray cod and Silver perch migrate upstream to spawn, with such movements being triggered by seasonal elevated flows during spring and early summer. Juvenile Silver perch may also move upstream in response to rising water levels. The endangered Freshwater catfish population, in contrast, is relatively sedentary and not thought to undertake spawning migrations. Changes to the timing of medium and high flows has the potential to impact on the recruitment of larval fish to new habitats, and the abundance of prey in those habitats.

It is likely that the temporal pattern of water releases will be managed to maintain dams at levels low enough to capture transient rainfall peaks. The timing of releases is likely to represent changes to the current pattern of flow variation in the creeks. As such, the potential impact of changes in the timing of peak flows cannot be adequately assessed. Significant changes to the flow regime could lead to reduction in recruitment of native species and/or a change in composition of species assemblages.

5.4 Changes in Habitat Connectivity

5.4.1 Changes in Flow

The lower reaches of Sandy and Laheys creeks are likely to experience slightly longer periods when pools are not connected by flowing water during dry climatic conditions as a result of altered hydrology associated with the Project. The decrease in connectivity would impact on aquatic ecology by reducing the amount of time that habitats in the lower and middle creek reaches are connected with the larger Talbragar River. When dry periods correspond with spawning or other migrations, fish, invertebrates and their propagules will have reduced access to upstream reaches, and upstream refuge habitats such as semi-permanent pools. While the lower reaches of Sandy Creek creeks are currently ephemeral and cease to flow on average 46 % of the time, the impact of reduced habitat connectivity would be to further reduce the biodiversity of fish and invertebrate fauna in a creek system that already shows minimal biodiversity. It is not possible to quantify the flow-on effects of the small reduction in connectivity that would cause significant reduction in creek biodiversity given the current conditions of the system.

5.4.2 Groundwater Drawdown

Groundwater contributes to creek base flow and is recharged via flood flows (Parsons Brinckerhoff 2012b). Semi-permanent pools within Sandy and Laheys Creek and in the Talbragar River near the confluence with Sandy Creek may rely on groundwater in dry periods to sustain water levels as surface water evaporates. To determine which semi-permanent pools are likely to be groundwater dependant, a set of geophysical criteria were applied (Parsons Brinckerhoff 2012a, App A) and coupled with field observations (this report). Field observations undertaken in 2009 provide information on water levels after a prolonged drought period, while those in 2011 represent pool water levels after a significant period of rain. For pools provisionally identified by geophysical characteristics (elevation of water table relative to creek bed), the presence of water in the 2009 field survey provides corroborating evidence that the pool is groundwater dependant. The pools evaluated corresponded to those targeted for ecological observations and assessments, but do not necessarily represent all pools along Sandy and Laheys Creeks.

Groundwater modelling predicts significant drawdowns from Permo-Triassic units adjacent and to the west of mining areas A and B that may induce leakage from the alluvium and cause a decline in water levels and more frequent drying in pools that are connected to groundwater systems along Sandy Creek and Laheys Creek (Parsons Brinckerhoff 2012b). Groundwater drawdowns are likely to be variable, but significant, temporary drawdowns are predicted within the alluvium or exposed Permo-Triassic rocks at several pools in the lower reaches of Sandy and Laheys creeks. Figure 8 summarises the predicted groundwater drawdown for sites in Sandy and Laheys creeks that correspond to semi-permanent pools.

Table 10 summarises the likelihood of groundwater dependence of selected pools. Figure 8 and Table 10 do not take into account changes in water level due to predicted changes in surface flow (Section 5.3.1). The overall predicted reduction in flow volume in the order of 5% in dry and average conditions may result in increased drawdown levels at groundwater dependent pools, but the combined influence of the two processes cannot be estimated quantitatively.

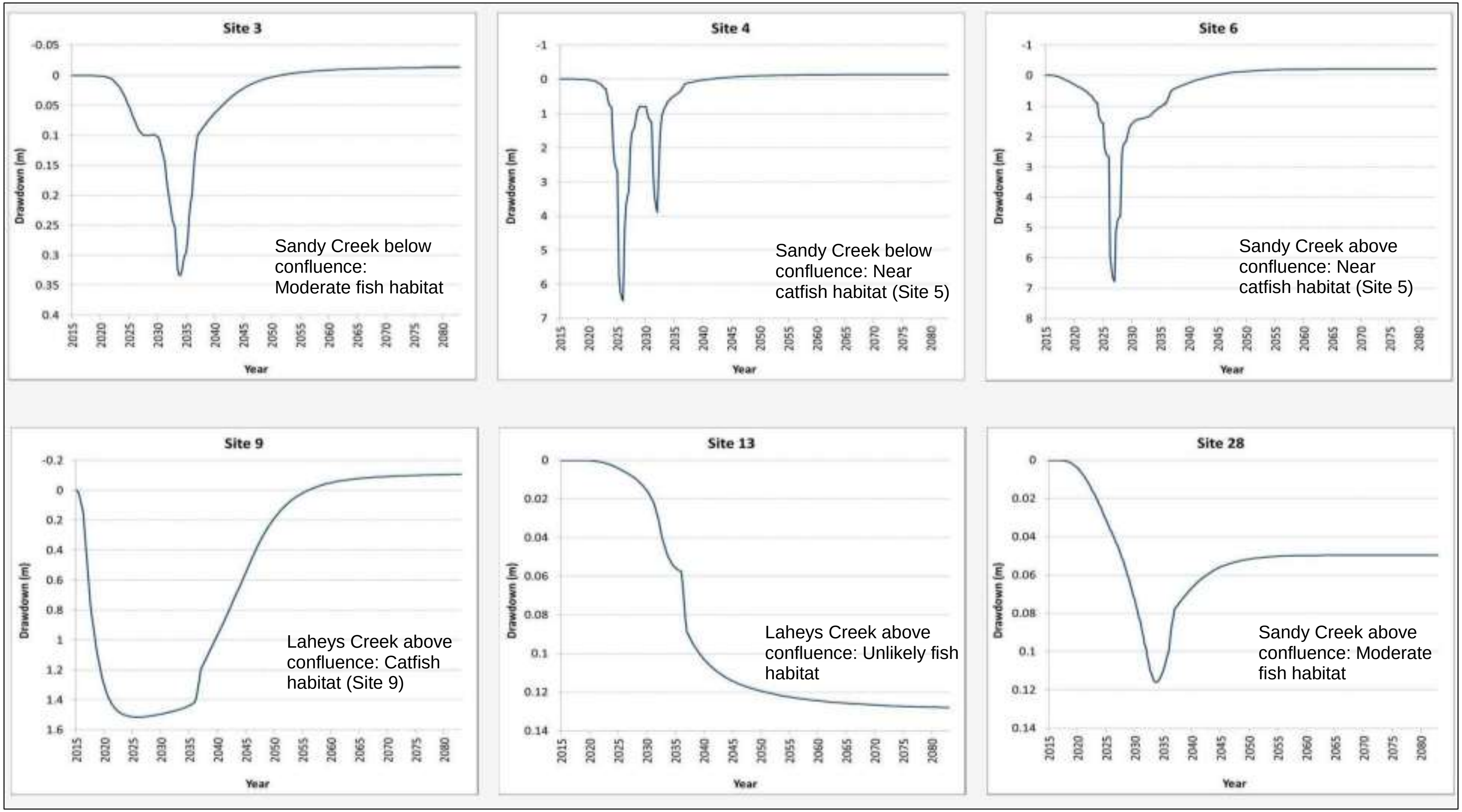

Figure 8: Predicted groundwater drawdown at sites with pools on Sandy and Laheys creeks. Annotated from Parsons Brinckerhoff 2012b.

Table 10: Evaluation of groundwater dependency and predicted scale of groundwater drawdown on ephemeral pools in Sandy and Laheys Creeks. Refer to Figure 3 for locations of pools assessed.

Site	Location and Watercourse	Groundwater Dependent based on geophysical criteria? (error +/- 1 m)	Water present after dry period (2009 field observations)	Scale of groundwater drawdown – Mine year 12 (m)	Scale of groundwater drawdown – Mine year 14 (m)	Scale of groundwater drawdown – Mine year 20 (m)
1	Talbragar River upstream of Sandy Creek confluence	Potentially	Yes, small pool	0	0	0
2	Sandy Creek downstream of Laheys Creek confluence	Potentially	Yes, very small pool	-0.12	-0.50	-1.04
3	Sandy Creek downstream of Laheys Creek confluence	Potentially	Yes	-0.14	-0.70	-1.29
4	Sandy Creek downstream of Laheys Creek confluence	No	Yes, very little	Not impacted	Not impacted	Not impacted
5	Sandy Creek downstream of Laheys Creek confluence	Yes	Damp creek bed only (note: catfish present in 2011)	-0.22	-0.13	-0.14

Site	Location and Watercourse	Groundwater Dependent based on geophysical criteria? (error +/- 1 m)	Water present after dry period (2009 field observations)	Scale of groundwater drawdown – Mine year 12 (m)	Scale of groundwater drawdown – Mine year 14 (m)	Scale of groundwater drawdown – Mine year 20 (m)
6	Sandy Creek upstream of Laheys Creek confluence	Potentially	Yes	-18.50	-9.18	-6.12
7	Laheys Creek downstream of Blackheath Creek confluence	No	No	Not impacted	Not impacted	Not impacted
8	Laheys Creek at Blackheath Creek confluence	No	Damp creek bed only	Not impacted	Not impacted	Not impacted
9	Laheys Creek at Blackheath Creek confluence	No	Yes (catfish present in 2009)	Not impacted	Not impacted	Not impacted
10	Laheys Creek upstream of Blackheath Creek confluence	Potentially	Damp creek bed	-3.39	-7.20	-9.31
11	Laheys Creek upstream of Blackheath Creek	No	No	Not impacted	Not impacted	Not impacted

Site	Location and Watercourse	Groundwater Dependent based on geophysical criteria? (error +/- 1 m)	Water present after dry period (2009 field observations)	Scale of groundwater drawdown – Mine year 12 (m)	Scale of groundwater drawdown – Mine year 14 (m)	Scale of groundwater drawdown – Mine year 20 (m)
	confluence					
12	Unnamed tributary of Laheys Creek upstream of Blackheath Creek confluence	No	No	Not impacted	Not impacted	Not impacted
13	Laheys Creek upstream of Blackheath Creek confluence	Potentially	Damp Creek bed at several locations	-0.10	-0.11	-0.19
14	Unnamed tributary of Fords Creek (unnamed tributary)	No	No	Not impacted	Not impacted	Not impacted

For those pools likely to depend on groundwater, the magnitude of the predicted drawdown suggests that groundwater drawdown would cause significant drying of pools after Year 12 of mining operations at Sites 6 and 10, with less significant drying at pools at Sites 2, 3, 5 and 13. While pools at Site 1 on the Talbragar River upstream of the confluence with Sandy creek are thought to be groundwater dependent, the predicted level of drawdown at that location is low and reductions in average flow volume during dry conditions are not expected to be observed. Hence the frequency of pool drying at that location is likely to be unchanged from that currently experienced.

The actual drying frequency at groundwater dependant pools during mine operation is likely to be influenced by physical characteristics of the pools, including bank morphology and height, pool depth, wetted perimeter and the type of substrata underlying each pool. Additionally, temporary groundwater storage in the alluvium may continue to sustain pools for 6 to 8 months following flood recharge events (Parsons Brinckerhoff 2012b) and variations in the local configuration the alluvium may also influence drying frequency.

While difficult to quantify, it is likely that groundwater drawdown would cause an increase in the drying frequency of pools in the lower reaches of Sandy and Laheys creeks and a significant increase in the upper reaches . While these impacts would not be expected until the middle of the life span of the mine, increases in drying frequency would reduce the connectivity of aquatic habitat and the number and size of refuge habitat available for Freshwater catfish, the Lowland Darling River aquatic ecological community, and would further degrade riparian vegetation in these creeks for a period of a decade or less. Because the local population of Freshwater catfish is low, any reduction in their numbers due to the operation of the mine may result local extirpation of the population.

5.5 Increased Sedimentation / Sediment Mobilisation

The Project involves alteration to hydrology and significant earthworks which have the potential to mobilise sediments into local waterways. Such works include:

- Site establishment and preparation works, mine operation, road/rail construction, drainage works (e.g. dams), the extraction from Cudgegong River and other ancillary works;
- Construction of temporary coffer dams or short diversions on Sandy Creek and Laheys Creek during construction of infrastructure crossings;
- Run-off over unvegetated or disturbed land (including loose sediment in channel realignments and rehabilitation works) and overflow from sediment ponds may also result in the mobilisation of sediments into waterways;

- Compaction in works areas may reduce infiltration of surface waters and contribute to sediment load in run-off; and
- Airborne dust from construction works may also enter the local waterways.

Downstream aquatic habitats in the Talbragar River drainage are potentially at risk as increases in suspended sediment can spread long distances (kilometres) downstream of construction sites (Wheeler *et al*. 2005).

An increase in sediment load can degrade water quality and important habitat features resulting in a loss of biodiversity and a shift towards a more pollution-tolerant biotic assemblage. For example, sedimentation can cause:

- Mortality and decreased growth. Suspended particles can clog respiratory gills and/or feeding apparatus of fish and macroinvertebrates;
- Degradation of habitat. Siltation can infill deep water refugia and interstitial spaces in the stream bed and smother aquatic macrophytes beds and spawning grounds; and
- Reduced water quality. Increased light attenuation associated with increased sediment load could decrease the productivity of aquatic plants while nutrients mobilized from sediments could increase eutrophication.

Increased sedimentation and habitat degradation is considered a threat to Southern purple-spotted gudgeon, Silver perch, Freshwater catfish, Olive perchlet and the Lowland Darling River aquatic ecological community.

In the absence of mitigation measures in the design, construction and operation phases of the Project, mobilised sediment would represent a potentially significant impact on aquatic ecology of Sandy and Laheys creeks, and, to a lesser extent the Talbragar River. Biota that persist in degraded ephemeral streams are likely to be adapted to changes in sediment load. Hence mobilised sediment is unlikely to pose a significant threat to the aquatic ecology of the Study Area provided adequate sediment control measures are implemented.

In overview, potential impacts from mobilised sediment can be minimised with standard sediment control measures and implementation of an Erosion and Sediment Control Plan (ESCP) as part of the Construction and Environmental Management Plan (CEMP) for the Project. Section 6 discusses details of appropriate best-practice procedures and recommended mitigation measures in the design, construction and operational phases of the Project.

5.6 Water Quality

The construction and operation of the Project has the potential to mobilise contaminants and increase salinity in aquatic habitats within the Study Area and downstream receiving waters. This could cause a loss of biodiversity and a shift towards a more pollution-tolerant assemblage. Sources of pollution potentially include:

- Contaminated discharge from mine areas. Contaminated water is likely to be saline, have elevated high metal and nutrient concentrations and could result in eutrophication of the waterway if released (Parsons Brinckerhoff 2012a Appendix B);
- Uncontrolled surface run-off/drainage from coal stockpiles and CHPP process water;
- Overflow of dams used to intercept and store contaminated water;
- Pollutants associated with materials used in the process of construction. Many of these materials can be toxic in their pure (non-amended) states, e.g. fly ash and asphalt cement crumb rubber elutriates (Eldin 2002). Contamination may result from spills on site or after construction from long-term run-off directly into aquatic habitats;
- Contamination from incorrect storage and use of hazardous materials on site;
- Pollutants associated with heavy vehicles, machinery, construction plant or equipment stores and wash down areas and fuel storage such aromatic hydrocarbons (lubricating oils and fuels) and heavy metals (e.g. copper in brake linings, and zinc and cadmium in tyres);
- Sewage overflows which could cause eutrophication;
- Pollutants and nutrients bound to disturbed sediments may be mobilised into aquatic habitat and/or released from sediment dams;
- Sediments containing flocculants used to settle particulates in sediment dams could enter waterways when sediment dams overflow. The use of flocculants as part of the Water Management System is not prescribed, however if operational conditions require their use a risk assessment would be required as some flocculants are acutely toxic to fish and aquatic invertebrates.
- Flow reduction in local waterways could increase concentration of contaminants; and
- Thermal pollution from dam releases (should the storages be large enough to stratify).

Pollution is considered a threat to Murray cod, Freshwater catfish and the Lowland Darling River aquatic ecological community.

If unmitigated, the impact of the Project on aquatic ecology may include a reduction of biodiversity, a shift to a more pollution-tolerant community assemblage and reduced capacity of the system to support native fish species.

The majority of potential impacts from pollution can be minimised by ensuring the proper selection, handling, storage, transport and disposal of potential pollutants and hazardous materials onsite and the incorporation of standard design features with respect to stormwater runoff and waste water storage. Section 6 discusses details of appropriate best-practice procedures and recommended mitigation measures in the design, construction and operational phases of the Project.

5.7 Local Depletions of Endangered Murray-Darling Population of Freshwater Catfish and Endangered Lowland Darling River Aquatic Ecological Community

If unmitigated, the impacts described above related to hydrological, sedimentary and chemical changes in Sandy and Laheys creeks together or in various combinations and levels of severity could directly or indirectly cause local depletions in the endangered Murray Darling population of Freshwater catfish and the endangered Lowland Darling River aquatic ecological community. Change in hydrology in Sandy and Laheys creeks associated with the Project is the driver for other changes, and hence is the focus of mitigative measures.

Given the implementation of mitigation measures described in Section 6, impacts on an aquatic system already under stress can be minimised if hydrological changes are managed to reflect the current hydrological pattern to the extent that this is possible. Those impacts that cannot be readily mitigated, such as those attributable to groundwater drawdown, or impacts for which there is uncertainty as to the effectiveness of mitigation can also be addressed by monitoring and the implementation of environmental compensation measures.

5.8 Entrainment of Fish Eggs and Larvae

Pumping of water from rivers can affect fish populations by removing fish and transferring them to offstream storages (entrainment), and by causing injury and mortality on screens (impingement) and pumps. Water intake also increases the risk of predation by increasing stress levels in fish and/or providing habitat for fish and bird predators (Blackley 2003). Effects of abstraction of water on fish are greatest during migration periods and after spawning when large numbers of eggs and larvae are in the water. If large numbers of fish are removed, this may affect the age structure and reproductive ability of the population.

Pumps can physically injure or kill fish during operation and the most commonly used type, with rotating impellors, render some species and size classes particularly susceptible to injury. In a study in the Namoi River, comparing the effects of two abstraction systems (36

ML/d and 150 ML/d), Baumgartner *et al*. (2009) found that the greatest proportion of injury and mortality occurred in high-volume pump systems. Native species that were entrained were Australian smelt, Freshwater catfish, Carp gudgeon, Spangled perch (*Leiopotherapon unicolour*), Golden perch (*Macquaria ambigua*), Murray cod, Murray rainbowfish (*Melanotaenia fluviatilis*) and Bony herring (*Nematolosa erebi*). Introduced species entrained were Goldfish and Carp. All of the above species (except Murray cod and Bony herring) have been recorded from the Cudgegong River in the reach from which water will be extracted via a pipeline for use in mine operations (Swales *et al.* 1993; Miles 2004). The proportions of deaths and injuries varied considerably among species, with Carp being most susceptible. Significantly more small fish (<50 mm) were killed or injured than large ones (>200 mm), while no medium sized fish (100 to 200 mm) were killed.

If unmitigated, the extraction of water from the Cudgegong River for use in the mine could reduce the population of native (and introduced) fish in the river. Section 6 provides discussion of appropriate mitigation measures for entrainment and impingement of fish associated with pumping water from the Cudgegong River. Given that recommended designs for screens and operational parameters are implemented, the impact of water abstraction on fish populations in the Cudgegong should be minimal.

5.9 Instream Structures and Waterway Crossings

The operation of the drainage structures constructed at various road, rail and pipeline waterway crossings for the Project should have little or no impact on aquatic ecology given that they conform to 'minimum' recommended crossing types (Section 6). The planned bridge structures over Sandy and Laheys Creek will satisfy requirements for fish passage in these creeks.

5.10 Listed Key Threatening Processes

5.10.1 Degradation of Riparian Vegetation

Some riparian vegetation would be removed at infrastructure crossings on Sandy and Laheys creeks. Groundwater drawdown caused by the Project may also lead to degradation of riparian vegetation along creek lines.

Loss of riparian vegetation is a threat to Silver perch and the Lowland Darling River aquatic ecological community. Historical clearing within the Study Area has resulted in a heavily modified landscape. Removing small sections of riparian vegetation at creek crossings is unlikely to have a significant negative effect on Silver perch or the Lowland Darling River aquatic ecological community, given its present condition.

5.10.2 Removal of Large Woody Debris

Permanent and temporary waterway crossings associated with construction and operation of roads, rail and the Cudgegong River pipeline could potentially cause the removal of instream woody debris. Similarly, works associated with the construction of the pipeline intake at the Cudgegong River will extend metres into the river channel and may require the removal or repositioning of instream woody debris.

The removal of large woody debris is a threat to Murray cod, Trout cod, Olive perchlet and the Lowland Darling River aquatic ecological community.

The recommended mitigation measures to avoid loss of instream woody debris focus on removal and post-construction replacement or relocation of existing woody debris. Given that the removal of woody debris would be minimal and recommended mitigation measures are implemented, this Key Threatening Process is not likely to have a significant impact on aquatic ecology of waterways in the Study Area.

5.10.3 Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands

The potential impacts of the Project related to the listed Key Threatening Process *Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands* have been discussed in Section 5.3 above. The combined effects of groundwater drawdown and alteration of natural flow regimes is a threat to Murray cod, Trout cod, Southern purple-spotted gudgeon, Silver perch, Freshwater catfish, Olive perchlet and the Lowland Darling River aquatic ecological community.

5.11 Threatened and Protected Species, Communities and Populations

5.11.1 Matters of National Environmental Significance (NES)

The assessments of the significance of impacts on threatened fish species listed under the *EPBC* Act presented below have been prepared in accordance with the Significant Impact Criteria specified in the MNES Significant Impact Guidelines 1.1 (Commonwealth of Australia 2009). These criteria are to determine whether the Project would:

- Lead to a long-term decrease in the size of a population;
- Reduce the area of occupancy of the species;
- Fragment an existing population into two or more populations;
- Adversely affect habitat critical to the survival of a species;
- Disrupt the breeding cycle of a population;

- Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
- Introduce disease that may cause the species to decline; and
- Interfere with the recovery of the species.

The assessments that have been prepared are based on the Project Description and CEL's understanding of the likely impacts of the Project on instream ecology. Issues raised in the DGRs have also been taken into consideration. The objective of these assessments is to determine whether the Project is likely to have a significant impact on the threatened species and population identified in Section 4.2. The assessment considers the potential direct and indirect impacts of the construction and operational phases of the Project.

The potential for adverse effects on the lifecycle of threatened fish species depends on whether the Project is likely to cause loss or degradation of habitat, reduction in water quality, limit their foraging activities and disrupt their reproduction and recruitment.

Matters of NES listed on the EPBC Act that may occur within the Study Area include two threatened fish species: Murray cod (vulnerable) and Trout cod (endangered). The impact of the Project on Murray cod and Trout cod has been assessed in accordance with the Significant Impact Criteria outlined in the Matters of National Environmental Significance Significant Impact Guidelines 1.1 (DEWHA 2009).

5.11.1.1 Murray Cod

The impact of the Project on Murray cod, which is listed as vulnerable under both the EPBC Act and FM Act, has been assessed below.

Assessment Criteria	Response
Long-term decrease in the size of local and regional populations	Murray cod were naturally widespread throughout the entire Murray-Darling Basin and abundant, particularly in the lower and mid-altitude reaches (Lintermans 2007). Overfishing, river regulation, sedimentation and barriers to passage have caused a dramatic decline in their abundance and the species now has a patchy distribution across its historical range. Murray cod are generally associated with deep 'holes' and submerged woody debris or undercuts, and are sedentary sit and wait predators. However, during late winter/ early spring, they migrate for distances of up to 80 – 120 km to spawn following seasonal floods or high flows

Assessment Criteria	Response
	(Morris et al. 2001, Lintermans 2007). In spring/summer, they spawn in relatively small anabranch streams, laying their adhesive eggs on snags, rocks or clay banks (Lintermans 2007).
Reduced area of occupancy	There are a number of recent records of Murray cod from the Macquarie River downstream of the Talbragar River. The species has been stocked in this reach and it can be difficult to ascertain if an observed individual was wild or hatchery-reared (Morris et al. 2001). There are no formal records of Murray cod from the Study Area but the author has heard anecdotal accounts of historical observations of Murray cod by residents along the Talbragar River. Given the proximity of Murray cod to the unregulated Talbragar River and the size of their spawning migrations, the Talbragar River (and potentially Sandy Creek) would constitute possible spawning habitat during an appropriately timed flow event. However, given that these rivers now have no flow approximately 35 – 40 % of the time (partly due to extraction within the catchment), it is possible that isolated individuals could persist in some of the Study Area's deeper and more cryptic pools, but unlikely that a reproducing, viable population had become established.
Fragmentation of an existing population into two or more populations.	There is no evidence of an existing population within the Talbragar River, Sandy Creek, Laheys Creek or the Cudgegong River, and hence the Project is unlikely to cause the fragmentation of an existing population.
Adverse effects on habitat that is critical to the survival of the species	The potential threats to Murray cod represented by the Project include: alterations to the natural flow regime, removal of large woody debris, construction of instream barriers to passage, degradation of habitat from sedimentation and loss of habitat. The installation of appropriate drainage structures at road, rail and pipeline crossings should ensure there is no detrimental effect on Murray cod passage. Whilst the existing structures in the Talbragar River do represent a barrier to passage, the majority of habitat upstream of these is ephemeral and it is unlikely Murray cod would attempt or benefit from access. Recommendations relating to woody debris and sediment control should mitigate any potential impacts from these threats.
Disrupt the breeding cycle of a population	Alterations to flow usually reduce Murray cod recruitment. Changes to the size, frequency, duration and seasonality of floods can mask spawning cues, reduce the availability of productive flooded areas for nursery habitat and impede upstream fish passage to spawning sites. The Project would alter the natural flow regime of the Study Area by producing more regular flow patterns with overall decrease in flow volume. The retention of runoff from medium to larger flood events may

Assessment Criteria	Response
	reduce cues that initiate upstream spawning migrations, but upstream sections of Sandy and Laheys creeks are unlikely to contain ideal spawning habitat for Murray cod and suitable habitats are present further downstream in the Talbragar River. The loss of some groundwater-fed pools could result in mortality to some adult Murray cod if they had become trapped in them as water levels fell, however most adults spawning in the area would probably return to home sites downstream. It is also possible that freshwater dams might capture or alter the hydrology of smaller storm events (i.e. dams can contain the 95^{th} percentile five day event), which could hypothetically conceal a flood signal, but this would probably have little effect on peak flows in the Talbragar River if the rest of the catchment was in flood.
Modify, destroy, remove, isolate or decrease the availability and or quality of habitat to the extent that the species is likely to decline.	Potential temporary impacts on the quality of habitat resulting from increased sediment loading during construction would be minimised by application of appropriate erosion and sediment control measures. The Project would not substantially alter flows or cause excessive sedimentation in the Talbragar River, and it is consequently highly unlikely that the Project would change habitat availability and/or quality to such an extent that the species (if present) would decline.
Result in invasive species that are harmful becoming established in the threatened species habitat	Populations of seven invasive fish species; Brown trout, Brook char, Eastern gambusia, European Carp, Goldfish, Rainbow trout and Redfin perch are known to occur in the Talbragar and Cudgegong rivers. The abstraction of water from the Cudgegong River has very limited potential to entrain adults, larvae and eggs of invasive species, but their translocation to the Talbragar River is highly unlikely and irrelevant given existing populations of the same species in the Talbragar River. It is therefore highly unlikely that additional invasive species will become established as a result of the construction and operation of the proposed pipeline or water management regime of the Project.
Introduce disease that may cause the species to decline	The construction and operation of the Project does not include any mechanisms that would introduce disease.
Interfere with the recovery of the species	The overall objective of the National Recovery Plan for Murray cod is to rehabilitate Murray cod populations in the Murray Darling Basin to 60 % (or better) of their estimated pre-European settlement levels after 50 years of implementation. Remnant pools within Talbragar River, and, to a lesser extent those in Sandy and Laheys creeks represent potential aquatic refugia for Murray cod. Hence the Project has potential to interfere with the recovery of the species if it reduces the quantity and quality of pools available to Murray cod as refugia in periods of low flow. The recovery actions specified in the Recovery Plan that is relevant to

Assessment Criteria	Response
	the Project is: • Identify, protect and repair key aquatic and riparian habitats for Murray cod that are impacted by the Project. The Project would have little impact on aquatic habitats and water quality within the Talbragar River, while providing a slight increase in flows during some operational phases. While the latter would not be a significant increase over the life of the Project, an increase in water flow would improve the access of Murray cod to aquatic habitats within the Talbragar River, enhancing the recovery of the species by providing additional aquatic refugia.
Conclusion	The key threats that Cobbora Coal Project poses to Murray cod relate to; alterations to natural flow regime, removal of large woody debris, creation of barriers to passage and increased sedimentation. These potential impacts can be minimised or eliminated by implementing the suggested recommendations. As such, the assessment of significance found that the proposal would be **unlikely** to significantly affect Murray cod.

5.11.1.2 Trout Cod

The impact of the Project on Trout cod, which is listed as endangered under both the EPBC Act and FM Act, has been assessed below.

Assessment Criteria	Response
Long-term decrease in the size of local and regional populations	Trout cod are endemic to the southern Murray-Darling river system, including the Murrumbidgee and Murray Rivers, and upper Macquarie River. This species has undergone a dramatic decline in its distributional range and abundance over the past century, with the only known natural population being restricted to the Murray River from below Yarrawonga Weir to Strathmerton. The species is not recorded from the Cudgegong River. There are two historic reports of this species occurring naturally in the Macquarie River, up- and downstream of the confluence with the Talbragar, but no recent records. Hatchery-bred Trout cod were released at multiple sites in the upper Macquarie River in 2009, with further stocking in 2010 and 2011. Trout cod are known to have been released into the Turon River, a tributary of the Macquarie River, in 1991 and 1993. There are no known stockings in the Talbragar River; however stocked Trout cod could, in theory, use habitats in the river. The Project is unlikely to cause a long term

Assessment Criteria	Response
	decrease in the size of local and regional populations, as local populations are unlikely to occur and regional populations are already small in size.
Reduced area of occupancy	Trout cod have been recorded in several aquatic habitats. The existing self-sustaining populations are found in deep, flowing rivers with sand, silt or clay substrata and numerous snags and in relatively narrow streams with rock, gravel and sand substrata, and shallow pools interspersed with rapids and cascades. The Talbragar River contains suitable habitat, but that in Sandy and Laheys creeks is less suitable due to the ephemeral nature of the aquatic habitats. The Project would result overall in little change to water flow in the Talbragar, and hence would not cause a reduced area of occupancy for Trout cod.
Fragmentation of an existing population into two or more populations.	There is no evidence of an existing population within the Talbragar River, Sandy Creek, Laheys Creek or the Cudgegong River, and hence the Project is unlikely to cause the fragmentation of an existing population.
Adverse effects on habitat that is critical to the survival of the species	Trout cod use a variety of aquatic habitats, including deep, flowing rivers with sand, silt or clay substrata and numerous snags and relatively narrow streams with rock, gravel and sand substrata, and shallow pools interspersed with rapids and cascades. Local information on the use of specific habitats is limited, however, in the Murray River, Trout cod frequent areas where there are large amounts of large woody debris, close to deep water and high surface flows. In narrow river sections, they frequented areas where large wood was abundant, but in other areas they use large wood that occurred in deep scour pools (Nicol *et al.* 2007). Trout cod in the Murrumbidgee River have a small home range and prefer to move along outer river bends where there is deeper water and more structural woody habitat (Thiem *et al.* 2008). Suitable habitat is present in the Talbragar, but not in Sandy and Laheys creeks to any appreciable extent. Given that the Project will have very little overall impact on habitats in the Talbragar River, it is unlikely that the effects of the Project on habitat would be critical to the survival of this species.
Disrupt the breeding cycle of a population	It is not known whether any of the Trout cod that have been released into the upper Macquarie River have survived to sexual maturity. Trout cod are believed to pair up prior to spawning which takes place in late October to early November, when water temperatures reach about 16°C. Trout cod are believed to deposit adhesive eggs on hard surfaces on or

Assessment Criteria	Response
	near the stream bottom. Larvae are thought to disperse downstream in the drift for a short distance, with peak dispersal occurring in November (Koehn and Harrington 2006). The environmental conditions favouring successful recruitment are not known. Given that the Project would have little overall impact on aquatic habitat in the Talbragar River, it is unlikely that it would disrupt the breeding cycle of a regional population.
Modify, destroy, remove, isolate or decrease the availability and or quality of habitat to the extent that the species is likely to decline.	Potential temporary impacts on the quality of habitat resulting from increased sediment loading during construction would be minimised by application of appropriate erosion and sediment control measures. The Project would not substantially alter flows or cause excessive sedimentation in the Talbragar River, and it is consequently highly unlikely that the Project would change habitat availability and/or quality to such an extent that the species (if present) would decline.
Result in invasive species that are harmful becoming established in the threatened species habitat	Populations of seven invasive fish species, Brown trout, Brook char, Eastern gambusia, European Carp, Goldfish, Rainbow trout and Redfin perch are known to occur in the Talbragar and Cudgegong rivers. The abstraction of water from the Cudgegong River has very limited potential to entrain adults, larvae and eggs of invasive species, but their translocation to the Talbragar River is highly unlikely and irrelevant given existing populations of the same species in the Talbragar River. It is therefore highly unlikely that additional invasive species will become established as a result of the construction and operation of the proposed pipeline or water management regime of the Project.
Introduce disease that may cause the species to decline	The construction and operation of the Project does not include any mechanisms that would introduce disease.
Interfere with the recovery of the species	The overall objective of the National Recovery Plan for Trout cod is to minimise the probability of extinction in the wild, and increase the likelihood of important populations becoming self-sustaining in the long term. Potential for the Project to interfere with the recovery of the species depends on whether stocking of Trout cod in the upper Macquarie River has led to the establishment of self-sustaining populations that would utilise aquatic habitats in the Talbragar River. The overall objective of the NSW Recovery Plan for Trout cod is to ensure the recovery and natural viability of this species throughout its former range. The specific objectives of this plan that are pertinent to the Project are: • Establishing and protecting stocked populations at selected locations throughout the species' former range;

Assessment Criteria	Response
	• Identifying management actions to minimise threats to populations. The recovery actions specified in the NSW Plan that is relevant to the Project is: • Minimising habitat degradation and improving protection and rehabilitation of key habitat. The Project would have little impact on aquatic habitats and water quality within the Talbragar River, while providing a slight increase in flows during some operational phases. While the latter would not be a significant increase over the life of the Project, an increase in water flow would improve the access of Trout cod to aquatic habitats within the Talbragar River, enhancing the recovery of the species by providing additional aquatic habitat.
Conclusion	It is unlikely that the Project will impact on a local or regional population of Trout cod. There is a possibility that the Project will slightly increase water flow in the Talbragar River, marginally improving access to habitats there that could be used by a stocked population of Trout cod population, if one exists.

5.11.2 Assessments of Significance under the FM Act

The assessments of the significance of impacts on threatened fish species and populations listed under the *FM* Act presented below have been prepared in accordance with the Draft Guidelines for Threatened Species Assessment that are applicable to development proposals that are to be assessed under Part 3A of the NSW Environmental Planning and Assessment Act, 1979 (DEC and DPI, 2005). These guidelines specify the important factors that must be taken into considered when assessing potential impacts on threatened species, populations, or ecological communities. The factors requiring consideration are:

- How is the Project likely to affect the lifecycle of a threatened species and/or population?
- How is the Project likely to affect the habitat of a threatened species, population or ecological community?
- Does the Project affect any threatened species or populations that are at the limit of its known distribution?
- How is the Project likely to affect current disturbance regimes?
- How is the Project likely to affect habitat connectivity?

- How is the Project likely to affect critical habitat?

The assessments that have been prepared are based on the Project Description and our understanding of the likely impacts of the Project on instream ecology. Issues raised in the DGRs have also been taken into consideration. The objective of these assessments is to determine whether the Project is likely to have a significant impact on the threatened species and population identified in Section 4.2. The assessment considers the potential direct and indirect impacts of the construction and operational phases of the project.

The potential for adverse effects on the lifecycle of threatened fish species depends on whether the Project is likely to cause loss or degradation of habitat, reduction in water quality, limit their foraging activities and disrupt their reproduction and recruitment.

5.11.2.1 Trout Cod (*Maccullochella macquariensis*) (Source: NSW DPI 2006a)

Assessment Criteria	Response
How is the proposal likely to affect the life cycle of the threatened species?	The Trout cod is a large, deep-bodied opportunistic predator which feeds on yabbies, crayfish, shrimp, fish and aquatic insects. Little is known about its biology or ecology. This species was initially thought to undertake significant upstream migrations, possibly for spawning. Studies undertaken in the Murray River, however, indicate that it may have a small home range. Spawning occurs in late October to early November. Trout cod do not appear to be dependent on flow conditions, so are unlikely to be affected by the small reduction in flows resulting from extraction of water. Trout cod produce relatively small numbers (1,200 to 11,000) of adhesive eggs at a time and are believed to deposit these on hard surfaces on or near the stream bottom. It is possible that the removal of large woody debris could adversely affect the life cycle of Trout cod, if present on site. Recommendations relating to the removal of woody debris would mitigate this possible threat. Larvae disperse downstream in the flow for a short distance, with peak dispersal occurring in November. The environmental conditions favouring successful recruitment are not known.
How is the proposal likely to affect the habitat of this threatened species?	Trout cod utilise several types of aquatic habitat. Existing self-sustaining populations occur in deep, flowing rivers with sand, silt or clay substrata and numerous snags as well as relatively narrow streams with rock, gravel and sand substrata, and shallow pools interspersed with rapids and cascades. The Talbragar River contains suitable habitat for this species, but the ephemeral nature of Sandy and Laheys Creeks limits their suitability.

	The Study Area represents just 6 % of the Talbragar River catchment, itself a small proportion of the existing and historical distribution of the species. The habitat of the Study Area is not critical to the long-term survival of the species. However, the Talbragar River does represent potential, albeit degraded, habitat should the stocked Trout cod population establish itself in the Macquarie River downstream of Dubbo. The Project would result overall in little change to water flow in the Talbragar, and hence would not cause a reduced area of occupancy for Trout cod. River regulation, in the form of barriers to passage and alteration to natural flow regimes, is believed to be a threat to Trout cod. The Project would alter natural flow regimes, which could lead to a reduction in flows and possibly the degradation, or even loss, of some discontinuous pools. Removal of instream woody debris associated with Project works is also possible. The construction of dams for the Water Management Strategy and installation of inappropriate drainage structures at road, rail and pipelines crossings could create instream barriers to fish passage; however it is unlikely that there would be appropriate freshwater habitat for Trout cod upstream of many of these structures. Recommendations relating to the removal of woody debris, installation of appropriate drainage structures and an appropriate release strategy for treated groundwater could mitigate some of these potential threats. Aquatic habitat in these variable low flow environments can become fragmented frequently. A reduction in flows associated with the Project could increase the fragmentation and isolation of aquatic habitat. There is, however, no evidence of an existing population within the Talbragar River, Sandy Creek, Laheys Creek or the Cudgegong River; hence the Project is unlikely to cause the fragmentation of an existing population.
Does the proposal affect a threatened species at the limit of its known distribution	The Project Area/Study Area is a considerable distance from the distribution limits of this species. Trout cod are endemic to the southern Murray-Darling river system, including the Murrumbidgee and Murray Rivers, and upper Macquarie River. This species has undergone a dramatic decline in its distributional range and abundance over the past century. There are two historic reports of this species occurring naturally in the Macquarie River, up- and downstream of the confluence with the Talbragar, but no recent records. The only known natural population is restricted to the Murray River from below Yarrawonga Weir to Strathmerton. Hatchery-bred Trout cod have been released at a number of sites on the upper Macquarie River on several occasions between 1991 and 2011. The Study Area is approximately 55 km upstream of the stocked

	population of Trout cod in the Macquarie River and probably does not qualify as aquatic habitat within the 'locality of the population' that requires maintenance and restoration. However, this species has been known to occasionally undertake exploratory movement of 20 – 60 km following flood events (Lintermans 2007). As the Talbragar River is unregulated it is feasible that individuals could reach the Study Area during a flow event.
How is the proposal likely to affect current disturbance regimes?	The major processes that affect aquatic habitats and their biota in the Project area are surface water flows, runoff during rainfall events and fire. Releases of captured water from dams, drawdown of groundwater and reduction in the size of the Laheys Creek and Sandy Creek catchments would alter natural flow regimes.
How is the proposal likely to affect habitat connectivity?	The drawdown of groundwater could lead to a reduction in the number of groundwater-dependant pools that connect to habitats upstream.
How is the proposal likely to affect critical habitat?	There are no critical habitats for Trout cod listed under the *FM Act*.
Conclusion	It is unlikely that the Project will impact on a local or regional population of Trout cod. There is a possibility that the Project will slightly increase water flow in the Talbragar River, marginally improving access to habitats there that could be used by a stocked population of Trout cod population, if one exists.

5.11.2.2 Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*) (Source: Fisheries Scientific Committee 2008c)

Assessment Criteria	Response
How is the proposal likely to affect the life cycle of the threatened species?	Southern purple-spotted gudgeon spawns during summer, depositing its adherent eggs onto hard surfaces such as rocks or submerged woody debris within slow moving or still river waters. Fluctuating water levels associated with river regulation can negatively affect recruitment. If this species is present within the Study Area, it is possible that the removal of large woody debris, the loss of deep persistent pools (either inside the mine footprint or from drawdown) and/or fluctuating flows potentially associated with groundwater releases could adversely affect the life cycle of Southern purple-spotted gudgeon. Recommendations relating to the removal of woody debris and an appropriate release strategy for treated groundwater could mitigate two of these potential threats.

How is the proposal likely to affect the habitat of this threatened species?	Southern purple-spotted gudgeon are slow-moving ambush predators. They are benthic species and usually found in areas with good cover such as cobble and rocks or aquatic vegetation. This species occurs in slow moving or still waters of creeks, rivers, wetlands and billabongs, but appears to prefer slower flowing, deeper habitats. The key threats that the proposal poses to the habitat of Southern purple-spotted gudgeon are smothering of aquatic vegetation by siltation, removal of submerged woody debris, the effects of groundwater drawdown on discontinuous pools and persistence of macrophyte beds and irregular flows from regulation. Recommendations relating to the mobilisation of sediment would prevent the smothering of macrophyte beds. The drawdown of groundwater could lead to the degradation, or even loss, of some discontinuous pools. A reduction in the number of available pools in dry conditions could increase the fragmentation and isolation of aquatic habitats. Although Southern purple-spotted gudgeon was not observed during the field survey, given the relative proximity of the newly-discovered population in a small tributary of the Macquarie River, it is possible that deep persistent pools within the Talbragar River (or its tributaries) constitute potential habitat for this species, should they be present in the Talbragar River.
Does the proposal affect a threatened species at the limit of its known distribution	The Project Area/Study Area is a considerable distance from the distribution limits of this species. There are two populations of purple-spotted gudgeon in NSW: the eastern population is found in coastal drainages to the north of the Clarence River catchment and a western population that was historically disjunct but present throughout the Murray-Darling system. The distribution of the western population has declined significantly in recent years and is now restricted to three areas west of the dividing range in the coastal drainage of NSW. This species was predicted to occur in the upper Macquarie River prior to human intervention (Davies *et al.* 2008). The species is now extremely rare in inland NSW and has been recorded only once from this area since 1983, when a new population was discovered at Wuluuman Creek in 2005 (~ 320 m AHD). Wuluuman Creek is a tributary of the Macquarie River approximately 8 km downstream of the Burrendong Dam wall. Prior to 1980, the species was recorded on three occasions within the region. Although Southern purple-spotted gudgeon was not observed during the field survey, given the relative proximity of the newly-discovered population in a small tributary of the Macquarie River, it is possible that deep persistent pools within the

	Talbragar River (or its tributaries) constitute potential habitat for this species, should they be present in the Talbragar River.
How is the proposal likely to affect current disturbance regimes?	The major processes that affect aquatic habitats and their biota in the Project Area are surface water flows, runoff during rainfall events and fire. Releases of captured water from dams, drawdown of groundwater and reduction in the size of the Laheys Creek and Sandy Creek catchments would alter natural flow regimes.
How is the proposal likely to affect habitat connectivity?	The drawdown of groundwater could lead to a reduction in the number of groundwater-dependant pools that connect to habitats upstream.
How is the proposal likely to affect critical habitat?	Critical habitat has not been declared for this species.
Conclusion	It is unlikely that the Project will impact on a local or regional population of Southern purple spotted gudgeon, as it is unlikely that one exists.

5.11.2.3 Silver Perch (*Bidyanus bidyanus*) Source (NSW DPI 2006b)

Assessment Criteria	Response
How is the proposal likely to affect the life cycle of the threatened species?	Silver perch is a moderate to large omnivorous species that consumes insects, molluscs, small crustaceans, worms, microscopic animals and algae. Adults migrate upstream from November to February while older juveniles do so between October and April. These movements appear to be stimulated by increases in water temperature above 20ºC and water level and, in the case of adults, may be for spawning. Females release non-adhesive, floating eggs which hatch within a few days. The larvae develop into juvenile fish within three weeks. The upland waterways in the Study Area could represent spawning habitat for Silver perch. Alteration to natural river flows from river regulation and water extraction have disrupted migration and reproductive behaviour of this species causing a decline in recruitment. Changes to the size, frequency, duration and seasonality of floods can mask spawning cues and reduce the availability of productive flooded areas for nursery habitat. Similarly, barriers to passage impede the movement of spawning migrations upstream. The Project would alter the natural flow regime. Modelling suggests there would be a predicted decrease in median annual flow and again (to a lesser extent) following the cessation of mining with sediment dam

	water reuse. However, these effects are most significant for low flows and zero flow periods, when Silver perch are least likely to migrate for spawning. It is possible that the dams might capture or flatten the profile of smaller storm events, which could hypothetically conceal a flood signal, but this would probably have little effect on peak flows within the Talbragar River if the rest of the catchment was in flood. The installation of appropriate drainage structures at road, rail and pipeline crossings should have no detrimental effect on fish passage. Freshwater habitat upstream of the sediment dams is ephemeral and it is unlikely that spawning Silver perch would try or benefit from accessing this habitat. As such, the Project is unlikely to have adverse effect on the life cycle of Silver perch.
How is the proposal likely to affect the habitat of this threatened species?	Silver perch occupy a variety of habitats across the Murray-Darling Basin, including cool, clear, gravel-bed streams in the upper reaches. Little is known about the specific habitat requirements of this species, particularly the extent to which they may depend on structural habitat components. NSW DPI sampling records show that they are usually caught near snags in rivers.
Does the proposal affect a threatened species at the limit of its known distribution	Historical records show that Silver perch were present throughout most of the Murray-Darling Basin. This species has undergone a dramatic decline in abundance and distribution over the last few decades and is now absent from most of its natural range. The largest natural population is found in the central Murray River system downstream of Yarrawonga Weir. There are also reports of self-sustaining populations in the Macquarie River. In the past ten years, this species has been released into several reservoirs and dams in the Upper Macquarie catchment, including Burrendong Dam. There are no records of Silver perch from the Talbragar River catchment, but it has been recorded from the Macquarie River upstream of the Talbragar River confluence prior to 1980 (Lintermans 2007), and most recently in 2006 from the Macquarie River, downstream of the Talbragar River confluence near Narromine. There are also anecdotal accounts of Silver perch caught by residents along the Talbragar River (Bob Hunt pers. com.). As the species migrates large distances upstream to spawn - and has been recorded from the Macquarie River - the Talbragar River would appear to represent possible spawning habitat during seasonal peak flows because it is unregulated. I&I NSW has included the Study Area within the natural distribution of the Silver perch (DPI NSW 2005b). However, given that wild Silver perch have been so rarely encountered during NSW fish surveys and flows in the Talbragar River have been

	degraded by extraction and diversion, it is unlikely that a population has established itself in the Study Area.
How is the proposal likely to affect current disturbance regimes?	The major processes that affect aquatic habitats and their biota in the Project area are surface water flows, runoff during rainfall events and fire. Releases of captured water from dams, drawdown of groundwater and reduction in the size of the Laheys Creek and Sandy Creek catchments would alter natural flow regimes.
How is the proposal likely to affect habitat connectivity?	The drawdown of groundwater could lead to a reduction in the number of groundwater-dependant pools that connect to habitats upstream.
How is the proposal likely to affect critical habitat?	No critical habitats for Silver perch are listed under the *FM Act.*
Conclusion	It is unlikely that the Project will impact on Silver perch

5.11.2.4 Murray River Basin Population of the Freshwater Catfish (*Tandanus tandanus*) (Source: Lintermans 2009; Fisheries Scientific Committee 2008d)

Assessment Criteria	Response
How is the proposal likely to affect the life cycle of the threatened species and/or population?	The Freshwater catfish is a benthic species that lives, feeds and breeds near the bottom. It does not migrate. This species spawns in spring and summer when water temperatures are 20-24° C. The species has an elaborate courtship display and lay eggs in a nest of up to 2 m in diameter built out of pebbles and/or gravel. The eggs are large and non-adhesive and settle into the interstices of the substratum. The nest is guarded and fanned by male fish. Potential impacts on the life cycle of this species relate to the removal of creek habitat, changes to natural flow regimes and elevated salinity levels and could include: • Catfish prefer stable low flows for spawning and nest building. Changes to the magnitude and temporal pattern of flows can lead to reduced spawning success and loss of spawning sites. A reduction in flow can reduce the amount of available spawning habitat and fluctuating flow that exposes nests before a catfish has laid its eggs can lead to the abandonment of nests; • Increased sedimentation can smother the gravel or cobble bed substrata preferred by catfish for nest building; and • Juveniles are thought to have lower salinity tolerance than adults (who are very tolerant) and could be impacted by the proposed high-conductivity overflow water into Sandy Creek

	and the Talbragar River. Lack of distinct spawning or dispersal migration makes populations of catfish susceptible to localised disturbance and slow to recolonise. Planned mitigation measures regarding the treatment of dam overflow water prior to release, erosion and sediment control and the adoption of an appropriate environmental release strategy may minimise some impacts associated with the Project.
How is the proposal likely to affect the habitat of this threatened population?	Freshwater catfish occur in a variety of habitats, including rivers, creeks, lakes, billabongs and lagoons, in clear to turbid waters and over a variety of substrata, including mud, gravel and rock. They may be found in flowing streams, but appear to prefer sluggish or still waters. This species has been observed in two remnant water holes: one on Laheys Creek and one on Sandy Creek. The Project would modify habitat for Freshwater catfish by altering hydrology in the creeks where they have been recorded. Releases of dam water and limited dam overflow events would produce more regular flows, with pools filling more regularly. However the pools dependent on groundwater during dry periods, will dry more frequently , resulting in loss of key habitat. The catfish habitat which will be altered is likely to be at or near the upstream extent of suitable habitat for this species, which may be reflected in the small number observed (two). Despite the sedentary nature of catfish, the discontinuous pools in which catfish were found may be refugia occupied during extended periods of low flow rather than preferred habitats within larger creeks. However, such habitats may contribute disproportionately to the long term survival of the species locally because downstream habitats in the larger Talbragar River are affected by blockages to fish passages, water abstraction, agricultural practices and suffer from elevated levels of salinity and metals and nutrients. Sandy Creek represents 6 % of the entire Talbragar River catchment, which is significant given the Talbragar River is one of the few unregulated rivers in a region of the Macquarie River catchment that is known to support a moderate-sized population of catfish. Freshwater catfish populations experience natural fragmentation during dry periods when they seek refuge in discontinuous pools. Predicted groundwater drawdown would reduce the number of pool refugia during the life of the mine and increase the fragmentation of catfish habitat. Small reductions in annual average flows may also slightly decrease habitat connectivity in dry and average climatic conditions. Recommended mitigation measures regarding sediment control, the adoption of a water release strategy may minimise some impacts

	associated with the Project.
Does the proposal affect a threatened populations at the limit of its known distribution	The Murray River Basin Freshwater Catfish population originally occurred throughout the Murray-Darling River System, except in the cooler parts of the southern tributaries. There has been a significant and rapid decline in the distribution and abundance of this species. Freshwater catfish are now rare or absent from many of the major tributaries in NSW, including the Murray, Darling, Murrumbidgee and Lachlan rivers. Freshwater catfish were recorded within the Project Area at Sandy and Laheys creeks during the current study and there are previous records from the Talbragar River near the Sandy Creek confluence and the Cudgegong and Macquarie Rivers. The Project Area is a considerable distance from the distribution limits of this species.
How is the proposal likely to affect current disturbance regimes?	The major processes that affect aquatic habitats and their biota in the Project area are surface water flows, runoff during rainfall events and fire. Releases of captured water from dams, drawdown of groundwater and reduction in the size of the Laheys and Sandy Creek catchments would alter natural flow regimes.
How is the proposal likely to affect habitat connectivity?	The drawdown of groundwater could lead to a reduction in the number of groundwater-dependant pools that connect to habitats upstream.
How is the proposal likely to affect critical habitat?	No critical habitats for Murray River Basin population of Freshwater catfish are listed under the *FM Act.*
Conclusion	The Project could lead to the loss of habitat and therefore further reduction in the very small population of catfish in creeks within the PAA.

5.11.2.5 Endangered Lowland Darling River Aquatic Ecological Community

Assessment Criteria	Response
How is the proposal likely to affect the life cycle of the threatened species and or population?	Not applicable. Endangered Lowland Darling River aquatic ecological community is not a species.
How is the proposal likely to affect the habitat of this threatened ecological community?	All waterways in the Study Area up to 500 m AHD (excluding artificial drainages and dams) form part of the Lowland Darling River aquatic ecological community which is listed as Endangered in NSW (DPI NSW 2005a, 2007). The Project would alter hydrology in Sandy and Laheys creeks,

	potentially adversely modifying the habitat and composition of the remaining ecological community within the Sandy Creek catchment (282 km^2). The potential loss of deep pool refugia due to groundwater drawdown could affect the ability of some populations to persist through prolonged dry periods during operation of the mine. The already fragmented EEC habitat and community would become more fragmented if semi-permanent pools decrease in number and aquatic habitats become less connected as a result of the Project. Groundwater drawdown at some semi-permanent pools will also cause degradation of riparian vegetation which contributes to the sustainability of the EEC. Whilst some impacts can be mitigated, it is likely that impacts will be localised within Sandy Creek and Laheys Creek and the EEC will recover post mining. The Project will not therefore significantly impact on the EEC.
Does the proposal affect a threatened population at the limit of its known distribution	Not applicable. Endangered Lowland Darling River aquatic ecological community is not an endangered population.
How is the proposal likely to affect current disturbance regimes?	The major processes that affect aquatic habitats and their biota in the Project area are surface water flows, runoff during rainfall events and fire. Releases of captured water from dams, drawdown of groundwater and reduction in the size of the Laheys and Sandy Creek catchments would alter natural flow regimes.
How is the proposal likely to affect habitat connectivity?	The drawdown of groundwater could lead to a reduction in the number of groundwater-dependant pools that connect to habitats upstream.
How is the proposal likely to affect critical habitat?	No critical habitats for the Lowland Darling River aquatic ecological community are listed under the *FM Act.*
Conclusion	Key threats to the endangered Lowland Darling River aquatic ecological community are the modification of natural flows, degradation of riparian habitat and the removal of instream woody debris. Whilst some impacts can be mitigated, it is likely that impacts such as reduced biodiversity will be localised within Sandy Creek and Laheys Creek and the EEC will recover post mining. Therefore, the Project will not significantly impact on the EEC in the longer term.

6 Mitigation of Impacts on Aquatic Ecology

The main issues relating to impacts on aquatic ecology to be addressed for the (i) design, (ii) construction and iii) operation of the proposed Cobbora Coal Project include:

- Alteration to natural flow regimes of rivers and streams;
- Mobilisation of sediments into waterways;
- Pollution;
- Degradation of riparian vegetation;
- Removal of large woody debris;
- Installation of instream structures; and
- Impacts on threatened species, populations and endangered communities.

Potential impacts on aquatic ecology of the Study Area and downstream reaches of the Talbragar River can be minimised with the implementation of recommended mitigation measures (see below).

6.1 Design

6.1.1 Waterway Crossings and Fish Passage

Specific guidelines for the design and construction of waterway crossings to maintain fish passage have been developed and are outlined in '*Guidelines and Policies for Aquatic Habitat Management and Fish Conservation* (Smith and Pollard 1999) and *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003). These guidelines include requirements for:

- Crossing structures appropriate for the size and type of watercourse;
- Preferred crossing designs; and
- Maintenance of fish passage throughout construction.

Appendix 2 details the criteria for assessing suitable waterway crossings that minimise obstruction to fish according to fish habitat class, based on Fairfull and Witheridge (2003). An assessment of minimum recommended crossing requirements for each site assessed in this study has been summarised in Table 7. Engineering guidelines in relation to different crossing designs are detailed in Witheridge (2002) and Fairfull and Witheridge (2003).

This information has guided the choice of the new waterway crossings over Sandy and Laheys Creeks. The bridge crossings planned as part of these road diversions would comply with guidelines for fish passage for this category of waterway and will provide effective mitigation of impacts associated with waterway crossings.

6.1.2 Dams

The Water Management Strategy (WMS) includes plans for the construction of 38 sediment dams and 9 mine water dams to capture and treat "dirty" water. The discharge or overflow points from all dams are located in close proximity to the creeks and should be designed to minimise erosion and scouring.

The number of dams, their sizes and locations should provide for the contingency treatment of water that may be required to meet discharge criteria.

Following the cessation of mining, the Proponent should remove all constructed dams and rehabilitate discharge or overflow paths to their previous profiles.

6.1.3 Sedimentation

The mobilisation of sediment into aquatic habitats within the Study Area and further downstream should be minimised through the implementation of an Erosion and Sediment Control Plan (ESCP) that encompasses construction, operational and rehabilitation stages of the Project. If treatment of water to increase settlement rates and efficiencies is to include use of flocculants, the flocculants used should be screened for toxicity to aquatic life using dilution factors that accurately reflect flocculant concentrations in the receiving water.

6.1.4 Pollution

Sediment dams have been designed and positioned to have minimal potential to cause pollution. The Water Management Plan should detail procedures that would be implemented to further treat water so that interim criteria for discharge can be met.

6.1.5 Entrainment

Extraction of water from the Cudgegong River for use in mining operations has the potential to impact on the aquatic ecology of the river by entraining adult fish, fish larvae and eggs. The key mitigation measures to minimise this impact would entail the use of screens of appropriate mesh size over the intake pipe and operate the pump such that fish can out-swim the intake current. Successful fish screening at water intakes requires the following conditions (Turnpenny *et al*. 1998):

- There must be a structure or stimulus that the fish can use to detect its approach to the intake;
- The escape velocity of the water must be within the swimming ability of the fish; and

- A suitable escape route or bypass must be provided.

The second consideration in mitigating the possibility of entrainment is the ability of native fish to swim against currents. Cotterell (1998) stated that water velocities of ≤ 0.3 m/s would facilitate passage of all native fish, but velocities >1 m/s would not. Harris and Mallen-Cooper (1994) recommended a mean water velocity of 0.3 m/s, but not exceeding 0.8 m/s for catadromous fish in south-eastern Australia. A velocity of 0.3 m/s is within the range of widely accepted fish escape criteria (Turnpenny *et al*. 1998). Reducing the flow into intake pipes or across screens would clearly help to reduce entrainment and/or impingement. In addition, the possibility of fish being drawn into the pump at start-up may be reduced if pumps are designed to start slowly and reach operational speed gradually.

Whether injury to fish can be reduced by altering the design of pumps may be largely academic if fish removed from the main stream have no way of returning to the river. Such fish are lost to the system in the same way as if they had suffered mortality.

The proposed specifications of the intake system on the Cudgegong River include the use of self-cleaning suction screens with a maximum mesh size of 1.9 mm (possibly 0.9 mm) and an intake velocity of 0.15 m/s. This would be effective for screening out adult fish, fish larvae and eggs, although the water velocity is slightly above the internationally accepted value of 0.12 m/s which provides protection for fish less than 40 mm in length (Blackley 2003). The screens will be arranged appropriately relative to stream flow (i.e. parallel or at a slight angle to the stream flow) so that most fish would be gently swept across the screen and downstream and no bypass channel would be required. No entrainment and relatively little impingement would be expected from such a system.

Excluding fish from water intakes and diversions has been achieved by using barriers which may be structural (referred to as positive barrier screens) or behavioural. Fish protection screens are designed to protect the weakest swimming species in their most vulnerable stages of development (Blackley 2003). A wide variety of barrier screens have been used in rivers and canals (NIWA 2007), including fixed and travelling screens with a variety of mesh sizes.

The proposed screening system for the Cudgegong River intake would be effective at reducing effects of entrainment and impingement, given that the pump can ramp-up gradually to the operational conditions and ramp down during any shut-down procedure. Intake velocities at the screen face should be maintained at no more than 0.12 m/s to minimise entrainment risk, which is only slightly lower than the planned 0.15 m/s specification. In addition, screens should be installed parallel with the direction of flow of the river.

6.1.6 Water Abstraction

The abstraction of water from the Cudgegong River should be done under the extraction management strategy agreed with NOW and State Water. Conformance to those criteria takes into account agreed environmental flow requirements and will minimise potential impacts on aquatic ecology related to water flow, volume and temporal flow patterns.

6.2 Construction

6.2.1 Mobilisation of Sediment into Waterways

The Surface Water Assessment makes several recommendations for minimising sediment loads in waterways onsite (Section 6.1.1 Parsons Brinckerhoff 2012a). Examples of possible mitigation measures recommended in the Surface Water Assessment include:

- Minimising clearing, particularly around flow lines, drainage lines and watercourses;
- Locating sediment traps, such as silt fences and check dams downstream of disturbed areas; and
- Providing sediment dams to capture runoff from all haul roads, where runoff is not captured in the overburden sediment dams.

In addition, the following mitigation measures are recommended during the construction phase:

- Use of coffer dams during potential instream works associated with the pipeline intake at the Cudgegong River;
- Revegetation and restoration of disturbed areas, such as the diversion channels and banks. Erosion and sediment control measures should be in place to treat run-off from these areas until adequate cover is established;
- Where possible, works should not take place within 50 m of any watercourse; and
- Fish passage should be considered where silt fences/curtains may be positioned across waterways. A permit may be required for works that require temporary blockage of fish passage.

Surface water quality monitoring should be incorporated into the Erosion and Sediment Control Plan (ESCP) with protocols in place for guideline breaches. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC (2000) trigger values for the protection of aquatic ecosystems (e.g. turbidity ranges of 2 – 25 NTU for upland rivers) can be used as thresholds to trigger mitigating management responses (e.g.

discovery and suppression of source or cessation of work). Turbidity is relatively easy to measure therefore readings could be taken daily or *in situ* data loggers used for continuous monitoring. Monitoring should take place during construction, with preconstruction sampling to provide baseline information about background patterns in turbidity.

6.2.2 Pollution

Background levels of key water quality parameters should be established prior to construction. Runoff should be monitored during construction and conform to the same interim criteria set for operational discharges from mine water and sediment dams to ensure minimisation of pollutant loads in the creeks (Parsons Brinckerhoff 2012a).

6.2.3 Degradation of Riparian Vegetation

Removal of native riparian vegetation should be minimised. Riparian vegetation is likely to be impacted during the construction of flow lines, drainage lines and any other works conducted near watercourses.

Riparian habitat disturbed during construction, along the diversion channels or in previously degraded areas should be rehabilitated by the revegetation of native riparian species and/or removal of exotic species and regeneration.

6.2.4 Removal of Large Woody Debris

Where large woody debris is encountered within an area of construction along the banks or within the watercourse, temporary relocation and re-alignment of woody debris should be the first priorities, followed by lopping. Removal of woody debris from the waterway should be adopted only as a last resort.

6.2.5 Alteration to Flow Regimes

Temporary installation of coffer dams and/or diversions in Sandy Creek and Laheys Creek during construction of crossings should be done in such a way as to maintain adequate flow.

6.3 Operation

6.3.1 Mobilisation of Sediment into Waterways

The Surface Water Assessment makes several recommendations for minimising sediment loads in waterways onsite (Section 6.1.1 in Parsons Brinckerhoff 2012a). Examples of appropriate mitigation measures include erosion and sediment controls such as bunding, silt fences/curtains, sediment basins/ponds and drains. These measures should be capable of operating effectively during high rainfall events.

The construction of 38 sediment dams over the life of the Project to intercept 'dirty' runoff from disturbed areas is proposed as one measure to minimise the discharge of water with high sediment loads into Laheys Creek (Parsons Brinckerhoff 2012a). Sediment dams should be maintained in a drawn-down state as much as practical so that sufficient capacity is available to capture run-off from subsequent rain events.

6.3.2 Pollution

Discharge from mine water and sediment dams should conform to recommended interim discharge criteria to ensure minimisation of pollutant loads in the creeks (Parsons Brinckerhoff 2012a).

Surface water quality monitoring should be incorporated into the ESCP with protocols in place for guideline breaches. The recommended interim discharge criteria are appropriate for dam releases where the volume of discharge will dilute the loads; however, these criteria should be re-evaluated should water be reused. Monitoring of water prior to release and in the receiving waters should take place during the entire operation period, with sampling undertaken immediately prior to construction to provide baseline information on parameters of concern.

6.3.3 Degradation of Riparian Vegetation

Surveys of significant components of native riparian should be undertaken periodically during the course of the Project to monitor potential impacts of flow reductions and groundwater drawdown on riparian trees and large shrubs. Should riparian vegetation show signs of degradation, a recovery plan should be developed by qualified ecologists. A range of recovery options should be proposed that consider the results of water quality monitoring in the receiving creek.

6.3.4 Removal of Large Woody Debris

It is not anticipated that removal of large woody debris will be required in the operational phase of the Project. If required, the approach taken should conform to that described in Section 6.2.4 above.

6.3.5 Alteration to Flow Regimes

To minimise potential impacts from changed hydrology, water releases should aim to mimic the historical flow regime to the extent possible, capturing seasonality in the frequency, magnitude and duration of flows, as well as the natural variability to which the native fauna are adapted.

6.3.6 Impacts on Threatened Species, Populations and Endangered Communities

Many of the potential impacts on threatened species can be mitigated by the implementation of the above recommendations. However, impacts on the local occurrences of Freshwater catfish populations and, to a lesser extent, the endangered Lowland Darling River aquatic ecological community within the Study Area are possible.

The level of entrainment and impingement of fish, their eggs and larvae during water abstraction from the Cudgegong River would be proportional to the volume of water removed from the river and density of fish, eggs and larvae present at the time.

6.3.6.1 Abstraction Volume

According to the water balance assessment (Parsons Brinckerhoff 2012a Appendix E), the number of water abstraction days each year is climate driven, with a dry climate increasing the demand for river water, and a wet climate reducing river demand due to increased onsite capture. To quantify river water demand against climate, the water balance used representative climates to determine respective annual demands. Based on the assumption that on any given day of pump operation the volume of water pumped would be 20 ML/day (corresponding to the maximum capacity of the pumps) the water balance indicates the following:

- For a 1 in 10 year dry climate scenario the maximum demand is 2,960 ML/yr requiring pump operation 41 % of the days per year;
- For a median climate scenario the maximum demand is 2,180 ML/yr requiring pump operation 30 % of the days per year;
- For a 1 in 10 year wet climate scenario the maximum demand is 520 ML/yr requiring pump operation 7 % of the days per year;

The annual 'no pumping' period is extended significantly in response to favourable (wetter) climatic conditions. Under the dry climate scenario, a substantial period exists during which there is no potential for entrainment and impingement of fish, their eggs and larvae. Because the life of the mine is 21 years, the potential exists for an extreme dry climate scenario during which the full river allocation of 3,311 ML/yr would be required. To meet this demand, pump operation would be required for some 166 days per year, or 45 % of days per year. This worst case scenario still allows for 55 % of days of the year when no pumping is required. Cognisant on acceptable seasonal timing of abstraction, the period of 'no pumping' is considered adequate to mitigate to acceptable levels the abstraction impacts on fish at various stages in their life cycles.

To mitigate potential entrainment of fish eggs, their eggs and larvae the total volume of river water pumped should minimised whenever possible with maximum on site reuse.

6.3.6.2 Seasonal Timing of Abstraction

Potential for entrainment and impingement may be further reduced by altering the timing of abstraction to avoid spawning periods or times when fish are most active. Two options are theoretically possible, namely pumping at times of day when fish are less active and/or pumping at times of year when there is minimal spawning activity. The Namoi study (Baumgartner *et al*. 2009) found no difference in fish abstraction rates between day and night, and hence the first mitigation option is likely to ineffective. The potential for seasonal adjustment of the frequency of pumping requires knowledge of which fish species are at risk of entrainment and details of their life cycles.

Threatened fish relevant to this Project all spawn in spring and summer, although the Trout cod has an extended spawning into autumn. The eggs of species such as Freshwater catfish, Murray cod and Trout cod, which are adhesive and/or negatively buoyant, are less susceptible to entrainment than those of Silver perch which are buoyant. However, the larvae of all species would be susceptible, particularly those which do not disperse, such as Freshwater catfish (Allen *et al*. 2002), as their complete removal by entrainment would lead to local extirpation of the species.

The largest mine water demand component is washing of coal. Coal washing demand is unaffected by seasonality. The next largest water demand is dust suppression. A higher portion of the 1000 ML/yr dust suppression requirement would be extracted preferentially in the warmer late spring and summer months when evaporation rates are typically higher. This period coincides with spawning of most relevant fish species. In an unregulated river system this might increase negative impacts on fish species. In the regulated Cudgegong River, spring to summer is the high irrigation demand period, and planned water releases from Windamere Dam are invoked to meet demand. The density of eggs and larvae in this season may be no different to other times of the year due to dispersion within higher river flows during the September to December period (NOW data monthly median flow data at Yamble Bridge from 1995 to 2011 a period selected as representative of current regulated river operation).

The altered flow patterns in the regulated Cudgegong River would likely counteract the potential effect of seasonal factors which might otherwise affect fish at various stages in their life cycles. As a result, no entrainment and relatively low rates of impingement of fish, their eggs and larvae are predicted as a result of the planned water abstraction from the Cudgegong River. Seasonal adjustments in pumping frequency are not required.

6.3.6.3 Daily Abstraction

Entrainment of larvae would typically be enhanced during relatively low river flow conditions as fish density may be elevated as a result of the lower water volume. However, environmental flow has been assessed and allowed for by NOW in their approval and licencing of the pumping station. An environmental flow restriction exists in CHC's Works Approval licence, stating that should flow in the Cudgegong River fall below 25 ML/day (measured at Yamble Bridge), suspension of abstraction would be required. The rates of impingement of fish, their eggs and larvae would be significantly reduced by this threshold environmental flow restriction.

In summary, no entrainment and relatively little impingement of fish, their eggs and larvae are predicted as a result of the planned water abstraction from the Cudgegong River and seasonal adjustments in pumping frequency are not required.

7 Conclusion

7.1 Existing Conditions

Key findings of field investigations of the major waterways in the Study Area, the Talbragar River and the Cudgegong River include:

- The Talbragar and Cudgegong River have been significantly degraded by agriculture, water abstraction and other uses but are classified as major fish habitat and Key Fish Habitats according the NSW classification scheme and guidelines.
- The Talbragar River is unregulated by major dams, but private dams and bores have altered natural flows.
- Historical records show an ephemeral flow pattern with flow ceasing 32 % of the time.
- The Cudgegong River has been significantly altered by regulated releases from Windamere Dam and natural flows have also been affected by private dams and bores.
- The physical characteristics of the two rivers were similar, with key features including:
  - Presence of a distinct channel
  - Banks mainly consolidated with pasture grasses and a thin strip of riparian vegetation
  - Presence of a variety of habitats including; deep pools, runs, backwater channels or anabranches, large woody debris, gravel beds, sand bars, riffles and occasional stands of macrophytes
  - Channel substratum generally composed of boulder, cobble, pebble, sand bars, and gravel beds with finer sediments accumulating in deeper pool sections
  - Poor water quality with the majority of the variables measured falling outside the ANZECC/ARMCANZ threshold limits.
- The aquatic macroinvertebrate assemblages indicated that the waterways had suffered severe pollution and/or habitat degradation.
- Invertebrate diversity within the Endangered Lowland Darling River Aquatic Ecological community was low, and no protected species within that community were collected.

- Invasive fish species had the highest abundance, diversity and distribution in these waterways and included carp, goldfish, mosquitofish and redfin perch.
- No threatened fish species were caught or observed.

Six creeks and their tributaries which drain into the Talbragar River (Sandy, Laheys, Fords, Blackheath, Patricks and Tucklan creeks) and four creeks and their tributaries that drain into the Cudgegong River (Mebul, Tallawang, Lambing Yard and Goodiman creeks) were investigated. Key findings of investigations in the major creeks and tributaries included:

- All sites had been heavily modified by regional agriculture and anthropogenic impacts.
- Surrounding land use was generally open grazing pasture with artificial structures including creek crossings.
- Private dams and bores were common and have altered natural flow by abstracting water and interrupting overland flow.
- Waterway classifications varied from moderate (Class 2 Waterway) to minimal fish habitat (Class 4 Waterway). The six creeks were mapped as Key Fish Habitat according to NSW Fisheries guidelines.
- The majority of waterways lacked surface water and aquatic macrophytes and were classified as minimal fish habitat.
- Physical characteristics included:
  - marginal or indistinct channel
  - banks mainly consolidated with pasture grasses and incomplete riparian vegetation
  - Few macrophytes
  - Large pool habitat without riffles present in low altitude, downstream locations
  - Upstream creeks ephemeral, characterised by shallow, disconnected pools and dry gullies
  - Channel substratum was cobble, pebble and sand bars with finer sediments accumulating in pool sections.
- Water quality was poor with the majority of the variables measured falling outside the ANZECC/ARMCANZ threshold limits.
- Aquatic macroinvertebrate assemblages indicated that the waterways had suffered severe pollution and/or habitat degradation.

- Invertebrate diversity within the Endangered Lowland Darling River Aquatic Ecological community was low, and no protected species within that community were collected.
- Invasive fish species had the highest abundance, diversity and distribution.
- Two individuals of the endangered western population of Freshwater catfish were observed or caught, one in each of two refuge pools in Sandy Creek (Site 5) and Laheys Creek (Site 9).

7.2 Context of Potential Impacts

The works and activities associated with the Project would take place against background ecological conditions that can be summarised as suboptimal and stressed, largely but not entirely due to past land uses. Of these uses, water abstraction represents a key stressor to aquatic ecology in waterways that are naturally ephemeral. Despite their degraded condition, the creeks adjacent to the proposed major mining areas are habitat for very small numbers of endangered Freshwater catfish, a relatively sedentary species which is adapted to turbid, saline conditions. The presence of the catfish in semi-permanent pools in Sandy and Laheys creeks demonstrates that despite the overall degraded condition of the creeks, the pools serve as valuable refuges for key aquatic species, and as such should have high priority for protection. While the invertebrate diversity within the Endangered Lowland Darling River Aquatic Ecological community was low, and no protected species within that community were collected, their presence is crucial as a supply of food resources for species such native fish.

The design and layout of mining areas have been altered through the development of the proposal to minimise impacts on the creeks. The current Project avoids complete diversion of the creeks originally proposed and has refined the water management system to maximise return of water to the creeks. Despite this, the works and activities associated with the Project have potential to further degrade biological diversity and ecological function in the Study Area's aquatic habitats. While some of the following processes operate to some extent in the existing system, the key processes associated with the Project that may impact on aquatic ecology include:

- drawdown of groundwater , altered hydrology from changes to catchment area, releases of captured water into waterways;
- habitat degradation from loss or degradation of riparian vegetation and increased and/or mobilised sediment;

- changes in frequency of riparian connectivity from predicted increase in low flow conditions; and
- changes in water quality.

Mitigation measures have been proposed for each of the above potential impacts, with the exception of groundwater drawdown. It is not possible to directly mitigate this impact, however the indirect potential impacts, may be addressed by management of freshwater dam releases. Notwithstanding this, a potential consequence of groundwater drawdown, and, to a lesser extent the reduction in annual average flow volumes is the increased frequency of drying of refuge pools under dry climatic conditions, which has potential to impact directly on the protected Freshwater catfish. Given the small number of catfish present, even a small reduction in their number would cause local extirpation of the species. In summary, the assessment of significance of potential impacts on local occurrences of endangered Murray-Darling population of Freshwater catfish indicated that, given the implementation of recommended mitigation measures, there may be small residual impact on the local population of the species which needs to be carefully monitored, with adjustments to water releases and implementation of compensation measures if required.

The assessment of significance of the Project on other listed fish species and the endangered lowland Darling River aquatic ecological community indicated that, given the implementation of mitigation measures, there would be no significant impact on these species or community.

7.3 Recommendations

- Manage clean water discharge to mimic natural pattern in flow, capturing seasonality in the frequency, magnitude and duration of flows, as well as the natural variability to which the native fauna are adapted, where possible;
- Minimise potential impacts from mobilised sediment by the implementation of sediment control measures, focussing on reduction of suspended sediments;
- Monitor the quality of dam overflow water and receiving waters to inform the Water Management Strategy and minimise impacts on aquatic habitats and biota in Sandy Creek, Laheys Creek and the Talbragar River;
- Design and build the proposed bridge crossings of Sandy and Laheys Creeks in accordance with the guidelines for the design and construction of waterway crossings to maintain fish passage within identified Class 1 and Class 2 waterways. The current approach of using bridge structures to cross the creeks will meet these criteria;

- Use appropriate-sized screens on the intake structure at the Cudgegong River extraction point to minimise entrainment (trapping) of fish eggs and larvae;
  - orientate the screens in the Cudgegong River appropriately;
  - operate pumps so as to ramp water velocity up and down gradually;
  - seek to reduce the water intake velocity to below 0.12 m/s;
  - minimise impact / removal of the native riparian vegetation; and
- Formulate an adaptable monitoring program for the population of Freshwater catfish in Sandy and Laheys Creek before, during and after Project commencement.
- Implement measures to compensate for the predicted drawdown of groundwater in groundwater-dependant semi-permanent pools and potential impact on Freshwater catfish populations.

Opportunities for implementation of specific compensation measures within the immediate catchment/ sub catchments are restricted due to the nature of the Project. A potential, achievable compensation measure that would address the specific residual impacts of the Project on aquatic ecology in general and Freshwater catfish in particular is the provision of funding to bring forward plans to upgrade weirs in the system that have been identified as barriers to fish passage. Removing barriers to fish passage in the greater Macquarie River system would assist the dispersion of fish larvae in the system and allow migrating adult fish better access to habitats and refuges in smaller creeks. Such a compensation measure would target fish biodiversity and complement existing government programs (DPI NSW 2006).

8 Acknowledgements

This report was written by Bob Hunt, Dr Peggy O'Donnell, Dr Arthur Dye, Dr Marcus Lincoln Smith and Oliver Silver. Review was undertaken by Dr Theresa Dye. Fieldwork was undertaken by Matt Harper, Bob Hunt and Oliver Silver. Laboratory work and AusRivAS analysis was done by Matt Harper. Oliver Silver and Bob Hunt created Figures and Plates. Oliver Silver created the maps.

9 References

Allen, G.R., Midgley, S.H. and Allen, M. (2002). Field *Guide to the Freshwater Fishes of Australia*. Western Australian Museum pp394.

ANZECC/ARMCANZ (2000). *Australian guidelines for water quality monitoring and reporting.* National water quality management strategy, No.7 .Prepared for: Australian & New Zealand Governments. ANZECC//ARMCANZ, Australia.

Baumgartner, L. J., Reynoldson, N. K., Cameron, L. and Stanger, J. G. (2009). Effects of irrigation pumps on riverine fish. *Fisheries Management and Ecology* **16**, 429-437.

Blackley, T. (2003). Screening Irrigation Off takes in the Murray-Darling Basin to Reduce Loss of Native Fish. In: *Downstream Movement of Fish in the Murray-Darling Basin*. Statement, recommendations and supporting papers. Workshop held in Canberra, June 2003. Eds. M. Lintermans and W. Phillips. Murray-Darling Commission, Canberra.

Bunn, S.E. and Arthington, A.H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity*. Environmental Management*, 30, pp. 492–507.

Chessman, B. C. (1995). Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* **20**, pp. 122-129.

Chessman, B. C. (2003). New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research* **54**, pp. 95-103.

Chessman, B., Growns, I., Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales. *Marine and Freshwater Research*, **48**, 159-172.

Clunie, P and Koehn, J. (2001). *Freshwater Catfish: A Resource Document*. Report for Natural Resource Management Strategy Project R7002 to the Murray Darling Basin Commission. July 2001.

Cotterell, E. (1998). *Fish passage in streams: fisheries guidelines for design of stream crossings*. Fish Habitat Guideline FHG001, Queensland Department of Primary Industries, Brisbane, Qld. 40pp.

CSIRO (2008). *Water Availability in the Macquarie-Castlereagh*. A report to the Australian Government from the CSIRO Murray-Darling Darling Sustainable Yields Project. CSIRO, Australia, 144p.

CWCMA (2007). *Central West Catchment Management Authority 2007 Annual report*. www.cw.cma.nsw.gov.au.

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2009). *Matters of National Environmental Significance Significant impact guidelines 1.1* Environment Protection and Biodiversity Conservation Act 1999, Commonwealth of Australia, Canberra.

Department of Land and Water Conservation (DLWC) (2002). *The NSW State Groundwater Dependent Ecosystems Policy*. Prepared by Department of Land and Water Conservation.

DPI NSW (2003). *Freshwater Fish Stocking in NSW - Environmental Impact Statement*. Public Consultation Document. NSW Fisheries, Cronulla, NSW. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0014/224303/STOKv1.pdf (Accessed October 2011).

DPI NSW (2005a). *Fisheries Scientific Committee – Final Determinations. Aquatic Ecological Community in the Natural Drainage System of the Lowland Catchment of the Lachlan River*. http://www.dpi.nsw.gov.au/data/assets/pdf_file/0004/208291/FR25-Lachlan-River-EEC.pdf (Accessed October 2011)

DPI NSW (2005b). *NSW DPI Primefact 8. Threatened Species in NSW. Silver Perch. Bidyanus bidyanus* .http://www.dpi.nsw.gov.au/data/assets/pdf_file/0014/5081/Primefact_Silver_perch.pdf (Accessed October 2011).

DPI NSW (2005c). *NSW DPI Primefact 10.Key Threatening Processes in NSW. Instream Structures and Other Mechanisms that Alter Natural Flows*. http://www.dpi.nsw.gov.au/data/assets/pdf_file/0016/34252/Primefact_Instream_structures.pdf (Accessed October 2011).

DPI NSW (2005d). *NSW DPI Primefact 12.Key Threatening Processes in NSW. Degradation of Native Riparian Vegetation along NSW Water Courses*.

http://www.dpi.nsw.gov.au/data/assets/pdf_file/0015/34251/Primefact_Degradation_of_Native_Riparian_Vegetation.pdfhttp://www.environment.gov.au/cgi-bin/wetlands/report.pl. Accessed 04 November 2008 (Accessed October 2011).

DPI NSW (2006). *Reducing the Impact of Weirs on Aquatic Habitat - New South Wales Detailed Weir Review*. Central West CMA region. Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

DPI NSW (2007). *NSW DPI Primefact 173.Endangered Ecological Communities in NSW. Lowland Darling River Aquatic Ecological Community.* http://www.dpi.nsw.gov.au/data/assets/pdf_file/0006/171573/Lowland-Darling-River-aquatic-ecological-community.pdf (Accessed October 2011).

DPI NSW (2012 access date) Key Fish Habitat Maps: Mid-western and Warrumbungle regions. http://www.dpi.nsw.gov.au/fisheries/habitat/publications/protection/key-fish-habitat-maps

Eldin, N.N. (2002). Road construction: Material and Methods. *Journal of Environmental Engineering*, **128**(5):423-430.

EMM (2012). Cobbora Coal Mine Project. *Terrestrial Ecology Impact Assessment*. Draft Report. For Cobbora Holding Company Pty Ltd. EMGA Mitchell McLennan.

Fairfull, S. and Witheridge, G. (2003). *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*. NSW Fisheries, Cronulla, 16 pp.

Gooderham, J and Tsyrlin, E. (2002). *The waterbug book: a guide to the freshwater macroinvertebrates of temperate Australia*. National Library of Australia Cataloguing in-Publication, CSIRO. 232pp.

Harris, J. H. and Mallen-Cooper, M. (1994). Fish passage development in the rehabilitation of fisheries in mainland south-eastern Australia. In Cowx, I. G. (Ed.) *Proceedings of the International Symposium and Workshop on Rehabilitation of Freshwater Fisheries.* Hull, April 1992.

Harris, J. H. and Gehrke, P. C. (1997). *Fish & Rivers in Stress: The NSW Rivers Survey*. NSW Fisheries, Cronulla, NSW, 298 pp.

Koehn, J.D. and Harrington, D.J. (2006). Environmental conditions and timing for the spawning of Murray cod (*Maccullochella peelii peelii*) and the endangered trout cod (*M. macquariensis*) in southeastern Australian rivers. *River Research and Applications* 22, pp. 327–342.

Koehn, J.D. and O'Connor, W.G. (1990). *Biological Information for Management of Native Freshwater Fish in Victoria*. Department of Conservation and Environment, Freshwater Fish Management Branch, Arthur Rylah Institute for Environmental Research. ISBN 0 7306 0590 6. 165 pp.

Lloyd, N., Quinn, G., Thoms, M., Arthington, A., Gawne, B., Humphries, P. and Walker, K. (2003). *Does flow modification cause geomorphological and ecological response in rivers? A literature review from an Australian perspective.* Technical report 1/2004, CRC for Freshwater Ecology.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An Introductory Guide*. Murray-Darling Basin Commission, Canberra, 157 pp.

McCormack, R., B. (2008). *The Freshwater Crayfish of NSW Australia*. Australian Aquatic Biological Pty Limited, Karuah, NSW, 138 pp.

McDowall, R. (1996). *Freshwater Fishes of South-Eastern Australia*. Reed Books, Sydney NSW, 1-247 pp.

McNeil, D.G., Westergaard, S. and Ye, Q. (2010). Chapter 2. Juvenile salinity tolerance of eight native fish species from the Lower River Murray, South Australia. In: *Influences of salinity, water quality and hydrology on early life stages of fished in the Lower River Murray, South Australia.* (Eds Q. Ye, K.J. Cheshire and D.G. McNeil) pp 48-72. (South Australian Research and Development Institute (Aquatic Sciences), Adelaide SARDI Publication No. F2009/000470-2. SARDI Research Report Series 446.).

Miles, N. (2004). The distribution and abundance of larval and juvenile fish in the Cudgegong River during the period of a pulsed bulk water transfer. School of Earth & Environmental Sciences, University of Wollongong. September 2004.

Morris, S. A., Pollard, D. A., Gehrke, P. and Pogonoski, J. J. (2001). *Threatened and Potentially Threatened Freshwater Fishes of Coastal New South Wales and the Murray-Darling Basin*. Prepared for: Commonwealth Government's Fisheries Action Program//World Wide Fund for Nature. NSW Fisheries Office of Conservation, NSW.

Murray Darling Basin Commission (2001). Upstream Downstream Fish of the Murray Darling Basin. CD ROM Prepared by The Ecology Lab Pty Lab.

Nicol, S.J., Barker, R.J., Koehn, J.D., and Burgman, M.A. (2007). Structural habitat selection by the critically endangered trout cod *Maccullochella macquariensis*). *Biological Conservation* 138, pp.30-37.

NIWA (2007). Fish Screening: Good Practice for Canterbury. NIWA Client Report CHC2007-092. Project INZ06501. pp 8-35.

NSW Department of Primary Industries (2006). *Reducing the Impact of Weirs on Aquatic Habitat – New South Wales Detailed Weir Review. Central West CMA Region*. Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

NSW DPI (2002a). Trout cod *Maccullochella macquariensis* NSW FISHERIES - FISHNOTE DF101R - ISSN 1034-7704

NSW DPI (2002b). Purple spotted gudgeon (western population) *Mogurnda adspersa* NSW FISHERIES - FISHNOTE NSWF1089 - ISSN 1034-7704

NSW DPI (2007). Recovery Plan for the Endangered River Snail (*Notopala sublineata*). NSW Department of Primary Industries.

OEH (2011a). Artesian springs ecological community - endangered ecological community listing. http://www.environment.nsw.gov.au/determinations/ArtesianSpringsEcologicalCommunityEndComListing.htm. Page updated 27 February 2011.

OEH (2011b). *Biodiversity offset principles*. Office of Environment and Heritage website http://www.environment.nsw.gov.au/biocertification/offsets.htm

Parsons Brinckerhoff. (2012a). *Cobbora Coal Mine Project: Surface Water Assessment*. Appendix E to the Environmental Assessment. PR_0082D-2162570C_Appendix E. Parsons Brinckerhoff Australia Pty Limited. June 2012.

Appendix A: *Baseline Hydrological Environment*

Appendix B: *Downstream Water Quality Impact Assessment*

Appendix C: *Downstream Flow Impact Assessment*

Appendix D: *Flood Impact Assessment*

Appendix E: *Water Balance and Surface Water Management System Report*

Parsons Brinckerhoff. (2012b). *Cobbora Coal Mine Project: Groundwater Assessment*. Appendix D to the Environmental Assessment PR_5716A_2162570A. Parsons Brinckerhoff Australia Pty Limited. June 2012.

Peterson, R.C Jr (1992). The RCE: a riparian, channel and environmental inventory for small steams in the agricultural landscape. *Freshwater Biology* ***27****, 295-306*

Preece, R. (2004). *Cold water pollution below dams in NSW: a desktop assessment*. Department of Infrastructure, Planning and Natural Resources.

Pusey, B., Kennard, M. and Arthington, A. (2004). *Freshwater Fishes of North-Eastern Australia*. CSIRO Publishing, Collingwood Vic, 684 pp.

Sheldon, F., Bunn, S.E., Hughes, J.M., Arthington, A.H., Balcombe, S.R. and Fellows, C.S. (2010). Ecological roles and threats to aquatic refugia in arid landscapes: dryland river waterholes. *Marine and Freshwater Research* **61:** 885-895.

Smith, A. K. and Pollard, D. A. (1999). *Policy and Guidelines Aquatic Habitat Management and Fish Conservation: 1999 Update*. NSW Fisheries, Port Stephens Research Centre.

Swales, S., Curran, S. and West, J. (1993). *A survey of fish resources of the Cudgegong River, April 1993.* Report to the NSW Department of Water Resources, NSW Fisheries Institute, Sydney.

Thiem, J.D., Ebner, B.C. and Broadhurst, B.T. (2008). Diel activity of the endangered Trout Cod (*Maccullochella macquariensis*) in the Murrumbidgee River. *Proceedings of the Linnean Society of New South Wales* 129, pp. 167-173.

Turak, E., Waddell, N. and Johnstone, G. (2004). *New South Wales (NSW) Australian River Assessment System (AusRivAS) Sampling and Processing Manual*. Department of Environment and Conservation (NSW).

Turnpenny, W. H., Struthers, G. and Hanson, K. P. (1998). *A UK Guide to Intake Fish Screening regulations, Policy and Best Practice.* Fawley Aquatic Research Laboratories and Hydroplan. Report ETSU H/06/00052/00/00.

Wheeler, A.P., Angermeier, P.L. and Rosenberger, A.E. (2005). Impacts of New Highways and Subsequent Landscape Urbanization on Stream Habitat and Biota. *Reviews in Fisheries Science*, **13**: 141 – 164.

Witheridge, G. (2002). *Fish Passage Requirements for Waterway Crossings – Engineering Guidelines*. Institute of Public Works Engineering, Brisbane.

10 Tables

Table 1. Aquatic ecology assessment sites within the Cobbora Study Area. (In text and appended).

Table 2. Type of sampling done within the Cobbora Study Area. (In text and appended)

Table 3. Water quality measured in situ in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines for upland watercourses in south-east Australia. (In text and appended).

Table 4. Percent (%) cover of macrophytes recorded within the 'wetted width' of the channel at each site. (appended).

Table 5. AusRivAS scores for macroinvertebrates from edge habitat in 2009 and 2011. (appended).

Table 6. Species of freshwater fish that have been recorded in the Cobbora Study Area. (appended).

Table 7. Suggested crossing drainage structures based on criteria established by Fairfull and Witheridge (2003). (appended).

Table 8. Threatened and protected aquatic species which may occur or for which suitable habitat may occur within the Study Area. (appended).

Table 9. Summary of changes in catchment areas for Sandy and Laheys Creek. (in text).

Table 10. Evaluation of groundwater dependency and predicted scale of groundwater drawdown on ephemeral pools in Sandy and Laheys Creeks. (in text).

Table 1. Aquatic ecology assessment sites within the Cobbora Study Area.

Site	Easting	Northing	Altitude (m)	Drainage	Watercourse	Fish Habitat Classification	RCE Score
1	712319	6452373	357	Talbragar River	Talbragar River	1	31
2	707396	6445239	441	Talbragar River	Sandy Creek	2	30
3	707419	6445085	357	Talbragar River	Sandy Creek	2	30
4	707660	6442670	359	Talbragar River	Sandy Creek	2	29
5	708542	6439931	373	Talbragar River	Sandy Creek	2	32
6	709237	6437522	373	Talbragar River	Sandy Creek	2/3	27
7	709071	6439734	378	Talbragar River	Laheys Creek	2	32
8	711922	6438799	395	Talbragar River	Laheys Creek	2	32
9	712009	6438685	393	Talbragar River	Laheys Creek	2	35
10	714386	6436042	407	Talbragar River	Laheys Creek	2	31
11	714960	6434887	460	Talbragar River	Laheys Creek	3	26
12	715939	6432354	458	Talbragar River	Unnamed tributary of Laheys Creek	3/4	24
13	716415	6431455	441	Talbragar River	Laheys Creek	3/4	33
14	720100	6434653	485	Talbragar River	Unnamed tributary of Fords Creek	4	26
15	722331	6434056	518	Talbragar River	Unnamed tributary of Fords Creek	4	22
16	711883	6438901	385	Talbragar River	Blackheath Creek	4	28
17	711358	6439419	388	Talbragar River	Unnamed tributary of Laheys Creek	4	23
18	729769	6434768	489	Cudgegong River	Tallawang Creek	3	32
19	717407	6434338	435	Talbragar River	Fords Creek	4	23
20	724521	6433691	536	Cudgegong River	Lambing Yark Creek	4	37
21	725399	6433559	517	Cudgegong River	Lambing Yark Creek	4	31
22	725823	6433561	517	Cudgegong River	Lambing Yark Creek	4	23
23	720086	6438392	480	Talbragar River	Patricks Creek	4	35
24	721074	6438588	495	Talbragar River	Unnamed tributary of Patricks Creek	4	33
25	720711	6445767	391	Talbragar River	Tucklan Creek	2	30
26	723792	6438959	481	Talbragar River	Tucklan Creek	4	24
27	722314	6439207	470	Talbragar River	Unnamed tributary of Tucklan Creek	4	27
28	709637	6432411	403	Talbragar River	Sandy Creek	2/3	32
32	721080	6414260	390	Cudgegong River	Cudgegong River	1	32

Site	Easting	Northing	Altitude (m)	Drainage	Watercourse	Fish Habitat Classification	RCE Score
33	720745	6414314	387	Cudgegong River	Cudgegong River	1	32
34	721739	6418020	419	Cudgegong River	Mebul Creek	3	26
35	719984	6420155	456	Cudgegong River	Unnamed tributary of Mebul Creek	3/4	20
36	719842	6421653	464	Cudgegong River	Unnamed tributary of Mebul Creek	4	21
37	719572	6421784	467	Cudgegong River	Unnamed tributary of Mebul Creek	4	29
38	719578	6421983	478	Cudgegong River	Mebul Creek	3	30
39	720038	6422204	467	Cudgegong River	Unnamed tributary of Mebul Creek	4	21
40	697099	6445760	301	Talbragar River	Talbragar River	1	31
65	719889	6427151	533	Cudgegong River	Goodiman Creek	4	33

GPS Datum: WGS 84, Grid: UTM, Position: 55
Data recorded 12/10/09 - 14/10/09 , 10/10/11 - 14/10/11 & 31/10/11 - 4/11/11.

Table 2. Type of sampling done within the Cobbora Study Area.

Site	Water Quality	RCE	Fish Habitat Classification	Macrophyte	AusRivAS	Fish and Large Mobile Macroinvertebrates		
						Bait Trap & Electrofishing	Seine Net	Plankton Net
1	•	•	•	•	•	•		
2	•	•	•	•				
3	•	•	•	•	•	•		
4	•	•	•	•	•	•		
5	•	•	•	•	•	•		
6	•	•	•	•	•	•		
7	•	•	•	•	•	•		
8	•	•	•	•				
9	•	•	•	•	•	•		
10	•	•	•	•	•	•		
11	•	•	•	•				
12		`	•	•				
13	•	•	•	•	•	•		
14*		•	•					
15		•	•					
16	•	•	•	•				
17		•	•	•				
18	•	•	•	•	•	•		
19	•	•	•	•				
20		•	•					
21		•	•					
22		•	•					
23		•	•					
24		•	•					
25	•	•	•	•				

Site	Water Quality	RCE	Fish Habitat Classification	Macrophyte	AusRivAS	Fish and Large Mobile Macroinvertebrates		
						Bait Trap & Electrofishing	Seine Net	Plankton Net
26		•	•					
27		•	•	•				
28		•	•	•				
32	•	•	•	•	•	•	•	•
33	•	•	•	•	•	•	•	•
34	•	•	•	•	•	•		
35		•	•	•				
36		•	•	•				
37		•	•	•				
38		•	•	•				
39		•	•	•				
40	•	•	•	•	•	•	•	•
65		•	•					

* RCE and Fish Habitat assessment not repeated at Site 14 in 2011 due to its proximity to a property with no access permission

Table 3. Water quality measured in situ in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines for upland watercourses in south-east Australia (see Appendix 3 for raw data).

Table 3a. Water quality measured in situ in the study area in October 2009.

Site	Conductivity (µS/cm)	pH	Dissolved Oxygen (% sat.)	Turbidity (NTU)
	30 - 350	6.50 - 8.00	90 - 110	2 - 25
1	↑	↑	↓	↑
3	↑	✓	↓	✓
6	↑	✓	↓	✓
9	↑	✓	↓	↑

Recorded by Cardno Ecology Lab 12/10/09 - 14/10/09.
↓ = below guidelines, ↑ = above guidelines, ✓ = within guidelines

Table 3b. Water quality measured in situ in the study area in October - November 2011.

Site	Conductivity (µS/cm)	pH	Dissolved Oxygen (% sat.)	Turbidity (NTU)
	30 - 350	6.50 - 8.00	90 - 110	2 - 25
1	↑	↑	↓	↑
2	↑	✓	↓	↑
3	↑	✓	↓	↑
4	↑	✓	✓	↑
5	↑	✓	↓	↑
6	↑	↑	↑	↑
7	↑	✓	✓	↑
8	↑	✓	↑	↑
9	↑	✓	✓	↑
10	↑	↑	✓	↑
11	↑	✓	↓	↑
13	↑	✓	↑	↑
16	✓	✓	↓	↑
18	✓	✓	↓	↑
19	↑	✓	✓	↑
25	✓	✓	↓	↑
32	↑	✓	↓	**na**
33	↑	✓	✓	**na**
34	↑	✓	↓	**na**
40	↑	✓	↓	**na**

Recorded by Cardno Ecology Lab 10/10/11 - 14/10/11 & 31/10/11 - 04/11/11.
↓ = below guidelines, ↑ = above guidelines, ✓ = within guidelines
na: faulty water quality probe: reading not available or unreliable

Table 4. Percent (%) cover of macrophytes recorded within the 'wetted width' of the channel at each site**.**

Family Name	Species Name	Common Name	Sites											
			1	2	3	4	5	6	7	8	9	10	11	12
Characeae	*Nitella* sp.	Stonewort						•						
Characeae	*Chara* sp.	Stonewort			•			•						
Chlorophyta (Phylum)		Unidentified green filamentous alga												
Cyperaceae	*Carex appressa*	Tussock sedge		•		*						•		*
Cyperaceae	*Bolboschoenus fluviatilis*	Marsh clubrush												
Cyperaceae	*Eleocharis acuta*	Common spike-rush											4	
Cyperaceae	*Schoenoplectus mucronatus*	Bog bulrush												
Haloragaceae	*Myriophylum* sp.	Watermilfoil												
Hydrocharitaceae	*Vallisneria americana*	Ribbonweed												
Juncaceae	*Juncus usitatus*	Common rush												
Poaceae	*Phragmites australis*	Common reed		80	20	4	•			1	2			
Polygonaceae	*Rumex crispus*	Curled dock						*					•	
Potamogetonaceae	*Potamogeton tricarinatus*	Floating pondweed												
Potamogetonaceae	*Potamogeton crispus*	Curly pondweed												
Typhaceae	*Typha orientalis*	Cumbungi			2			10	40		•	•		

introduced species

• macrophyte species is present but cover is less than 1 per cent

* macrophyte species is present but outside the wetted width of the watercourse

Table 4 (Continued). Percent (%) cover of macrophytes recorded within the 'wetted width' of the channel at each site.

Family Name	Species Name	Common Name	Sites											
			13	15	16	17	18	19	20	21	22	23	24	25
Characeae	*Nitella* sp.	Stonewort												
Characeae	*Chara* sp.	Stonewort												
Chlorophyta (Phylum)		Unidentified green filamentous alga	20				5							
Cyperaceae	*Carex appressa*	Tussock sedge	2		10									
Cyperaceae	*Bolboschoenus fluviatilis*	Marsh clubrush												
Cyperaceae	*Eleocharis acuta*	Common spike-rush	5											
Cyperaceae	*Schoenoplectus mucronatus*	Bog bulrush												
Haloragaceae	*Myriophylum* sp.	Watermilfoil												
Hydrocharitaceae	*Vallisneria americana*	Ribbonweed												
Juncaceae	*Juncus usitatus*	Common rush												1
Poaceae	*Phragmites australis*	Common reed												
Polygonaceae	*Rumex crispus*	Curled dock												*
Potamogetonaceae	*Potamogeton tricarinatus*	Floating pondweed												
Potamogetonaceae	*Potamogeton crispus*	Curly pondweed												
Typhaceae	*Typha orientalis*	Cumbungi	2											

introduced species

• macrophyte species is present but cover is less than 1 per cent

* macrophyte species is present but outside the wetted width of the watercourse

Table 4 (Continued). Percent (%) cover of macrophytes recorded within the 'wetted width' of the channel at each site.

Family Name	Species Name	Common Name	Sites											
			26	27	28	32	33	34	35	36	37	38	39	40
Characeae	*Nitella* sp.	Stonewort			•			2						•
Characeae	*Chara* sp.	Stonewort						2	40					
Chlorophyta (Phylum)		Unidentified green filamentous alga					1							
Cyperaceae	*Carex appressa*	Tussock sedge										*		
Cyperaceae	*Bolboschoenus fluviatilis*	Marsh clubrush												•
Cyperaceae	*Eleocharis acuta*	Common spike-rush												
Cyperaceae	*Schoenoplectus mucronatus*	Bog bulrush						3						
Haloragaceae	*Myriophylum* sp.	Watermilfoil					•							•
Hydrocharitaceae	*Vallisneria americana*	Ribbonweed					•							
Juncaceae	*Juncus usitatus*	Common rush												
Poaceae	*Phragmites australis*	Common reed				*	*							
Polygonaceae	*Rumex crispus*	Curled dock		*	1			*	*	*	*	*		
Potamogetonaceae	*Potamogeton tricarinatus*	Floating pondweed							2					
Potamogetonaceae	*Potamogeton crispus*	Curly pondweed				•								
Typhaceae	*Typha orientalis*	Cumbungi			•			3						

introduced species

• macrophyte species is present but cover is less than 1 per cent

* macrophyte species is present but outside the wetted width of the watercourse

Table 5. AusRivAS scores for macroinvertebrates from edge habitat in 2009 and 2011. AusRivAS band categories are: Band X = macroinvertebrate assemblage at the site is richer (more taxa) than the reference condition; Band A = assemblage is similar to the reference condition; Band B = assemblage is significantly impaired relative to the reference condition; Band C = assemblage is severely impaired relative to the reference condition; Band D = the assemblage is impoverished.

Table 5a. AusRivAS scores for macroinvertebrates from edge habitat in 2009.

Site	Watercourse	NTE50	NTP50	NTC50	OE50	E50Signal	O50Signal	OE50Signal	E0Signal	O0Signal	OE0Signal	Band
3	Sandy Creek	11	15	8	0.73	3.61	3.50	0.97	3.86	3.71	0.96	B
9	Laheys Creek	11	15	6	0.55	3.61	3.17	0.88	3.86	4.00	1.04	B

Field data collected by Cardno Ecology Lab 12/10/09 - 14/10/09.

Table 5b. AusRivAS scores for macroinvertebrates from edge habitat in 2011. Source: Field data recorded by Cardno Ecology Lab (10/10/11 - 14/10/11 and 31/10/11 - 04/11/11).

Site	Watercourse	NTE50	NTP50	NTC50	OE50	E50Signal	O50Signal	OE50Signal	E0Signal	O0Signal	OE0Signal	Band
1	Talbragar River	11	15	6	0.55	3.61	4.67	1.29	3.86	4.10	1.06	B
3	Sandy Creek	11	15	12	1.09	3.61	3.08	0.85	3.86	3.50	0.91	A
4	Sandy Creek	11	15	12	1.09	3.61	3.58	0.99	3.86	3.57	0.92	A
5	Sandy Creek	11	15	9	0.82	3.61	3.22	0.89	3.86	3.47	0.90	B
6	Sandy Creek	11	15	10	0.91	3.61	3.00	0.83	3.86	3.36	0.87	A
7	Layheys Creek	11	15	9	0.82	3.61	2.78	0.77	3.86	3.27	0.85	B
9	Layheys Creek	11	15	7	0.64	3.61	3.29	0.91	3.86	3.71	0.96	B
10	Layheys Creek	11	15	8	0.73	3.61	2.88	0.80	3.86	3.63	0.94	B
13	Layheys Creek	11	15	14	1.27	3.61	3.71	1.03	3.86	3.65	0.95	X
18	Tallawang Creek	10.95	15	7	0.64	3.62	2.57	0.71	3.92	2.80	0.71	B
32	Cudgegong River	11	15	10	0.91	3.61	3.60	1.00	3.86	3.79	0.98	A
33	Cudgegong River	11	15	12	1.09	3.61	3.58	0.99	3.86	3.96	1.03	A
34	Mebul Creek	11	15	11	1.00	3.61	3.27	0.91	3.86	3.67	0.95	A
40	Talbragar River	11	15	10	0.91	3.61	3.60	1.00	3.86	3.86	1.00	A

Field data collected by Cardno Ecology Lab 10/10/11 - 14/10/11 & 31/10/11 - 04/11/11.

Table 6. Species of freshwater fish that have been recorded in the Cobbora Study Area. Highlighted taxa are listed threatened species and populations.

Family Name	Species Name	Common Name	Lintermans (2007)			BIONET		Cardno Ecology Lab Survey (2009 & 2011)	McDowall (1996)
				Macquarie River					
			Talbragar River Catchment	Downstream of Talbragar confluence	Upstream of Talbragar confluence	Talbragar River	Cudgegong River		
Clupeidae	*Nematalosa erebi*	Bony herring		s					d^
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias				s@	c		
Galaxiidae	*Galaxias olidus*	Mountain galaxias	s	s	s				d
Galaxiidae	*Galaxias rostratus*	Flat-headed galaxias			s*				d
Retropinnidae	*Retropinna semoni*	Australian smelt	s	s	s	s	c	s	
Plotosidae	*Tandanus tandanus*	Freshwater catfish[1]	s	s	s	s	c	s	d^
Atherinidae	*Craterocephalus stercusmuscarum*	Un-specked hardyhead	s*	s			c		d^
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray-Darling rainbowfish	s*	s		s	c		d^
Chandidae	*Ambassis agassizii*	Olive perchlet[1]							d
Percichthyidae	*Macquaria ambigua ambigua*	Golden perch		s	s	s	c	s	d
Percichthyidae	*Maccullochella macquariensis*	Trout cod[2,3]		s*	s*	s@			d
Percichthyidae	*Maccullochella peelii peelii*	Murray cod[4]		s	s	s@	c		d
Terapontidae	*Bidyanus bidyanus*	Silver perch[5]		s	s*	s@	c		d
Terapontidae	*Leiopotherapon unicolor*	Spangled perch		s					d^
Gadopsidae	*Gadopsis marmoratus*	Northern river blackfish	s*	s	s	s	c		d
Gobiidae	*Philypnodon grandiceps*	Flathead gudgeon		s	s	s@	c		d
Gobiidae	*Philypnodon* sp.	Dwarf flathead gudgeon			s				
Gobiidae	*Mogurnda adspersa*	Southern purple-spotted gudgeon[3]		s*	s	s@	c		d

Family Name	Species Name	Common Name	Lintermans (2007)			BIONET		Cardno Ecology Lab Survey (2009 & 2011)	McDowall (1996)
				Macquarie River					
			Talbragar River Catchment	Downstream of Talbragar confluence	Upstream of Talbragar confluence	Talbragar River	Cudgegong River		
Gobiidae	*Hypseleotris* spp.	Carp gudgeons	s	s	s	s	c	s	d
Gobiidae	*Hypseleotris klunzingeri*	Western carp gudgeon				s	c		d
Gobiidae	*Hypseleotris* sp. [4]	Midgely's carp gudgeon							d
Gobiidae	*Hypseleotris* sp. [5]	Lake's carp gudgeon							d
Salmonidae	*Salmo trutta*	Brown trout[#]			s	s[@]	c		d
Salmonidae	*Salvelinus fontinalis*	Brook char[#]			s*	s[@]	c		
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout[#]			s	s[@]	c		d
Cyprinidae	*Cyprinus carpio*	Carp[#]	s	s	s	s	c	s	d^
Cyprinidae	*Carassius auratus*	Goldfish[#]	s	s	s	s	c	s	d
Poeciliidae	*Gambusia holbrooki*	Mosquito fish[#]	s	s	s	s	c	s	
Percidae	*Perca fluviatilis*	Redfin perch[#]			s	s[@]	c	s	d

[1] = endangered population (FM Act), [2] = endangered species (EBPC Act), [3] = endangered species (FM Act), [4] = vulnerable species (EPBC Act), [5] = vulnerable species (FM Act), [#] = introduced species.

Lintermans (2007): s = records after 1980, s* = records before 1980.

MacDowall (1996): d = published distribution in region of project area, d^ = published distribution includes the Macquarie River but in reaches downstream of Talbragar confluence.

BIONET: s = records from the Talbragar River catchment, s[@] = records from Macquarie River upstream of Talbragar River confluence, c = records from the Cudgegong River catchment (including Windamere Dam and Burrendong Dam).

Cardno Ecology Lab field survey of Talbragar River, Sandy Creek, Laheys Creek, Mebul Creek, Tallawang Creek and Cudgegong River was done on 12/10/09 - 14/10/09, 10/10/11 - 14/10/11 and 31/10/11 - 4/11/11.

Source: Field data recorded by Cardno Ecology Lab (12/10/2009 - 14/10/2009) and literature review (McDowall 1996, Lintermans 2007, NSW Government BioNet Database).

Table 7. Suggested crossing drainage structures based on criteria established by Fairfull and Witheridge (2003; see Appendix 2).

Site	Drainage	Watercourse	Fish Habitat Classification	Proposed Project Crossing Structure	Existing Drainage Structure	Suggested Drainage Structure
5	Talbragar River	Sandy Creek	2	None	Causeway	Bridge, arch structure, culvert or ford
7	Talbragar River	Laheys Creek	2	None	Causeway	Bridge, arch structure, culvert or ford
10	Talbragar River	Laheys Creek	2	None	Causeway	Bridge, arch structure, culvert or ford
16	Talbragar River	Blackheath Creek	4	Pipeline	Pipe Culvert - Quadruple	Culvert, causeway or ford
18	Cudgegong River	Tallawang Creek	3	Railway	Causeway	Culvert or ford
19	Talbragar River	Fords Creek	4	Pipeline**	Box culvert -Single	Culvert, causeway or ford
20	Cudgegong River	Lambing Yard Creek	4	Railway	Causeway	Culvert, causeway or ford
21	Cudgegong River	Lambing Yard Creek	4	Railway	Pipe Culvert - Twin	Culvert, causeway or ford
22	Cudgegong River	Lambing Yard Creek	4	Railway	Causeway	Culvert, causeway or ford
23	Talbragar River	Patricks Creek	4	None***	Pipe Culvert - Single	Culvert, causeway or ford
24	Talbragar River	Unnamed tributary of Patricks Creek	4	None***	Pipe Culvert - Single	Culvert, causeway or ford
26	Talbragar River	Tucklan Creek	4	None***	Pipe Culvert - Triple	Culvert, causeway or ford
27	Talbragar River	Unnamed tributary of Tucklan Creek	4	None***	Pipe Culvert - Single	Culvert, causeway or ford
28	Talbragar River	Sandy Creek	2/3	Road	Causeway	Bridge, arch structure, culvert or ford
34	Cudgegong River	Mebul Creek	3	Pipeline	Box Culvert - Quadruple	Culvert or ford
35	Cudgegong River	Unnamed tributary of Mebul Creek	3/4	Pipeline	Pipe Culvert - Single	Culvert or ford
36	Cudgegong River	Unnamed tributary of Mebul Creek	4	Pipeline	Pipe Culvert - Single	Culvert, causeway or ford
37	Cudgegong River	Unnamed tributary of Mebul Creek	4	Pipeline	Pipe Culvert - Single	Culvert, causeway or ford
38	Cudgegong River	Mebul Creek	3	Pipeline	Pipe Culvert - Twin	Culvert or ford
39	Cudgegong River	Unnamed tributary of Mebul Creek	4	Pipeline	Pipe Culvert - Single	Culvert, causeway or ford
65	Talbragar River	Goodiman Creek	4	Road	Pipe Culvert - Triple	Culvert, causeway or ford

** Site established downstream or upstream of proposed crossing location for logistical reasons
*** Sites that were previously associated with infrastructure and have now been superseded.

Table 8. Threatened and protected aquatic species which may occur or for which suitable habitat may occur within the Study Area.

Table 8a. Aquatic species listed under the EPBC Act

Common Name	Scientific Name	Category
i. Endangered Species		
Trout cod	*Maccullochella macquariensis*	Fish
ii. Vulnerable Species		
Murray cod	*Maccullochella peeli peeli*	Fish

Table 8b. Aquatic species listed under the FM Act

Common Name	Scientific Name	Category
i. Endangered Species		
Southern purple-spotted gudgeon	*Mogurnda adspersa*	Fish
ii. Vulnerable Species		
Silver Perch	*Bidyanus bidyanus*	Fish
iii. Endangered Populations		
Murray Darling population of freshwater catfish	*Tandanus tandanus*	Fish population
Western population of olive perchlet*	*Ambassis agassizi*	Fish population
iv. Endangered Ecological Communities		
Aquatic Ecological Community in the Natural Drainage System of the Lowland Catchment of the Darling River		Ecological community

Table 8c. Aquatic species listed under the TSC Act

Common Name	Scientific Name	Category
iv. Endangered Ecological Communities		
Artesian Springs Ecological Community**		Ecological community

* Although the historical distribution of the species included the Darling River catchment it is possible that it did not extend to the study area.

** No springs were recorded within the study area and hence no assessments for this ecological community were undertaken.

11 Figures (in text)

Figure 1. Study area regional overview.

Figure 2. Location of key project infrastructure within the PAA.

Figure 3. Location of the aquatic ecology survey sites.

Figure 3. Aquatic habitat inspections sites on Sandy Creek Road.

Figure 4. Watercourse classifications.

Figure 5. Sandy and Laheys Creek subcatchment and mine pit areas.

Figure 6. Mine pit projections.

Figure 7. Predicted changes in downstream surface water flow through the lifetime of the Project, expressed as percent change from pre-mining conditions.

Figure 8: Predicted groundwater drawdown at sites with pools on Sandy and Laheys creeks.

12 Plates

Plates 1a – 1d. Talbragar River, Site 1, facing upstream (a) 2009 (b) 2011. Talbragar River, Site 1, facing downstream of pool habitat (c) 2009 (d) 2011.

Plates 2a – 2d. (a) Talbragar River, Site 1, 2009 (a) Yabby (*Cherax destructor*) burrowed into damp sediment underneath woody debris (b) Freshwater mussel shell found on river bed. Talbragar River, Site 40, 2011 facing (c) upstream (d) downstream.

Plates 3a – 3d. Sandy Creek, Site 6, facing upstream (a) 2009 (b) 2011. Sandy Creek, Site 3, facing downstream of pool habitat (c) 2009 (d) 2011.

Plates 4a – 4d. Laheys Creek, Site 9, 2009 (a) Carp (*Cyprinus carpio*) (b) Freshwater catfish (*Tandanus tandanus*). Cudgegong River, Site 32, 2011 (c) Carp gudgeons (*Hypseleotris* sp.). Sandy Creek, Site 28, 2011 (d) Freshwater snake necked turtle (*Chelodina longicollis).*

Plates 5a – 5d. Laheys Creek, Site 13, adjacent the proposed south pit, facing upstream (a) 2009 (b) 2011. Sandy Creek, Site 5, facing upstream (c) 2009 (d) 2011.

Plates 6a – 6d. Laheys Creek, 2009, upstream of the confluence with Sandy Creek, facing downstream (a) Site 7 (b) Site 8. Laheys Creek, Site 9, facing downstream (c) 2009 (d) 2011.

Plates 7a – 7d. Mebul Creek, 2011 (a) Site 34 facing downstream. (b) Site 38 facing upstream. Tucklan Creek, 2011 facing downstream (c) Site 25 (d) Site 26.

Plates 8a – 8d. Cudgegong River, Site 32, 2011 (a) upstream of new pipeline location (b) Freshwater prawn (*Macrobrachium* sp.). Cudgegong River, Site 33, 2011 (c) upstream of superseded pipeline location (d) Yellow Belly (*Macquaria ambigua ambigua*).

Plates 9a – 9d. Blackheath Creek, Site 16, 2011 (a) Triple-pipe box culvert creek crossing (b) facing downstream. Tallawang Creek, Site 18, 2011 facing (c) upstream (d) downstream.

Plates 10a – 10d. (a) Lambing Yard Creek, Site 20, 2011, facing upstream (b) Lambing Yard Creek, Site 22, 2011 facing downstream. Ford's Creek, Site 19, 2011, facing (c) upstream (d) downstream.

Plates 11a – 11d. Talbragar River, Site 1, 2009 standing water containing (a) carp (*Cyprinus carpio*) (b) freshwater turtle (*Emydura macquarii*). Laheys Creek, site 13, 2011 (c) within-channel fence, secured by metal sheets (d) facing downstream.

Plates 12a – 12d. Goodiman Creek, Site 65, 2011, facing (a) upstream (b) downstream. Patricks Creek, Site 23, 2011, facing (c) upstream (d) downstream.

(a)

(b)

(c)

(d)

Plates 1a – 1d. Talbragar River, Site 1, facing upstream (a) 2009 (b) 2011. Talbragar River, Site 1, facing downstream of pool habitat (c) 2009 (d) 2011.

(a)

(b)

(c)

(d)

Plates 2a – 2d. (a) Talbragar River, Site 1, 2009 (a) Yabby (*Cherax destructor*) burrowed into damp sediment underneath woody debris (b) Freshwater mussel shell found on river bed. Talbragar River, Site 40, 2011 facing (c) upstream (d) downstream.

(a)

(b)

(c)

(d)

Plates 3a – 3d. Sandy Creek, Site 6, facing upstream (a) 2009 (b) 2011. Sandy Creek, Site 3, facing downstream of pool habitat (c) 2009 (d) 2011.

(a)

(b)

(c)

(d)

Plates 4a – 4d. Laheys Creek, Site 9, 2009 (a) Carp (*Cyprinus carpio*) (b) Freshwater catfish (*Tandanus tandanus*). Cudgegong River, Site 32, 2011 (c) Carp gudgeons (*Hypseleotris* sp.). Sandy Creek, Site 28, 2011 (d) Freshwater snake necked turtle (*Chelodina longicollis).*

(a)

(b)

(c)

(d)

Plates 5a – 5d. Laheys Creek, Site 13, adjacent the proposed south pit, facing upstream (a) 2009 (b) 2011. Sandy Creek, Site 5, facing upstream (c) 2009 (d) 2011.

(a) (b) (c) (d)

Plates 6a – 6d. Laheys Creek, 2009, upstream of the confluence with Sandy Creek, facing downstream (a) Site 7 (b) Site 8. Laheys Creek, Site 9, facing downstream (c) 2009 (d) 2011.

(a)

(b)

(c)

(d)

Plates 7a – 7d. Mebul Creek, 2011 (a) Site 34 facing downstream. (b) Site 38 facing upstream. Tucklan Creek, 2011 facing downstream (c) Site 25 (d) Site 26.

(a)

(b)

(c)

(d)

Plates 8a – 8d. Cudgegong River, Site 32, 2011 (a) upstream of new pipeline location (b) Freshwater prawn (*Macrobrachium* sp.). Cudgegong River, Site 33, 2011 (c) upstream of superseded pipeline location (d) Yellow Belly (*Macquaria ambigua ambigua*).

(a)

(b)

(c)

(d)

Plates 9a – 9d. Blackheath Creek, Site 16, 2011 (a) Triple-pipe box culvert creek crossing (b) facing downstream. Tallawang Creek, Site 18, 2011 facing (c) upstream (d) downstream.

Plates 10a – 10d. (a) Lambing Yard Creek, Site 20, 2011, facing upstream (b) Lambing Yard Creek, Site 22, 2011 facing downstream. Ford's Creek, Site 19, 2011, facing (c) upstream (d) downstream.

(a)

(b)

(c)

(d)

Plates 11a – 11d. Talbragar River, Site 1, 2009 standing water containing (a) carp (*Cyprinus carpio*) (b) freshwater turtle (*Emydura macquarii*). Laheys Creek, site 13, 2011 (c) within-channel fence, secured by metal sheets (d) facing downstream.

Plates 12a – 12d. Goodiman Creek, Site 65, 2011, facing (a) upstream (b) downstream. Patricks Creek, Site 23, 2011, facing (c) upstream (d) downstream.

13 Appendices

Appendix 1. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman *et al*. (1997).

Appendix 2. Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003).

Appendix 3. Raw data for water quality measured in situ in the study area.

Appendix 4. Field data for fish and mobile macroinvertebrate sampling.

Appendix 5. Raw data for fish and large macroinvertebrate taxa caught by electrofisher within the study area.

Appendix 6. Raw data for fish and large macroinvertebrate taxa caught by seine net within the study area.

Appendix 7. Total number of fish and large macroinvertebrate taxa caught by bait traps at each site within the study area.

Appendix 8. Fish larvae caught by plankton net within the study area.

Appendix 1. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman *et al*. (1997).

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		**8. Riffle / pool sequence**	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		**9. Retention devices in stream**	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		**10. Channel sediment accumulations**	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		**11. Stream bottom**	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		**12. Stream detritus**	
Banks fully stabilised by trees, shrubs etc	4	Mainly unsilted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		**13. Aquatic vegetation**	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and	1

Descriptor and category	Score	Descriptor and category	Score
		algal growth	
7. Channel form			
Deep: width / depth ratio < 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio > 15:1	2		
Artificial: concrete or excavated channel	1		

Appendix 2. Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003).

Classification	Characteristics of Waterway Type	Minimum Recommended Crossing Type
Class 1 – Major Fish Habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge, arch structure or tunnel.
Class 2 – Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and / or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford.
Class 3 – Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora present).	Culvert, causeway or ford

Appendix 3. Raw data for water quality measured *in situ* in the study area.

Appendix 3a. Raw data for water quality measured *in situ* in the study area in October 2009.

Site	Replicate	Temperature (°C)	Conductivity (ms/cm)	Conductivity (us/cm)	Salinity (ppt)	pH	ORP (mV)	Dissolved Oxygen (% sat.)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Turbidity (NTU)	Turbidity (NTU)	Alkalinity
1	1	14.38	0.70	547	0.33	8.29	168	29.1	3.0	388.0	392.0	404.0	ns
	2	14.37	0.70	551	0.33	8.23	168	30.2	3.1	537.0	538.0	538.0	
3	1	14.77	3.90	3313	2.06	7.50	162	40.0	4.0	17.9	18.1	18.0	400
	2	14.77	3.90	3316	2.06	7.50	162	39.7	4.0	16.0	16.1	16.2	
6	1	21.12	3.90	3371	2.05	7.14	155	60.7	5.3	0.4	0.4	0.4	ns
	2	21.17	3.90	3374	2.08	7.13	145	61.1	5.4	0.4	0.4	0.4	
9	1	17.54	4.50	3834	2.37	7.94	166	62.9	6.0	31.9	31.8	31.9	450
	2	17.49	4.40	3815	2.37	7.97	165	63.4	5.9	31.5	31.2	31.1	

Recorded by Cardno Ecology Lab 12/10/09 - 14/10/09.

Appendix 3b. Raw data for water quality measured *in situ* in the study area in October 2011.

Site	Replicate	Temperature (°C)	Conductivity (ms/cm)	Conductivity (us/cm)	Salinity (ppt)	pH	ORP (mV)	Dissolved Oxygen (% sat.)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Turbidity (NTU)	Turbidity (NTU)	Alkalinity	Specific Conductance (ms/cm)
1	1	16.23	0.59	686	0.30	8.21	434	87.1	8.6	600.0	600.0	600.0	150	ns
	2	16.22	0.59	686	0.30	8.21	434	86.8	8.6	600.0	600.0	600.0		ns
2	1	15.13	1.30	1476	0.68	7.89	449	88.4	8.9	360.3	351.3	353.0	110	ns
	2	15.11	1.34	1471	0.68	7.88	450	88.7	8.9	356.5	349.5	351.3		ns
3	1	14.70	1.31	1447	0.67	7.73	476	72.3	7.3	434.1	460.0	434.3	105	ns
	2	14.62	1.31	1454	0.67	7.76	475	72.0	7.3	433.0	429.6	427.6		ns
4	1	16.30	1.40	1531	0.71	7.98	422	94.8	9.3	370.0	372.2	370.4	105	ns
	2	16.32	1.40	1535	0.71	7.98	424	94.8	9.3	367.5	370.4	365.2		ns
5	1	13.70	1.70	1851	0.85	7.95	459	88.2	9.1	224.4	219.1	215.7	100	ns
	2	13.56	1.65	1853	0.85	7.97	459	88.0	9.2	241.7	217.4	226.1		ns
6	1	18.13	1.11	1230	0.56	8.14	434	117.0	11.0	285.2	274.4	293.3	105	ns
	2	18.11	1.11	1231	0.56	8.15	430	116.8	10.9	287.0	288.7	274.8		ns
7	1	16.03	1.94	2065	0.98	7.86	435	105.8	10.4	200.0	201.7	203.5	125	ns
	2	16.02	1.89	2066	0.98	7.87	434	104.5	10.2	200.0	203.5	200.0		ns
8	1	18.79	1.91	2031	0.98	7.91	413	120.5	11.1	165.2	163.5	167.0	105	ns
	2	18.76	1.91	2035	0.98	7.91	415	119.8	11.1	158.3	160.0	158.3		ns
9	1	15.33	1.88	2052	0.97	7.82	447	98.9	9.8	153.0	154.0	151.3	100	ns
	2	15.28	1.88	2060	0.97	7.84	448	97.5	9.8	153.0	154.8	156.5		ns

Site	Replicate	Temperature (^oC)	Conductivity (ms/cm)	Conductivity (us/cm)	Salinity (ppt)	pH	ORP (mV)	Dissolved Oxygen (% sat.)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Turbidity (NTU)	Turbidity (NTU)	Alkalinity	Specific Conductance (ms/cm)
10	1	15.72	2.30	2072	1.19	8.05	440	105.8	10.5	167.0	168.7	177.4	125	ns
	2	15.68	2.30	2471	1.19	8.07	440	105.0	10.4	167.0	173.2	165.2		ns
11	1	14.70	1.26	1421	0.64	7.70	421	84.6	8.5	29.6	27.8	29.6	ns	ns
	2	14.70	1.26	1415	0.64	7.65	415	84.1	8.5	27.6	27.8	29.6		ns
13	1	16.70	1.68	1831	0.86	7.50	425	119.7	11.6	33.0	34.8	33.0	125	ns
	2	16.68	1.68	1826	0.86	7.51	425	118.2	11.5	33.0	34.8	36.5		ns
16	1	12.00	0.19	255	0.10	6.86	171	1.5	0.1	600.0	600.0	600.0	ns	ns
	2	11.87	0.19	254	0.10	6.85	163	1.3	0.1	600.0	600.0	600.0		ns
18	1	16.80	0.04	111	0.02	7.01	390	56.9	5.6	600.0	600.0	600.0	125	ns
	2	16.74	0.08	111	0.04	6.96	391	56.5	5.4	600.0	600.0	600.0		ns
19	1	21.65	3.16	3282	1.66	7.88	425	100.9	8.8	57.4	53.9	53.7	ns	ns
	2	21.67	3.15	3285	1.66	7.89	425	100.6	8.6	53.9	59.1	57.4		ns
25	1	16.30	0.04	112	0.04	7.11	378	65.6	6.4	600.0	600.0	600.0	ns	ns
	2	16.27	0.08	117	0.02	7.00	381	64.7	6.4	600.0	600.0	600.0		ns
32	1	20.41	ns	ns	0.44	7.61	221	92.7	8.1	na	na	na	ns	0.82
	2	19.87	ns	ns	0.43	7.69	225	81.5	7.3	na	na	na		0.82
33	1	18.46	ns	ns	0.43	7.68	255	81.4	7.3	na	na	na	119	0.82
	2	18.22	ns	ns	0.43	7.71	258	107.9	9.2	na	na	na		0.82
34	1	16.88	ns	ns	1.23	7.78	328	52.8	5.0	na	na	na	230	2.28
	2	16.94	ns	ns	1.23	7.75	326	56.7	5.6	na	na	na		2.32

Site	Replicate	Temperature (°C)	Conductivity (ms/cm)	Conductivity (us/cm)	Salinity (ppt)	pH	ORP (mV)	Dissolved Oxygen (% sat.)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Turbidity (NTU)	Turbidity (NTU)	Alkalinity	Specific Conductance (ms/cm)
40	1	21.21	ns	ns	0.62	7.86	312	78.1	6.9	na	na	na	260	1.19
	2	22.98	ns	ns	0.63	7.89	310	79.4	6.8	na	na	na		1.19

Recorded by Cardno Ecology Lab 10/10/11 - 14/10/11 and 31/10/11 - 04/11/11.

ns: not sampled - attribute not available on water quality probe used

na: faulty water quality probe: reading not availabe or unreliable

Appendix 4. Macroinvertebrate taxa found in the pool edge habitat sampled at nine sites in the Study Area.

Order or Family	2009 Sites		2011 Sites														SIGNAL2 Score
	3	9	1	3	4	5	6	7	9	10	13	18	32	33	34	40	
Ancylidae							1							1			4
Atyidae	6	5	6	7	8	10	4	5	4	10	1	3	8	10	5	4	3
Baetidae	3		1	2	2			1	1		2			1			5
Caenidae	9			7	7	10	10	6	2	2	2		10	3	5	2	4
Ceratopogonidae	1	2					1	1	2	1	2				1	2	4
Chironomidae/Chironominae	10	10		8	4	10	7	5	4	6	3	2	6	3	10	5	3
Chironomidae/Orthocladiinae			1	1	2	1	3	4	7		4		2	3			4
Chironomidae/Tanypodinae	7	4		2	2	1	4				1	1	4	2	6	3	4
Cladocera	8			2	10	4					10		1	2			
Coenagrionidae	1	9	1	4	5	3	1	3		7	2		2	4	10		2
Copepoda		10	2	5	10	2		1	2	10	10	10	1			1	
Corixidae			5	4	10	2	4		1	5	3	4		10	2	10	2
Curculionidae								1									2

Order or Family	2009 Sites		2011 Sites														SIGNAL2 Score
	3	9	1	3	4	5	6	7	9	10	13	18	32	33	34	40	
Dugesiidae					1		2										2
Dytiscidae	6	10		1		1	2	4	1	1	6	7	1		10		2
Ecnomidae						1				1	5			1		1	4
Elmidae		3												1			7
Gerridae													1	1			4
Gomphidae											1						5
Gyrinidae	1	1			1						2		2	1	1	1	4
Hemicorduliidae (=Corduliidae)	3	2					3	2			1				10	2	5
Hydracarina		1		1	1	1		1	1	4			2	2	2		6
Hydraenidae (= Limnebiidae)	4															3	3
Hydrometridae				1	1				1			1					3
Hydrophilidae				8	6			3		2	2			1	1	3	2
Hydropsychidae																1	6
Hydroptilidae				8	10	6	4	4	3	2	5			1		3	4
Hypogastruridae		1										1					

Order or Family	2009 Sites		2011 Sites														SIGNAL2 Score
	3	9	1	3	4	5	6	7	9	10	13	18	32	33	34	40	
Isostictidae			1										1				3
Leptoceridae	3	3	4	8	4	3	1			3	1		1	6	3	5	6
Leptophlebiidae			1		2						7		9	5	10	1	8
Lestidae								1			2						1
Libellulidae													2				4
Nematoda							2	1									3
Nepidae				1				1				1		1			3
Notonectidae		2		1	1	2	1	1		2	3	6	2	2	1	1	1
Oligochaeta	8	10		1	3	1	2	5				4				1	2
Ostracoda	10	5		10	5	4	5	5	3	10	10	3	5	1	3	2	
Palaemonidae			1										1	1		5	4
Parastacidae			1	1			1			1	1		1	1	2	1	4
Physidae	3			4	1		7	3					1	8	5		1
Planorbidae								1			2						2
Protoneuridae				1										1			4

Order or Family	2009 Sites		2011 Sites														SIGNAL2 Score
	3	9	1	3	4	5	6	7	9	10	13	18	32	33	34	40	
Pyralidae					2			1									3
Scirtidae (= Helodidae, Cyphonidae)	2	3		1	2			2		2	1						6
Simuliidae						1	6	3	5								5
Stratiomyidae					5	1	3	1	1		1						2
Telephlebiidae (=Aeshnidae)		1		1													9
Tetragnathidae														1			
Tipulidae							2										5
Veliidae											3	1				1	3
Number of Taxa	17	18	11	25	25	19	23	26	15	17	28	13	21	27	18	22	
SIGNAL grade	3.6	4.3	4.1	3.6	3.5	3.4	3.3	3.1	3.6	3.5	3.6	2.6	3.7	3.9	3.6	3.8	
Total Number of Taxa																	51
Overall SIGNAL grade																	3.8

Appendix 5. Raw data for fish and large macroinvertebrate taxa caught by electrofisher within the study area.

			Fish							Macroinvertebrates		
Year	**Site**	**Replicate Shot**	**Freshwater catfish**	**Golden perch**	**Carp gudgeons**	**Carp#**	**Goldfish#**	**Mosquito fish#**	**Redfin perch#**	**Yabby**	**Freshwater prawn**	**Freshwater shrimp**
2009	1	1				23				2		•
	3	1			10	2	1	3				•
	9	1	1		35	1						•
2011	1	1			2			2		2	2	•
		2			4		4	4		2	2	•
		3			2	1	8	2				•
	3	1			1			3		1		•
		2										•
	4	1						8				•
		2			1			12				•
	5	1	1**		6			3			2	•
		2			2							•
	6	1				1		11		3		•
		2				2		17				•
	7	1						6				•
		2			1			7				•
	9	1						4				•
		2						5				•
	10	1			3							•
		2			1	1		3		1		•
	13	1								1		•
		2								5		•
	18	1								7		•
		2			5					3		•
	32	1			1					2	3	•
		2			1			15		2	3	•
		3*		1	1	6			1	1		•
	33	1*		1		10			1	1	1	•

			Fish							Macroinvertebrates		
Year	**Site**	**Replicate Shot**	**Freshwater catfish**	**Golden perch**	**Carp gudgeons**	**Carp#**	**Goldfish#**	**Mosquito fish#**	**Redfin perch#**	**Yabby**	**Freshwater prawn**	**Freshwater shrimp**
	34	1			1			30		2		•
		2			2			3		7		•
	40	1			1			1		1	2	•
		2			2			5		1	6	•
		3*				9						•

Each replicate shot had a cumulative duration of 120 seconds of active electrofishing at 120 Hz and 100 volts, with the exception of the replicates marked with an asterix (*).

The duration of these shots was much longer (~1600 seconds) as the intention was not to provide a comparable (with other sites) replicate shot but to exhaustively fish a larger reach of the river beyond the AusRivAS site boundaries.

introduced species

• Species present. Freshwater shrimp numbers were not measured as they were very abundant and this level of resolution was not necessary for the EA.

** fish observed but not caught

Appendix 6. Raw data for fish and large macroinvertebrate taxa caught by seine net within the study area.

Scientific Name	Common Name	Year	2011					
		Site	32		33		40	
		Replicate Shot	1	2	1	2	1	2
Fish								
Retropinna semoni	Australian smelt		1		3		9	1
Hypseleotris spp.	Carp gudgeons						4	3
Gambusia holbrooki	Mosquito fish #					1	1	1
Macroinvertebrates								
Cherax destructor	Yabby					1	4	1
Macrobrachium sp.	Freshwater prawn						1	4
Atyiidae (Family)	Freshwater shrimp	•	•	•	•	•	•	•

• Species present

Appendix 7. Total number of fish and large macroinvertebrate taxa caught by bait traps at each site within the study area. Five bait traps (*n* = 5) were deployed at each site with a fishing time of approximately 18 hrs.

Scientific Name	Common Name	Year	2011													
		Site	1	3	4	5	6	7	9	10	13	18	32	33	34	40
Fish																
Hypseleotris spp.	Carp gudgeons			2		5				1			1	8	1	
Gambusia holbrooki	Mosquito fish[#]			1			2								1	
Macroinvertebrates																
Cherax destructor	Yabby		3				9		3	2	1				11	1
Macrobrachium sp.	Freshwater prawn		2			1							2	5		14
Atyiidae (Family)	Freshwater shrimp		•	•	•	•	•	•	•	•	•	•	•	•	•	•

[#] introduced species

• Species present.

Appendix 8. Fish larvae caught by plankton net within the study area.

Scientific Name	Common Name	Year	2011				
		Site	**32**	**33**	**32 & 33***	**40**	
		Replicate Shot	**1**	**1**	**1**	**1**	**2**
Fish							
Retropinna semoni	Australian smelt				7		•
Fish eggs - unknown species							
Macroinvertebrates							
Oligochaeta (Class)	Segmented worm		•	•			
Platyhelminthes (Phylum)	Flatworm					•	
Hirudinaea (Class)	Leech					•	•
Bivalvia (Class)	Bivalve		•				
Gastropoda (Class)	Snail		•	•		•	•
Arachnida (Class)	Spider		•	•		•	•
Cladocera (Order)	Waterfleas		•	•		•	•
Ostracoda (Class)	Seed shrimp					•	
Copepoda (Subclass)	Copepods		•				
Atyiidae (Family)	Freshwater Shrimp		•	•		•	•
Lepidoptera (Order)	Aquatic caterpillars						•
Mecoptera (Order)	Scorpionfly larvae		•	•		•	•
Coleoptera (Order)	Beetles		•	•		•	•
Diptera (Order)	Flies		•	•		•	•
Hemiptera (Order)	True bugs		•	•		•	•

* Fish larvae removed from AusRivAS (dip net) and Seine Net samples from Site 32 and Site 33

• taxa present (not quantified)