Report

Red Hill Mining Lease

Aquatic Ecology Technical Report

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Prepared for

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42627136

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Abbreviations

Abbreviation	Description
ANOSIM	analysis of similarity
BMA	BM Alliance Coal Operations Pty Ltd
BRM	Broadmeadow Underground Mine
CHPP	coal handling and preparation plant
DERM	Department of Environment and Resource Management
EC	electrical conductivities
EHP	Department of Environment and Heritage Protection
EIANZ	Environment Institute of Australia and New Zealand
EIS	Environmental Impact Statement
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
GMS	Goonyella Middle Seam
GPS	Global Positioning System
GRM	Goonyella Riverside Mine
MDS	Multi-Dimensional Scaling
MIA	mine industrial area
ML	mining lease
MLA	mining lease application
PET	Plecoptera Ephemeroptera Trichoptera
RHM	Red Hill Mine
TDS	total dissolved solids
URS	URS Australia Pty Ltd

Units	Definition
^{o}C	degrees celsius
>	greater than
<	less than
Cumecs	cubic metres per second
L	litre
m	metre
mg/L	milligrams per litre
µg/L	microgram per litre
mm	millimetre
µm	micrometre
µS/cm	microsiemens per centimetre (at 25^{o}C)

Executive Summary

A field assessment of the aquatic habitat was undertaken in May 2011 for the Red Hill Mining Lease (the project). This assessment characterised the degree of impact, significance of impact, management and mitigation, resulting net impact and makes recommendations to avoid or mitigate impacts. The ecological impact assessment criteria is in keeping with intent of the recent Environment Institute of Australia and New Zealand draft guidelines for ecological impact assessment (EIANZ 2010).

Objectives of the 2011 aquatic survey were to:

- document the fish and invertebrate fauna of the environmental impact statement (EIS) study area, with particular reference to the occurrence of endangered, vulnerable, rare or significant fauna;
- provide an assessment of spatial and temporal patterns in biological assemblages;
- review existing aquatic fauna data for the EIS study area and surrounds;
- identify conservation significant or poorly known species;
- identify any occurrences of exotic aquatic fauna in the EIS study area;
- identify habitat requirements for conservation significant or noteworthy species; and
- discuss potential impacts and mitigation measures for the EIS.

In situ water quality results indicated elevated electrical conductivity at some sites unaffected by mining activity suggesting localised salinity and other measured parameters suggest anthropogenic impacts in the wider catchment use. A total of 40,231 macroinvertebrates from 48 taxa were collected from the 12 sites sampled in the EIS study area. A total of 2,909 fish from 7 species were collected across the EIS study area. No exotic species were collected in the survey and no fish collected exhibited any signs of disease.

Changes to the ecosystem in the wider catchment have been associated with historical land management and prioritisation of land use. Vegetation clearing for grazing, modification of streams for water infrastructure and mining appear to have impacts on the larger catchment which in turn impact on aquatic ecosystems.

The aquatic fauna assemblages surveyed in 2011 indicate the observed taxa are resilient and opportunistic species. Many of the macroinvertebrates are highly mobile and will readily inhabit newly inundated waters. Fish exhibit breeding strategies associated with intermittent streams where populations rapidly increase upon the availability of favourable conditions. Primarily connectivity of waterways and therefore flow are the driving forces behind the maintenance of these populations.

Subsidence in the Isaac River and tributaries through the proposed mining activity has been identified as contributing to the re-establishment of deep pools in the EIS study area. If these pools retain water they will in the short term create refuge habitat for both macroinvertebrates and fish during the dry season and this is deemed a beneficial outcome for the aquatic fauna.

With continued monitoring and appropriate management strategies that ensure waterway connectivity and the management of water quality the project is not expected to have a significant detrimental impact upon the aquatic fauna in the EIS study area. Additionally, habitat restoration such as the provision of buffered and restored riparian habitat, would aid in the maintenance or increase of the ecological integrity of the EIS study area and wider catchment.

Introduction

The Red Hill Mining Lease is located adjacent to the existing Goonyella, Riverside and Broadmeadow (GRB) mine complex in the Bowen Basin, approximately 20 kilometres north of Moranbah and 135 kilometres south-west from Mackay, Queensland.

BHP Billiton Mitsubishi Alliance (BMA), through its joint venture manager, BM Alliance Coal Operations Pty Ltd, proposes to convert the existing Red Hill Mining Lease Application (MLA 70421) to enable the continuation of existing mining operations associated with the GRB mine complex. Specifically, the mining lease conversion will allow for:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM).
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM).
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRM.

The three project elements described above are collectively referred to as 'the project'.

1.1 The Project

The key project infrastructure includes:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM). Key aspects include:
  - No new mining infrastructure is proposed other than infrastructure required for drainage of incidental mine gas (IMG) to enable safe and efficient mining.
  - Management of waste and water produced from drainage of IMG will be integrated with the existing BRM waste and water management systems.
  - The mining of the Broadmeadow extension is to sustain existing production rates of the BRM and will extend the life of mine by approximately one year.
  - The existing BRM workforce will complete all work associated with the extension.
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM). Key aspects include:
  - underground mining associated with the RHM underground expansion option to target the Goonyella Middle Seam (GMS) on mining lease (ML) 1763;
  - a new mine industrial area (MIA);
  - a coal handling and preparation plant (CHPP) adjacent to the Riverside MIA on MLA1764 and ML1900 − the Red Hill CHPP will consist of up to three 1,200 tonne per hour modules;
  - construction of a drift for mine access;
  - a conveyor system linking RHM to the Red Hill CHPP;
  - associated coal handling infrastructure and stockpiles;
  - a new conveyor linking product coal stockpiles to a new rail load-out facility located on ML1900; and

   - means for providing flood protection to the mine access and MIA, potentially requiring a levee along the west bank of the Isaac River.
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRB mine complex to target the GMS on MLA70421, as well as development of key infrastructure including:
   - a network of bores and associated surface infrastructure over the underground mine footprint for mine gas pre-drainage (IMG) and management of goaf methane drainage to enable the safe extraction of coal;
   - the proposed mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south.
   - a ventilation system for the underground workings;
   - a bridge across the Isaac River for all-weather access. This will be located above the main headings, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply;
   - a new accommodation village (Red Hill accommodation village) for the up to 100% remote construction and operational workforces with capacity for up to 3,000 workers; and
   - potential production capacity of 14 million tonnes per annum (mtpa) of high quality hard coking coal over a life of 20 to 25 years.

1.2 Aims and Objectives

An assessment of the aquatic habitat was undertaken in May 2011 to characterise the aquatic ecological values present as a basis for determining the degree and significance of impact of the proposed project and identify management and mitigation measures, resulting net impact and recommendations. The ecological impact assessment criteria is in keeping with the intent of the recent Environment Institute of Australia and New Zealand draft guidelines for ecological impact assessment (EIANZ 2010).

Objectives of the 2011 aquatic survey were to:

- Document the fish and invertebrate fauna of the EIS study area, with particular reference to the occurrence of endangered, vulnerable, rare or significant fauna;
- Provide an assessment of spatial and temporal patterns in biological assemblages;
- Review existing aquatic fauna data for the EIS study area and surrounds;
- Identify conservation significant or poorly known species;
- Identify any occurrences of exotic aquatic fauna in the EIS study area;
- Identify habitat requirements for conservation significant or noteworthy species; and
- Discuss potential impacts and mitigation measures for the EIS,

1.3 Previous Studies

Ecological surveys of the Goonyella Riverside area were undertaken during 1998, 2001 and 2005 by WBM Oceanics and by FRC in 2009. The 1998 survey examined a range of components including terrestrial vegetation, terrestrial vertebrate fauna and fish. In July 2001 an ecosystem health assessment of waterbodies within and immediately adjacent to the Goonyella Riverside area was completed using aquatic fauna as biological indicators. One of the recommendations of this report

1 Introduction

was that further investigations be undertaken to gain an appreciation of the characteristics of aquatic communities that would utilise the study area during the wet season (WBM Oceanics 2001); this was completed in February 2005. The 2009 study was completed to assess the ecological value of the aquatic habitat, to identify significant species and habitat, and to discuss potential impacts and mitigation measures arising from future development.

Methods

2.1 EIS Study Area

The project is situated in the upper reaches of the Isaac River catchment in east-central Queensland, within the Bowen Basin, where Moranbah is the closest town. At the Department of Environment and Heritage Protection (EHP) (formerly Department of Environment and Resource Management (DERM)) stream gauge located at Goonyella Rail Bridge, the Isaac River drains a catchment area of 1,215 km^2. The catchment upstream of the Isaac River and MacKenzie River junction is approximately 22,000 km^2. The catchment falls within the Subtropical, distinctly dry winter climatic zone. The Isaac River and its tributaries are seasonally intermittent streams dominated by surface water runoff. The average annual rainfall in the Isaac River catchment was 535 mm for the period 1889 to 2011 (Bureau of Meteorology unpublished data). Highest rainfalls occur between November and March. The mean monthly rainfall is highest in January and lowest in September.

The study area contains several ephemeral streams, which form a series of discontinuous pools during low flow periods. The largest stream is the Isaac River, which has its headwaters upstream of the EIS study area. The Isaac River forms a major tributary of the Fitzroy River, which discharges into the Coral Sea near Rockhampton.

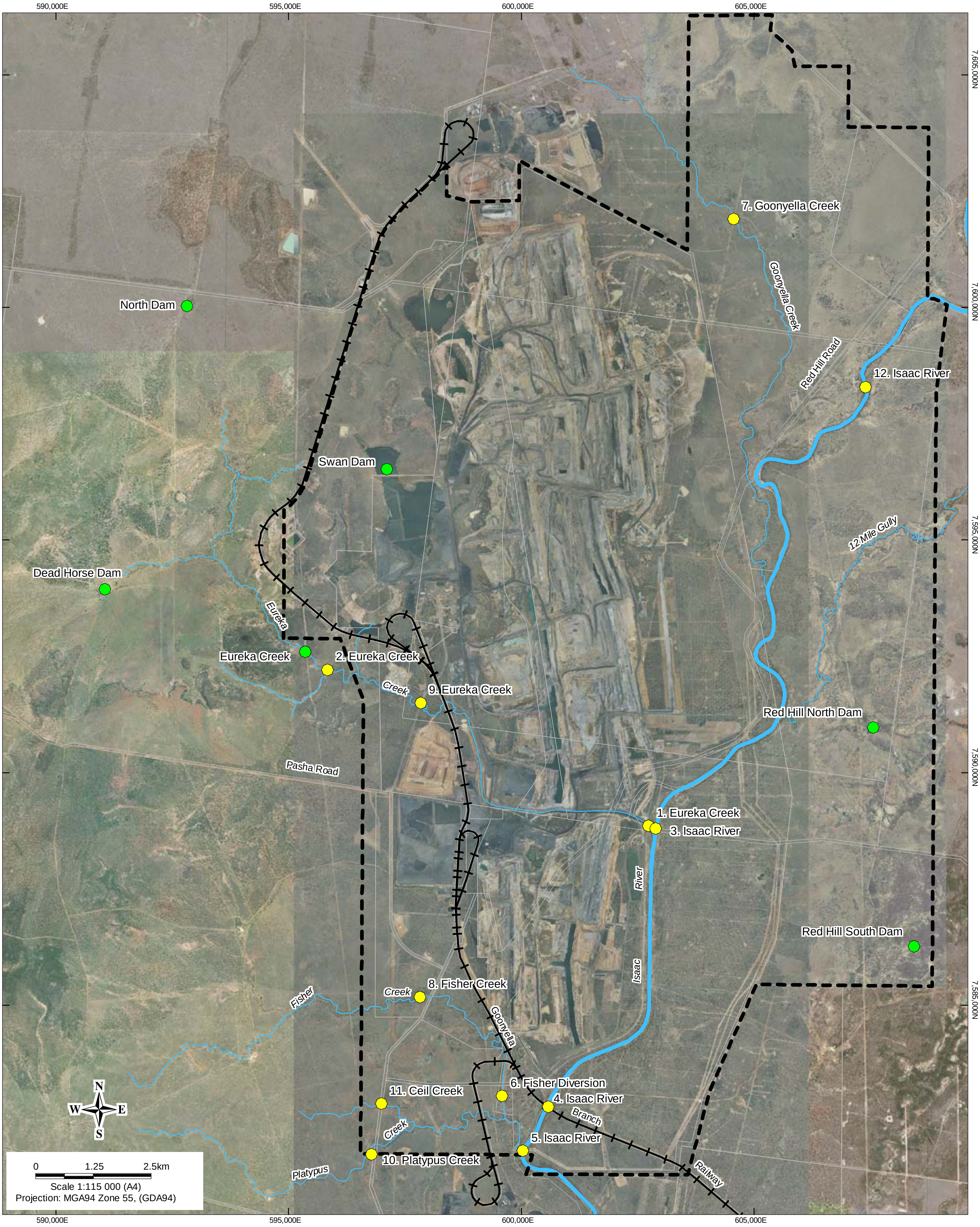
Additionally prior to catchment clearing and subsequent erosion, the Isaac River has been described as having large reed-surrounded pools (Leichhardt 1847).

2.2 Site Selection

In addition to sites examined on the Isaac River, five tributaries of the Isaac River (Eureka, Goonyella Platypus, Fisher and Ceil Creeks) were also examined in this study (**Figure 2-1**). Site locations were selected taking into account sites previously surveyed to ensure temporal comparisons of the data, and to ensure reference conditions were sampled. In a limited number of cases, site selection was constrained by the absence of water. For the purposes of this report the area covered by the sampling sites is called the survey area. This is a wider area than the EIS study area.

Eureka Creek is the largest local tributary of the Isaac River and runs in a roughly north-south direction joining the Isaac River in the southern portion of the EIS study area. The majority of this waterway is upstream of potential mine impacts and has been extensively impacted by cattle grazing. The development of GRM necessitated the diversion of part of Eureka Creek. This section of the waterway is now located in a corridor within the active mining operation and is used to transport mine water to the GS4A dam on Eureka Creek. Releases from the GS4A dam operations occur when the environmental authority release criteria are satisfied. The reaches of the Isaac River immediately downstream of the Eureka Creek confluence also consist of an excavated channel constructed by stream diversion works (the Isaac River diversion). Platypus, Fisher and Ceil Creeks are situated in the southern end of the EIS study area, have historically received isolated volumes of mine affected water through diversions and are also disturbed through cattle grazing. Goonyella Creek is in the north of the study area and is potentially affected by Goonyella North Mine operated by Peabody Energy. 12 Mile Gully is located in the east of the site.

Mine water management is addressed in detail in Section 7 of the Red Hill Mining Lease EIS.



EIS Study Boundary

Aquatic Sampling Site (2011)

Aquatic Sampling Site (2009)

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BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
AQUATIC ECOLOGY TECHNICAL REPORT

AQUATIC ECOLOGY STUDY SITES

AQUATIC ECOLOGY

Figure: **2-1**

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2.3 Site Condition

Sampling was completed between 24 and 27 May 2011 (**Table 2-1**).

Table 2-1 Location of Aquatic Ecology Sampling Sites (UTM)

Site	Type	Waterway	Site Name	Easting	Northing	Sampled
1	I	Eureka Ck	d/s of Causeway	602615.0	7588680.0	25/05/2011
2	C	Eureka Ck	Upstream control	595839.0	7592209.0	24/05/2011
3	B	Isaac R.	u/s Eureka Ck	602885.0	7588802.0	25/05/2011
4	I	Isaac R.	Rail Crossing	600580.0	7582824.0	25/05/2011
5	I	Isaac R.	Near Platypus confluence	600031.6	7581875.2	25/05/2011
6	B	Fisher Ck	Fisher Diversion	599473.0	7582873.0	24/05/2011
7	R	Goonyella Ck	Broadmeadow	604563.0	7601899.0	26/05/2011
8	R	Fisher Ck	Upstream of Main Road	597822.0	7585183.0	26/05/2011
9	B	Eureka Ck	Middle reach	597837.0	7591499.0	24/5/2011
10	R	Platypus Ck	Goonyella Rd	596778.1	7581804.4	27/05/2011
11	R	Ceil Ck	Goonyella Rd	596997.5	7582886.1	27/05/2011
12	C	Isaac R.	Riverside Station	607390.0	7598290.0	25/05/2011

Note: Site Type: I potential impact from existing mine, B background -other impacts in catchment apart from existing mine, R reference condition - typical landuse, C control site.

Sites were not sampled earlier than May due to lack of access. At the time of sampling, all streams exhibited minimal flow or had retreated to isolated pools. Signs of recent flow was evident at all sites examined on the Isaac River although hyporheic flow is expected between isolated pools. Minimal flow was also evident on all sites examined in Eureka Creek. Water within the remaining tributaries was restricted to isolated pools; no flow was evident.

Sampling was completed at the end of a long wet season after extensive rainfall that had occurred each wet season since 2007, which followed a prolonged drought from 2001 to 2006 (**Figure 2-2**). In 2011, little rainfall fell post mid-February with only occasional daily totals above zero millimetres.

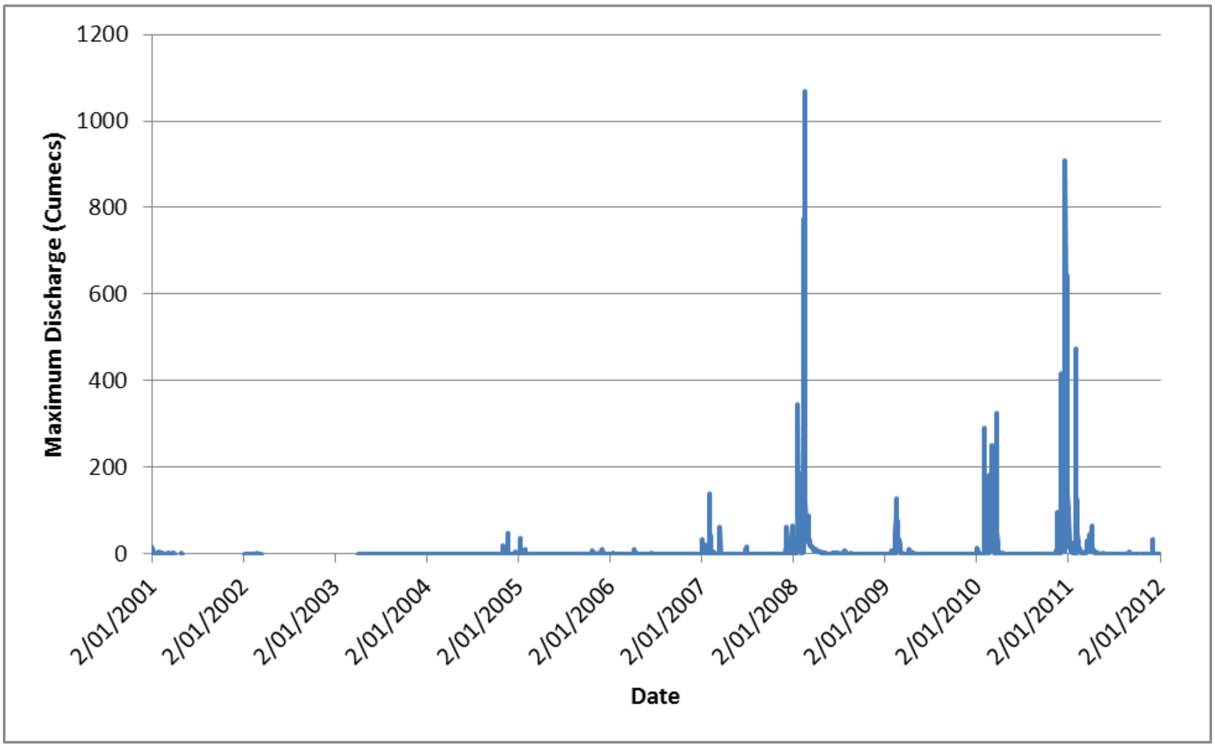

Figure 2-2 Maximum Discharge (Cumecs) Isaac River at Goonyella (from EHP)

2.4 Macroinvertebrates

Macroinvertebrates were collected over a 10 m stretch of edge habitat at each site using sweep nets with a 250 μm mesh size. The 10 m distance was necessarily continuous to ensure that all habitat structures were sampled. Edge habitat is defined as the bank area of pools where little or no current is evident. Sampling involved vigorously sweeping the net through the water column and above the substrate resulting in macroinvertebrates being suspended in the water column before being collected with the net. Any aquatic vegetation or snags in edge habitats were sampled in a similar manner.

The sweep net contents were emptied into a 20 L bucket for elutriation. The elutriated contents were poured through a 250 μm mesh sieve. This process was repeated a minimum of three times to ensure all organic material had been separated from the coarse sand. The contents of the sieve were then preserved in 1 L containers in 80% ethanol after larger plant material was washed and discarded. Before disposing of the remaining sediment, the substrate was examined for molluscs and other heavier bodied fauna.

A quantitative assessment of the fauna was completed to allow comparison with historic data. Quantitative data was achieved by sub-sampling the contents using a sub-sampler similar in design to that described by Marchant (1989). A minimum of 10 per cent of the sample was examined unless the sample was particularly abundant and the maximum sorting time was four hours. At the completion of sub-sampling the remaining portion of the sample was scanned for any additional taxa. Any taxa found in the scan were recorded separately and only added to overall abundances at after multiplying the sub-sampled abundance by the inverse of the percentage examined.

With the aid of a stereomicroscope, macroinvertebrates were identified to family taxonomic resolution with the exception of Chironomidae (Diptera) which were identified to sub-family, and Mites and Oligochaetes to order, in accordance with AusRivAS protocols.

2.5 Fish

Fish were surveyed after the completion of the macroinvertebrate monitoring at each of the 12 sampling sites. Fish were collected using a Smith Root Backpack Electrofisher and followed the *Guideline—Activities in a watercourse, lake or spring associated with a resource activity or mining operations* (DERM 2010) protocols which included a maximum water depth of below the operator's crotch height. Additionally electrofishing was completed when the electrical conductivity at the site was below the electrofisher's maximum operating range of 1,500 µS/cm. Electrofishing was initially conducted in the most downstream area and the survey began in a crisscross pattern in an upstream direction using a single pass. Where fish were not able to be collected in the dip net, for example due to them being caught under a snag or within a crevice, the fish were still recorded and noted as "sighted only".

Where water depth prevented a crisscross pattern being used the upstream direction was conducted along one bank and the downstream direction on the opposite bank. Electrofishing was conducted under Queensland Fisheries permit number 147070.

Extreme care was taken to limit the shocking time for each fish to reduce the potential for electrofishing induced injuries resulting from extended or repeated exposure. Once shocked, the fish were immediately removed to a water filled bucket with lid.

Where the electrical conductivity was above 1,500 µS/cm a seine net of 15 m length, 2 m drop and 5 mm mesh was hauled across the site. Typically the net was dragged length ways along the site, however at some sites (e.g. Goonyella Creek) the net was dragged across the width of the pool at three separate locations to avoid snags and other course woody debris.

At all sites 10 bait traps were deployed overnight to see if additional taxa were collected.

Taxonomic identifications were confirmed using taxonomic references such as Allen *et al* (2002). Total fish lengths were completed for the first 50 individuals of a species at each site. At the completion of the sampling and the recording of the fish community structure, all native fish were released back to their habitat.

2.6 Habitat and Water Quality

Site characteristics were recorded on habitat sheets provided online by the Queensland Government Department Natural Resources River Bioassessment Program. Summaries of the site characteristics are presented in **Appendix A**. This included measurements of mean depth, mean channel width, substrate composition, riparian characteristics, presence of trailing bank vegetation and over hanging bank. Sites were also examined for periphyton, moss, filamentous algae, macrophytes, detritus and snag habitat, however as these entire habitat structures at all sites were less than 10 per cent, giving a categorical value of 0, they are not presented. Photographs of all sites were taken and are presented in **Appendix B**.

Water quality was measured immediately upon arriving at the site; prior to the fauna surveys. Water quality (temperature, dissolved oxygen, electrical conductivity) was measured with a calibrated

AquaRead – Global positioning System (GPS) Aquameter multi parameter meter. Turbidity was measured using a HACH Turbidimeter, model 2100Q. Alkalinity was measured using a HACH alkalinity titration kit, model 1451-00.

Water testing was conducted only to provide contextual information for aquatic habitat conditions at the time of sampling rather than any attempt to characterise water quality. The DERM *Monitoring and Sampling Manual, Environmental Protection (Water) Policy, 2009* guidelines require the medium of multiple samples to determine compliance with water quality objectives and therefore any single reading captured in this analysis does not indicate compliance or non-compliance. Water quality in the surveyed streams is discussed in the Red Hill Mining Lease EIS Appendix I8.

2.7 Data Analysis

2.7.1 Biotic Indices

For macroinvertebrate data the total number of taxa, total abundances, SIGNAL '95, SIGNAL 2 and PET scores were determined for all sites.

The biotic index SIGNAL (Stream Invertebrate Grade Number – Average Level) (Chessman 1995, 2003) was determined for the families at each site. Families of aquatic invertebrates have been assigned pollution sensitivity grades based on their known sensitivity to a variety of pollution types. The resulting average value, or SIGNAL, can vary between 1 and 10 and can be used to assess a site's status in terms of water quality. For SIGNAL 95 a site with typically high water quality will have a SIGNAL value (>6) and a site with probable severe pollution would have a low value (<4). The health grades produced using SIGNAL 95 do not apply to the average site score produced for SIGNAL 2. SIGNAL 95 and SIGNAL 2 (Chessman 2003) provide different views of the data and together provide for an interpretation of water quality from observed biota.

SIGNAL 2 scores (Chessman 2003) are also presented as allocated scores are provided for a greater range of taxa. Weighting of the abundances was not completed as the weight factor is derived for qualitative samples using rapid bioassessment sampling techniques. Note that the grades for SIGNAL 95 do not apply to SIGNAL 2. Characterisation of sites is based on plotting SIGNAL 2 against taxa richness and there position in the resultant graph determines what impact is occurring. For example, a reference site should have a high SIGNAL 2 value and a high richness and indicate favourable habitat and chemically dilute waters. Sites with high taxa richness and low SIGNAL 2 indicate salinity or nutrient impacts. Sites with low taxa richness and high SIGNAL 2 indicate toxic pollution, harsh physical conditions or inadequate sampling. Sites with low taxa richness and low SIGNAL 2 usually indicate urban, industrial or agricultural pollution, or downstream effects of dams.

PET scores is another index based on the pollution sensitivity of macroinvertebrates. Three insect orders, Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies) are known to be more sensitive to pollution compared to other orders. The number of families within each order observed at a site is summed to provide the PET score. Generally the higher the PET scores the higher the habitat and water quality rating.

For fish data the species richness and abundances were calculated for each site.

2.7.2 Multivariate Statistics

All multivariate analyses were completed using the Primer 6 software package (Clark and Gorley 2006). For both macroinvertebrate and fish community data multidimensional scaling (MDS) was used to create two dimensional plots based on site by site similarity matrices using the Bray-Curtis similarity measure. These plots are essentially a graphical representation of the degree of similarity between the macroinvertebrate or fish assemblages of sites. Sites with similar communities will be closer together on an MDS plot than sites with different community structure. Bubble plots are also superimposed over the sites representing taxa richness and abundance where larger circles imply higher values.

Given only 2 of the 12 sites were considered as control sites, an analysis of similarity (ANOSIM) was not completed as there was not enough power in the survey design to assess differences between control and test sites.

Results and Comparisons with Historic Data

This section summarises the results of water quality samples; macroinvertebrate composition, biotic indices and spatial distribution; and fish community composition and spatial distribution based purely on taxa richness and abundance. Macroinvertebrate and fish results are compared with historic data.

3.1 Water Quality

Water temperature varied between sites from 12.2°C at Platypus Creek (site 10) to 22.3°C at Fisher Diversion (site 6) (**Table 3-1**). Variation in the temperature can largely be attributed to the time of day the temperature was recorded, the depth of the water, isolation of the site and finally the extent of shading by banks and overhanging riparian vegetation. For example, the site at Platypus Creek was sampled in the morning before peak temperatures would be seen, the mean depth was 0.3 m however a deep pool with water deeper than 1 m was present, the stream was flowing and extensive riparian vegetation was present. In Fisher Creek upstream of the diversion the water flow was limited and shallow over boulders that would aid in warming the water.

Single spot electrical conductivity readings varied from 280 µS/cm at the upstream control site on Eureka Creek (site 2) to 5,521 µS/cm at Eureka Creek downstream of the Causeway (site 1) (**Table 3-1**). Releases from the GRB water management system via Eureka Creek had not occurred in the week prior to the survey (Ben Stewart, *pers. comm*). Repeat measurements are required to assess the validity of these readings.

Electrical conductivities of 2,521 µS/cm and 3,706 µS/cm were observed on Eureka Creek middle reach (site 9) and Fisher Diversion (site 6) each of which is not affected by mining activity suggesting that locally elevated salinities are not uncommon in the area. Further details on water quality sampling, refer to the Red Hill Mining Lease EIS Appendix I8.

Ceil Creek (site 11), Fisher Creek (site 8) and Platypus Creek (site 10) had similar electrical conductivity readings with variation expected to be only partially attributable to the degree of evaporation of the isolated pools and the subsequent increase in salt concentration. Sites 3, 4 and 5 on the Isaac River had similar electrical conductivity to the Isaac River control site (site 12). Goonyella Creek (site 7) exhibited a relatively high reading of 2,062 µS/cm suggesting effects of evaporation, possible discharges from the Goonyella North Mine and/or localised erosion of sodic soils. Salt concentration is expected to increase as the isolated pool evaporates.

Table 3-1 Water Quality

Site #	Waterway	Water Temp (°C)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Alkalinity (mg/L CaCo3)
1	Eureka Creek	18.8	5,521	8.81	6.24	36	440
2	Eureka Creek	17.4	280	7.15	3.62	152	120
3	Isaac River	19.5	752	8.70	6.77	22	160
4	Isaac River	20.7	909	8.68	7.18	5	160
5	Isaac River	14.1	883	8.55	5.12	5	180
6	Fisher Diversion	22.3	3,706	8.67	7.66	136	140

Site #	Waterway	Water Temp (°C)	Electrical Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Alkalinity (mg/L $CaCo_3$)
7	Goonyella Creek	12.8	2,062	8.68	4.89	234	380
8	Fisher Creek	17.4	239	7.93	4.33	512	120
9	Eureka Creek	18.5	2,476	7.44	3.29	38	120
10	Platypus Creek	12.2	446	7.44	4.53	387	80
11	Ceil Creek	14.3	515	7.58	3.31	629	140
12	Isaac River	14.5	857	8.43	5.45	114	180

pH varied between sites from 7.15 to 8.81. The background site on the Isaac River at Riverside (site 12) had pH of 8.43 near the upper range of the guidelines for the Upper Isaac River of between 6.5 and 8.5 (DERM, 2009b). This is consistent with findings of the Red Hill Mining Lease EIS Surface Water Quality Report – Appendix I8) suggesting the Isaac River catchment naturally has slightly alkaline pH under low flows.

Dissolved oxygen concentrations were low at most sites. Only the Fisher Diversion had a dissolved oxygen concentration above the lower limit of the DERM (2009b) guidelines for the protection of aquatic ecosystems (85-110%). Dissolved oxygen concentrations were low at the control sites, 3.62 mg/L at Eureka Creek (Site 2) and 5.45 mg/L at Isaac River at Riverside (site 12). This suggests that the readings are due to broadscale effects such as the low flows during the sampling period, the decomposition of organic material, and perhaps other landuse activities such as cattle grazing.

Turbidity levels were generally above the DERM (2009b) guideline of <50 NTU although it is acknowledged that turbidity can vary greatly within a site over time. Of note is that the turbidity of the control sites was higher than that observed at other sites within the same stream. The alkalinity was fairly consistent across the catchment with the exceptions of higher alkalinity at Goonyella Creek and also at Eureka Creek downstream of the causeway. The causeway is expected to contribute to elevated readings while there appears to be potential impact occurring at Goonyella Creek relating to the mining activity or localised erosion.

3.2 Macroinvertebrates

3.2.1 Results

A total of 40,231 individuals from 48 taxa were collected from the 12 sites sampled in the survey area (refer to **Table 3-2** and **Appendix C**). Diptera dominated the abundances, followed by *Ephemeroptera*, *Trichoptera* and *Coleoptera* and *Hemiptera*. Chironominae (Diptera) were the dominant taxa, representing 27 per cent of the total number of macroinvertebrates and were present at all sites examined. Baetidae (*Ephemeroptera*) were the next most abundant taxa representing 27 per cent of the total number. Other abundant taxa included Tanypodinae (Diptera, 10.3 per cent), Caenidae (*Ephemeroptera*, 10.3 per cent) and Leptoceridae (*Trichoptera*, 6.3 per cent). Water mites, Mollusca and Crustacea were in low abundances. Diptera were the most diverse family with 13 taxa recorded, followed by Hemiptera and Coleoptera with 8 taxa each.

3 Results and Comparisons with Historic Data

The highest abundances and taxa richness were recorded from Isaac River near the confluence with Platypus Creek (site 5) (**Table 3-2**). Ceil Creek (site 11) and Isaac River at Rail Crossing (site 4) also had high taxa richness with 28 taxa. The least abundant site was Goonyella Creek (site 7) with 195 individuals although this included 17 taxa. Fisher Diversion contained the least number of taxa (13) probably reflecting the impacts of channelisation and removal of natural habitat.

The biotic index SIGNAL (Stream Invertebrate Grade Number – Average Level) (Chessman 1995 and 2003) was determined for the families at each site. Families of aquatic invertebrates have been assigned pollution sensitivity grades based on their known sensitivity to a variety of pollution types. The resulting average value, or SIGNAL, can vary between 1 and 10, and can be used to assess a site's status in terms of water quality. For SIGNAL 95 a site with typically high water quality will have a high SIGNAL value (greater than six) and a site with probable severe pollution would have a low value (smaller than 4). The health grades produced using SIGNAL 95 do not apply to the average site score produced for SIGNAL 2. SIGNAL 95 and SIGNAL 2 (Chessman 2003) provide different views of the data and together provide for an interpretation of water quality from observed biota.

SIGNAL 95 scores were relatively consistent across all sites with an average of 5.1. Eureka Creek downstream of the Causeway (site 1) showed the most impact with the lowest SIGNAL 95 score of 4.8. This combined with scores between 4 and 5 for Eureka Creek (site 2) and Fisher Creek (site 8), indicates probable moderate pollution (**Table 3-2**). The highest SIGNAL 95 score of 5.5 was evident at Isaac Creek upstream of Eureka Creek (site 3).

The Stream Invertebrate Grade Number – average level – 2 (SIGNAL 2) index uses a simple scoring system to provide an indication of water quality and ecosystem health (Chessman, 2003). When used in conjunction with taxa richness, SIGNAL 2 can provide an indication of the types of pollution and other physico-chemical factors that are influencing macroinvertebrate community structure and function. SIGNAL 2 scores were calculated for each site and it was established that the 'health' rating of sites changes order. Fisher Diversion (site 6) and the Isaac River at the Railway crossing (site 4) exhibit the highest average score and the least impact with a score of 3.9. All sites ranged between 3.2 and 3.9. Eureka Creek downstream of the Causeway (site 1) and Fisher Creek (site 8) exhibited the most impact with a SIGNAL 2 score of 3.2.

Based on the SIGNAL 2 characterisation plot developed by Chessman (2003) where SIGNAL 2 score is plotted against taxa richness, Fisher Diversion (sites 6), Isaac River upstream of Eureka Creek (site 2) and Goonyella Creek (site 7) may fall into Chessman's (2003) "industrial or agricultural pollution category". In this case these results are expected to reflect potential mining and/or grazing activity on water quality. All other sites are expected to reflect higher salinity levels. Refer to **Section 2.6.1** for a definition of the indices.

PET scores is another index based on the pollution sensitivity of macroinvertebrates. Three insect orders, Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies) are known to be more sensitive to pollution. The number of families within each order observed at a site is summed to provide the PET score. Generally, a higher PET score indicates better quality habitat and water quality.

PET scores, which indicate the presence of sensitive taxa, were highest at Isaac River at Rail Crossing (site 4) where 7 of the target taxa were collected (**Table 3-1**). The lowest PET was recorded from Platypus Creek (site 10) indicating poor water quality.

3 Results and Comparisons with Historic Data

Table 3-2 Macroinvertebrate Indices

Site	Waterway	Total Abundance	Taxa Richness	SIGNAL 95	SIGNAL 2	PET
1	Eureka Creek	2 996	27	4.8	3.2	4
2	Eureka Creek	2 904	22	4.9	3.5	5
3	Isaac River	3 910	17	5.5	3.8	5
4	Isaac River	4 630	28	5.0	3.9	7
5	Isaac River	11 626	33	5.2	3.5	6
6	Fisher Diversion	2 091	13	5.2	3.9	3
7	Goonyella Creek	195	17	5.4	3.7	3
8	Fisher Creek	1 632	21	4.9	3.2	3
9	Eureka Creek	5 374	25	5.2	3.5	4
10	Platypus Creek	987	19	5.3	3.3	2
11	Ceil Creek	842	28	5.0	3.4	4
12	Isaac River	3 044	24	5.3	3.7	4

Figure 3-1 shows the results of MDS ordination. Circles labelled 40 and 60 indicate the separation of sites into groups according the level of similarity between observed taxa (40% or 60% respectively). The numbers are site numbers and are consistent in **Figure 3-1a, b** and **c**. **Figure 3-1b** and **Figure 3-1c** show taxa richness and abundance respectively. The size of bubble indicates the relative richness or abundance of that site compared with all other sites.

Stress = 0.09 corresponds to a good ordination with no real prospect of misleading interpretation (Clarke and Warwick 2001). The sites restricted to isolated pools (Fisher Creek (site 8), Ceil Creek (site 11), Platypus Creek (site 10) and Goonyella Creek (site 7)) form one cluster while the remaining sites macroinvertebrate community structures, which include the control sites are more similar and form the other cluster (**Figure 3-1a**). Taxa richness does not appear to be separating the two clusters (**Figure 3-1b**). However, sites with lower abundances are in the right of the ordinal space (**Figure 3-1c**). Sites in the cluster with higher abundances include all sites in Isaac Creek and Eureka Creek in addition to Fisher Diversion. The macroinvertebrate community structure of the Isaac River at Riverside control site (site 12) has a similarity of above 60 per cent with the Isaac River upstream of Eureka Creek (site 3), Railway Crossing (site 4) and Eureka Creek middle reach (site 9) downstream of mining activities.

In summary, the MDS ordination indicates that the diversity (richness) of macroinvertebrate taxa is similar between sites, but there are reduced numbers (abundance) of macroinvertebrates at sites with isolated pools - possibly due to predation, available resources (e.g. food) or habitat. Sites downstream of mining activity have similar macroinvertebrate communities to reference sites indicating that macroinvertebrates abundance is currently more significantly influenced by habitat than water quality. This is discussed further in **Section 4**.

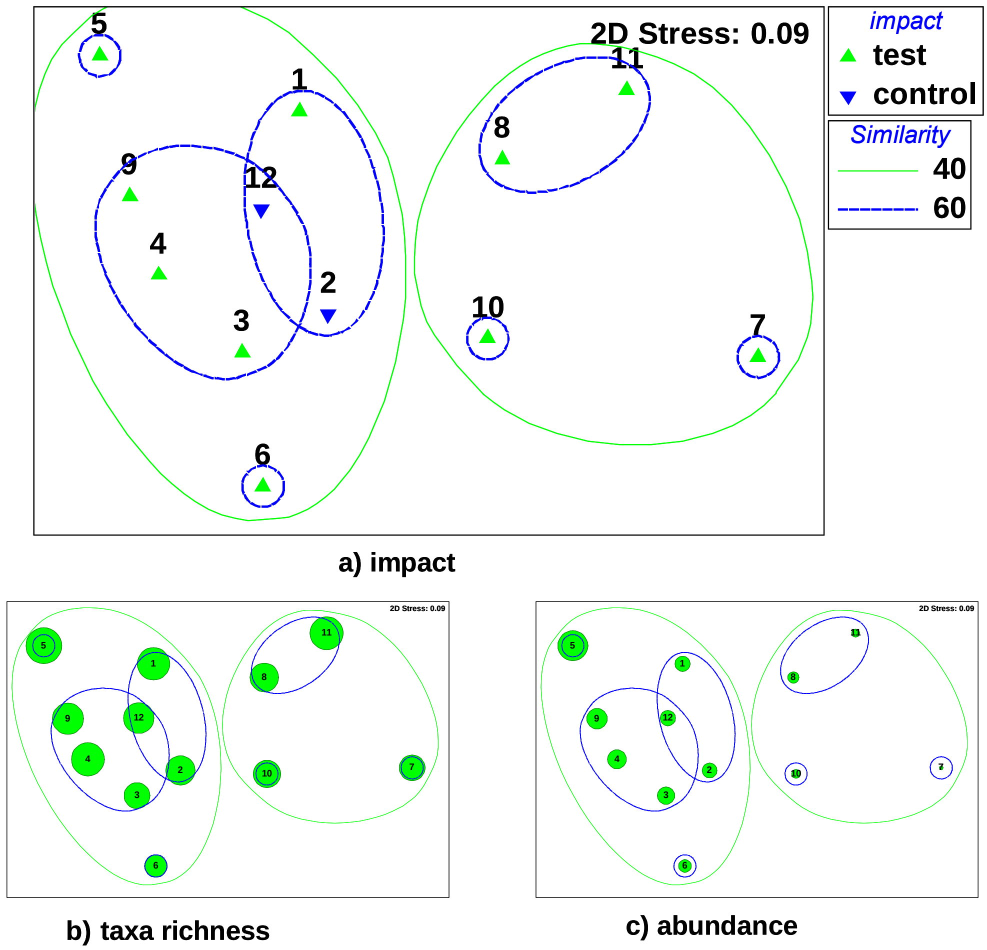

Figure 3-1 Macroinvertebrate Ordination

3.2.2 Comparison of Macroinvertebrate Results with Historic Data

Temporal comparisons with macroinvertebrates collected in 2009 (FRC Environmental 2009) and in 2004 and 2005 (WBM Oceanics 2005) can be made with that collected in the current study even though site locations are not always identical. Approximate locations and similar expected potential impacts are evident that allow for reasonable comparison. Additionally, while taxa lists are not provided by previous studies, macroinvertebrate indices allow for comparisons at the community level. One consideration is that microcrustacea (e.g. Cladocera, Copepoda, Ostracoda) excluded from the current assessment are included in at least the 2004 and 2005 taxa counts. However, they are not included in indices such as SIGNAL 2 or PET. Additional consideration of the comparison of the historic SIGNAL 2 data is that they were incorrectly assigned classifications based on the SIGNAL 95 data and these categories do not apply to interpreting SIGNAL 2 data.

The control site on the Isaac River (site 12) can be compared with previous control sites on the Isaac River. Taxa richness that includes microcrustacea has been measured at 23 and 35 at control sites in 2005 while in 2011 it was determined as 24. Given PET scores remained at the highest recorded value of 4 and that SIGNAL 2 scores increased from a historic maximum of 3.47 to 3.7 the health of the Isaac River upstream can be considered as slightly improved. This improvement could partially be attributed to the extensive rainfall that occurred each wet season since 2007, which followed a

3 Results and Comparisons with Historic Data

prolonged drought from 2001 to 2006. Increased flows would have allowed for increased colonisation of macroinvertebrates and dilution of anthropogenic impacts. Additionally, from the 2007/08 wet season, Burton Gorge Dam has overflowed every wet season providing fresh flushing flows and enhanced opportunities for fauna dispersal.

Historic sampling of the Isaac River upstream of Eureka Creek equates to site 5 in the current study. There has been an increase in taxa richness from 20 to 33 taxa. A high SIGNAL 2 of 3.63 was recorded from 2001, although this decreased to 2.92 in 2005. In the current study a recovery in the site's health was evident with the SIGNAL 2 recorded as 3.5. Additionally a high PET score of 6 was recorded in 2011 supporting the increased health of the site. In 2001 a PET score of 2 was recorded while a maximum of 4 was recorded in March 2004 and in 2005. This indicates that the health of the river at site 5 has increased over the monitoring period.

Health of the Isaac River at site 3 also increased with an improvement in the SIGNAL 2 score to 3.5 from 3.25 in 2001 and 2.8 in 2005. A higher PET score of 5 in 2011 from a score of 2 in 2001 and 2005 also supports the improvement in the condition of the Isaac River at this site.

The control site on Eureka Creek (site 2) corresponds to the control site previously surveyed on the creek. Taxa richness was lower in 2011 although this may be an artefact of microcrustacea historically being considered as macroinvertebrates. In 2001 the SIGNAL 2 score was 2.67 and this increased to 2.8 in 2005. In 2011 the SIGNAL 2 increased to 3.5 indicating an increase in health of the site. Supporting the increase in health of the site was an increase in the PET score from 1 in 2001 to 4 in 2005 and to 5 in 2011.

The condition of Goonyella Creek was shown to improve with an increase in SIGNAL 2 from 2.7 in 2005 to 3.7 in 2011. However, the PET score decreased over the period from 4 to 3. The more extensive wet seasons between 2007 and 2011 are expected to have contributed to greater opportunities for colonisation. Goonyella Creek also receives authorised discharges from the Goonyella North Mine. Also of note is that the current health of this site, based on macroinvertebrates, is compromised by the high abundance of fishes that are expected to place predatory pressure on the macroinvertebrates present in the isolated pool.

Platypus Creek was also shown to increase in health where the PET score increased from 3 in 2001 and 2005 to 6 in 2011. The 2011 SIGNAL 2 score of 3.7 increased from 2001 where it was determined as 2.99 but decreased from to 3.73 in 2005.

While a full comparison of taxonomic lists cannot be made, previous reports have indicated the presence of freshwater shrimps (Atyidae; Crustacea) and phantom midges (Chaorbidae: Diptera) that were absent from the current sampling. Atyid shrimps are common and widely distributed. These are often present with freshwater prawns (Paelomonidae; Crustacea) that were collected in the current study. Breeding is known to occur in isolated pools of rivers where the species exhibits a planktonic stage for the first month of their life cycle (Gooderham & Tsyrlin, 2002). The absence of freshwater shrimps (Atyidae; Crustacea) and phantom midges (Chaorbidae: Diptera) is attributed to the absence of suitable food sources such as detritus, fine decomposing vegetation, algae or bacteria. Additionally, Phantom midges are mainly planktonic predators in lakes or small still waterbodies (Gooderham and Tsyrlin 2002) and therefore are expected to be present in dams not sampled in the current survey.

3.3 Fish

3.3.1 Results

A total of 2,909 fish from 7 species were collected across the survey area (refer to **Table 3-3** and **Appendix D**). No exotic species were collected in the survey. All fish were examined for lesions, ectoparasites and deformities. No fish collected during the survey exhibited any signs of disease.

The most abundant site was Goonyella Creek (site 7) where 1,010 individuals were collected. This site along with Platypus Creek (site 10), and Eureka Creek downstream of the Causeway (site 1) contained the highest fish species richness with 6 of the 7 species being recorded. Within the Isaac River the fish richness varied between 5 and 2 species. Sleepy Cod (*Oxyeleotris lineolata*) were restricted to Isaac River at Railway Crossing (site 4).

Glassy Perchlet (*Ambassis agaassizi*) with 1,229 individuals, was the most abundant species in the survey area and was recorded from all sites except the Isaac River near Platypus Creek confluence (site 5). Eastern Rainbowfish (*Melanotaenia splendida*) was the next most abundant taxa with 858 individuals followed by Spangled Perch (*Leiopotherapon unicolour*) with 325 individuals. Both species were recorded from all sites except site 5.

Five species were collected from the control site, Isaac River at Riverside (site 12) and the absence or presence of taxa downstream in the Isaac River is expected to be attributable to available habitat.

The control site on Eureka Creek (site 2) contained 4 species and all species remained present at site 9 downstream of the mining activities. Abundances of Eastern Rainbowfish were higher downstream (site 9) than the control site.

Table 3-3 Fish Indices

Site	Waterway	Species Richness	Total Abundance
1	Eureka Creek	6	66
2	Eureka Creek	4	59
3	Isaac River	5	615
4	Isaac River	5	60
5	Isaac River	2	4
6	Fisher Diversion	5	669
7	Goonyella Creek	6	1 010
8	Fisher Creek	4	20
9	Eureka Creek	4	80
10	Platypus Creek	6	129
11	Ceil Creek	5	21
12	Isaac River	5	176

The ordination of the fish community structure produced a Stress = 0.07 corresponding to a good ordination with no real prospect of misleading interpretation (Clarke and Warwick 2001). At the 20 per cent level of similarity there are two distinct clusters with Isaac River near confluence with Platypus Creek (site 5) appearing as an outlier (**Figure 3-2a**). The site is characterised by having only 2 taxa and 4 individuals as a result of little habitat. Within the larger cluster the Isaac River at Railway Crossing (site 4) is isolated at the 40 per cent similarity level. The site, as previously indicated, was the only site where Sleepy Cod were recorded. The fish community structure at the control site on the Isaac River (site 12) is more similar in fish community structure with that recorded at Platypus Creek (site 10) and the most downstream site on Eureka Creek (site 1). The control site on the Eureka Creek (site 2) remains similar with that recorded downstream of mining activities and with Fisher Diversion. While the total number of species does not appear to influence the similarity of sites (**Figure 3-2b**), the influence of total abundance appears to influence the relationship of sites where sites with higher abundances are grouped together (**Figure 3-2c**).

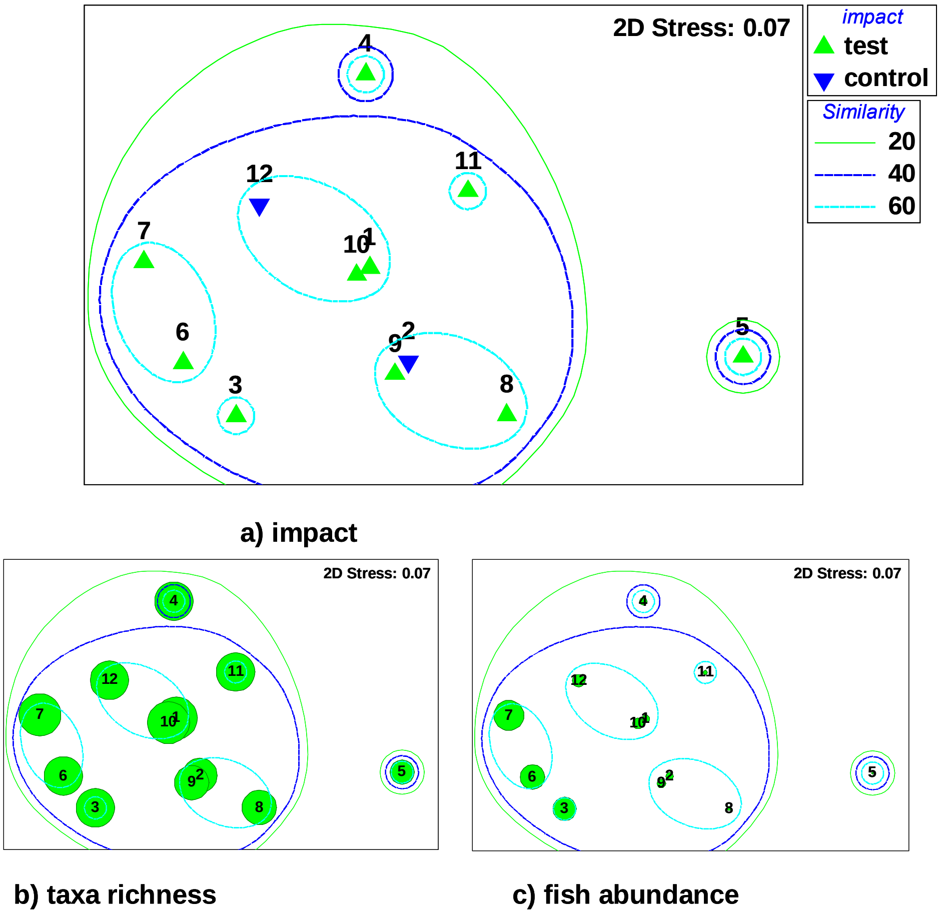

Figure 3-2 Fish Ordination

Fish abundance seems to be a significant factor affecting the similarity between observed fish communities at a site. This is not a surprising result given the range of abundances observed compared with the small range in species richness.

There is no apparent correspondence between the clusters observed for fish and for macroinvertebrate species.

3.3.2 Comparison of Fish Results with Historic Data

Comparisons of fish community structure between sampling years is compromised by the more efficient sampling methods used in 2011. In 2001 the only equivalent site examined is from Eureka Creek where 1 Western Carp Gudgeon (*Hypseleotris klunzingeri*) and 1 Eastern Rainbowfish (*Melanotaenia splendida)* were collected (FRC 2001). Eastern Rainbowfish were abundant while Western Carp Gudgeon were not collected in the current study. In 2005 seven species were collected that included Western Carp Gudgeon, Midgley's Gudgeon (*Hypseleotris sp1*), and Leathery Grunter (*Scortium hilli*) that were not collected in 2011.

In 2005 Western Carp Gudgeon were present at all sites examined except from a control site on Isaac River. In 2001 Western Carp Gudgeon were collected in higher abundances in the North Dam and Red Hill Dam. The species is known to be more common in areas of low water velocity and their spawning sites are known to be vulnerable to erratic fluctuations in water level (Pusey *et al* 2004). Their absence in the 2011 survey may reflect high flow levels in the catchment and subsequent loss of suitable breeding habitat that includes aquatic and submerged vegetation, woody debris and backwaters. Only 4 individuals of Midgley's Gudgeon were recorded across 10 sites in 2005, although the species has been reported as widespread across coastal drainages of eastern Queensland. The species may still be found in vegetated backwaters or dams in the area. Leathery Grunter is considered an estuarine species and they migrate upstream with summer rainfall to spawn (Allen *et al* 2002). The single juvenile individual may represent a stranded individual that was unable to return downstream before stream flow ceased.

Recorded in 2011 but not recorded in 2005 were Hyrtl's Tandan, Purple Spotted Gudgeon and Sleepy Cod. All species have a wide distribution and are considered common. Of note is the restriction of Sleepy Cod in the current study to a deep pool associated with scouring around a railway crossing pillar and snag on the Isaac River at site 4. Similar habitat was not found at any of the other sites examined.

Conservation Status and Fauna Tolerances

The Chapter presents the conservation status of the taxa observed in the current study, and discusses the tolerance of fauna to water quality and other disturbances.

The current community structures are then discussed relative to known potential impacts to water quality of aquatic fauna and how the observed water quality is expected to influence the aquatic community structure. This provides a basis for assessment of project-related impacts in **Section 1** of this report.

4.1 Conservation Status

4.1.1 Macroinvertebrates

The macroinvertebrate community structures were typical of seasonal streams in central Queensland. Although taxa were not identified to species, no freshwater macroinvertebrates are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the EIS study area. Additionally no taxa are listed under *Nature Conservation Act* 1992 (NC Act) endangered fauna of Queensland.

4.1.2 Fishes

None of the fish species collected in the study are listed under the EPBC Act or NC Act. Additionally no taxa are listed under NC Act for endangered fauna of Queensland. The Queensland *Fisheries Act 1994* provides legislation for the management of fishes and invertebrates in marine and fresh waters but does not list particular species. Presently the only freshwater species listed under the EPBC Act is the lungfish *(Neoceratodus forsteri*). The Red-finned Blue-Eye (*Scaturiginichthys vermeilipinnis*) is currently being considered for listing. Neither species are known from the EIS study area (Pusey *et al* 2004). While Morris *et al* (2009) recommended listing Purple-spotted Gudgeon as rare in southern inland waters of southern Queensland, the species is common and widely distributed in coastal Queensland and the populations are not listed (Pusey *et al* 2004).

4.1.3 Other Vertebrates

The Fitzroy River turtle (*Rheodytes leukops*) is listed as 'vulnerable' both in Queensland and nationally (NC Act, EPBC Act). Whilst not observed during the current survey or past surveys of the EIS study area, the species may occur in the wider area and is listed by EHP (2010) as occurring in the Fitzroy River tributaries, such as the Isaac River. The species requires flowing streams and permanent waterbodies for survival, and as the Isaac River is ephemeral, this may not provide habitat of preference to the turtle.

4.2 Fauna Tolerance to Water Quality

This section describes known tolerances of fauna to water quality, based on historical data. The observed tolerances, based on data collected in this survey, is then presented in **Sections 4.3.6** and **4.3**. This information provides a basis for the assessment of impacts arising from the development and discussed in **Section 4.4** and **Section 5**.

The inhabitants of intermittent water bodies such as those in the EIS study area are subject to a greater variation in water quality conditions than species that inhabit permanent water. Consequently, taxa collected in the current study reflect species with relatively wide thresholds in chemical condition tolerance. Intermittent stream fauna have a lower total density, taxon richness, and species diversity than perennial streams. Within intermittent streams, freshwater animals use refuges such as perennial pools, aestivation (summer hibernation), adult flight and/or desiccation resistant eggs for survival. The longer a temporary stream holds water, the higher the likelihood of colonisation of highly mobile taxa such as hemipterans and beetles, or emerged taxa such as mayflies, odonates, caddisflies and dipterans. The semi-ephemeral nature of the upstream reaches of the Isaac River system that typically form isolated pools during the dry season also provide natural movement barriers to migratory fish species. Lack of water, connectivity, and reduced holding time has the highest potential impact upon the fauna diversity.

4.2.1 Electrical Conductivity

Electrical conductivity (EC) is closely correlated to Total Dissolved Solids (TDS) or salinity. Flow rate and salinity have been highlighted as the most decisive environmental variables that determine the communities of organisms living in aquatic systems (Dallas and Day 1993). Salinity can have a substantial effect on aquatic communities by direct toxicity through physiological effects (i.e. osmotic stress) and indirect effects such as changes in food sources or habitat structure such as macrophytes (ANZECC/ARMCANZ 2000).

Since Hart *et al* (1991) reviewed the salt sensitivity of Australian freshwater biota, and suggested that salinities greater than 1,000 mg/L TDS could result in an impact to aquatic ecosystems, many studies have shown that some species are more tolerant of elevated salinity than previously thought. Dallas and Day (1993) indicate that it is the rate of change rather than the final salinity that is critically important and that the critical level of salinity in the middle and lower reaches of rivers is about 500 to 8,000 mg/L TDS.

In a recent review of Fitzroy River water quality issues, Hart (2008) indicated that adverse effects on macroinvertebrate communities in the Fitzroy River would occur at electrical conductivity levels rising 1, 000 – 1, 500 µS/cm and that taxa most affected would be within the orders Ephemeroptera, Plecoptera and Trichoptera. Hart (2008) also indicated that adult fish species within the catchment are tolerant of elevated salinities, although the effects of salinity on spawning, survival of eggs, larvae and migration cues are unknown. Based on the tolerance studies on other fish species it was suggested that adverse effects are likely on early life stages at salinities around 1,000 – 1,500 µS/cm.

GRM operates under EA No. EPML00853413 dated 6th September 2013 (formerly EA No. MIN100921609 dated 28th February 2013). This details compliance requirements for GRB in relation to discharges of mine water. This EA permits the release of mine affected water from the GS4A dam into the Isaac River when the following criteria are satisfied:

- Natural flow rate measured at the upstream Isaac River gauging station (upstream of confluence with Goonyella Creek) > 3 m3/s.
- Release criteria under flow conditions:
  - The salinity of mine affected water released from GS4A must not exceed an EC of 10,000 µS/cm; and
  - The salinity in the Isaac River at the downstream release point must not exceed an EC of 2,000 µS/cm.

4.2.2 pH

The pH of natural water is determined by geological and atmospheric influences. Most freshwaters are relatively well buffered and are more or less neutral with ranges between 6 and 8 (Dallas and Day 1993). pH influences the toxicity of many compounds found in water. For example the toxicity of cyanide and aluminium increases with decreasing pH, while the toxicity of ammonia and other nutrients caused by anthropogenic eutrophication is increased with increasing pH. Small changes in pH are not normally lethal however sublethal effects such as slow growth and reduced fecundity may occur due to increased physiological stress resulting from increased energy requirements to maintain normal bodily function. Waters in the survey area indicate reasonably high alkalinity levels ($CaCO_3$ mg/L) that contribute to the buffering of the water and pH measurements indicate that waters are slightly alkaline. pH measurements from the control sites indicate similar measurements to that recorded in downstream zones. It is expected that fauna are adapted to the naturally occurring alkaline waters.

The DERM (2011) water quality objective for pH is 6.5 – 8.5. The median values indicate compliance with this objective (Red Hill Mining Lease EIS Appendix I8). Some spot measurements taken as part of this investigation found pH slightly higher than the water quality objective range in the Isaac River, Eureka Creek below the causeway, Fisher Diversion and Goonyella Creek.

4.2.3 Dissolved Oxygen

Dissolved oxygen has been described as one of the most important determinants of the well-being of an aquatic organism (Dallas and Day 1993).

Various factors determine the concentration of dissolved oxygen and these include re-aeration from the atmosphere, temperature, salinity, respiration and photosynthesis rates, organic enrichment and biological and chemical oxygen demand. The degree of impact upon an organism is related to its dependence on dissolved oxygen as its source. Sub-lethal impacts may include changes in behaviour, blood chemistry, growth rate and food intake. Natural diurnal variations in dissolved oxygen occur in water bodies as respiration and photosynthetic rates change with light availability and should be considered when interpreting results.

The DERM (2011) dissolved oxygen water quality objective for the protection of the aquatic ecosystem is 85-110%. Only water at the Fisher Diversion met this objective. Given the control sites did not meet this objective, it is suggested that impacts occurring from grazing and the limited flow evident at the time of sampling, which decreases re-aeration, are contributing to the low dissolved oxygen readings.

4.2.4 Turbidity

Turbidity is measure of light penetration and reflects the amount of suspendoids. Increases in suspendoids therefore impact upon light penetration and subsequently increase turbidity. Increases in turbidity impact upon primary production and subsequently food availability to fauna higher up the food chain. Furthermore suspendoids that settle out may smother habitat and this can result in changes in community composition. However, it is noted that the streams in the survey area have sand beds which are highly mobile and this would contribute to naturally elevated turbidity readings.

The DERM (2011) water quality objective for turbidity is less than 50 NTU. The median values for turbidity indicate they were below the objective at Fisher Creek, Platypus Creek, Upper Eureka Creek, Upper Isaac River and Lower Isaac River (Red Hill Mining Lease EIS Appendix I8).

Spot samples in the current study showed turbidity less than 50 NTU in Isaac River upstream of Eureka Creek, at the Rail Crossing and near the confluence with the Platypus Creek. Turbidity in the mid reach of Eureka Creek was also < 50 NTU. The control sites had turbidity >50 NTU suggesting that either the natural turbidity of the waterways is higher than DERM (2011) guidelines or non-mining activity impacts are occurring. The water quality assessment (Red Hill Mining Lease EIS Appendix I8) found that median turbidity exceeded water quality guidelines at all sites.

4.2.5 Toxicants

The sensitivity of biota to toxicants such as trace metals, ammonia and NO_x is dependent on a range of factors. Toxicity and impacts will vary upon concentration, source and species as well as physical factors such as suspended sediment, pH and temperature.

The movement of toxicants such as trace metals, ammonia and NO_x has not been assessed in the current project. However, Sellens *et al* (2011) investigated the water quality at eight sites in the survey area that correlate with current survey sites and determined the dissolved metal concentrations were above the trigger levels of the site's environmental authority in Upper Goonyella Creek. Recorded concentrations for copper, nickel, molybdenum and uranium were: Cu 6 µg/L cf 3 µg/L (environmental authority trigger level); Ni 57 µg/L cf 11 µg/L; Mo 40 µg/L cf 34 µg/L; and U 6 µg/L cf 1 µg/L. Sellens *et al* (2011) also indicated that the high levels were due to other activities outside of mining as the site is upstream of possible mine influence. Dissolved zinc was recorded above the trigger level of the site's environmental authority in the lower Isaac River (9 µg/L). However, Sellens *et al* (2011) do not offer an explanation for the elevated value. They also determined that dissolved nutrients were all below the old environmental authority trigger levels.

In the absence of specific information on the toxicity of individual species local and national trigger values are considered suitably conservative and appropriate for the assessment of impacts on biota in this study.

4.2.6 Macroinvertebrates

Hart (2008) recommended electrical conductivity less than 1,000 µS/cm to protect macroinvertebrate diversity in the Fitzroy River in the absence of detailed information on the tolerances of individual species and life stages to salinity.

Assessments of the salt sensitivity of macroinvertebrate species collected in the Murray Darling Basin (Morris *et al* 2009) have been summarised to family level and are presented in **Appendix E**. The majority of taxa from the survey area were found in water below the maximum electrical conductivity recorded from their presence in the Murray Darling Basin. The only exceptions to this include the caddisfly (*Hydropyschidae*) found in waters approximately 1,650 mg/L TDS greater than the Murray Darling maximum of 1,885 mg/L TDS; and the surface dweller *Gerridae* (*Hemiptera*) found in waters approximately 300 mg/L TDS above the maximum observed in the Murray-Darling Basin.

The degree of impact of low dissolved oxygen on macroinvertebrates is determined by the organism's dependence on water as a medium. Taxa that respire through gills or by direct cuticular exchange are more susceptible to apoxia than those that are atmospheric breathers, such as true bugs (*Hemiptera*) and many beetles (*Coleoptera*). Additionally snails of the family *Planorbidae* are pulmonates and as such have a vulcanarised pulmonary cavity that enables them to breathe atmospheric air (Wiggins *et al* 1980). The rate of respiration while varying between species may also be influenced by the size, age, activity and physiological state of an individual. Local trigger values would need to be developed to determine when hypoxia occurs for the more susceptible taxa such as mayflies (*Ephemeroptera*) or alternatively the mayflies can be used as biological indicators.

Given that *Baetidae* (*Ephemeroptera*) were collected at the majority of sites and those sites where they were not collected had relatively moderate dissolved oxygen concentrations, dissolved oxygen does not appear as a limiting factor to macroinvertebrate community composition. *Leptophlebiidae* (*Ephemeroptera*), which are regarded as more sensitive to water quality impacts, were found on the Isaac River at Rail Crossing (site 4) but not at other sites. Given that electrical conductivity was lower at other sites on the Isaac River it is suggested that habitat structure is also contributing to the presence/absence of this taxonomic order.

4.2.7 Fishes

The published range of water quality records that different fish species have been collected from are collated from Pusey *et al* (2004) (**Table 4-1**). All species collected in the current study fall within the range of water temperatures previously recorded for each of the species. The published data indicates that the collected species are tolerant of low dissolved oxygen concentrations and that the current snapshot of dissolved oxygen concentrations is within each species tolerance range. The slightly alkaline waters observed during sampling are also well within the range of species tolerances to variability in pH with the exception of Eastern Rainbowfish which is shown to be more tolerant of alkaline water in the current study. Pusey *et al* (2004) indicate the highest pH of water Eastern Rainbowfish have been recorded from is 8.47 while in the current study the maximum pH measurement from where they were collected was 8.81.

According to Pusey *et al* (2004) the majority of the fish species recorded within the survey area are tolerant of elevated salinities above those recorded in the current study. Conversely some species are shown to be more tolerant of elevated salinity than previously noted by Pusey *et al* (2004). This is evident by the highest taxa richness across the survey area and particularly the taxa collected from the Goonyella Creek. Bony Bream and Spangled Perch that were moderately abundant in the survey area are tolerant of waters approaching the salinity of sea water. Purple-spotted Gudgeon were shown to be much more tolerant of elevated salinities than reported by Pusey *et al* (2004). The species was collected in waters with the maximum EC measurement of 5,521 µS/cm recorded at Eureka Creek (site 1). Hyrtl's Tandan was also shown to be more tolerant of elevated EC as it was also recorded Fisher Diversion. Sleepy Cod appear the most susceptible species to elevated EC as evidenced by its restriction to the Isaac River although the measured EC at site 4 of 909 µS/cm was above the maximum known tolerance of 650 µS/cm reported by Pusey *et al* (2004). Additionally as previously noted the habitat structure may be more indicative of limiting Sleepy Cod distribution as the species was restricted to deep pool with snag cover.

Assessments of the salt sensitivity of fish species collected in the Murray Darling Basin indicate only two common listed taxa, Bony Bream and Spangled Perch (Morris *et al* 2009). Boney Bream and Spangled Perch were recorded with an upper salinity limit of 35,000 and 35,500 mg/L respectively giving similar results as described by Pusey *et al* (2004). While adult fish appear more tolerant of elevated salinity, Hart (2008) has indicated the effects of salinity on spawning, survival of eggs, larvae and migration cues are unknown.

Table 4-1 Fish water quality tolerances (after Pusey *et al* (2004))

Species	Common Name	Temp ºC)	DO (mg/L)	pH	EC (µS/cm)	Turbidity (cm)
Ambasis agasizii	Agassiz's Glassfish	11-33	0.3-19.5	6.3-9.9	19.5-15,102	0.2-144
Leiopotherapon unicolor	Spangled Perch	4.1-41.8	0.4-40% saturation	4-8.6	30-54,000	152-250
Melanotaenia splendida	Eastern Rainbowfish	15-32.5	1.1-10.8	5.1-8.5	6- 13,500	0.1-16
Mogurnda adspersa	Purple-spotted Gudgeon	11.9-31.7	0.6-12.8	5.6-8.8	13.3-2,495	0.1-200
Nemaralosa erebi	Bony Bream	12-38	0.1-12	5.1-9.1	2- 60,000	1-581
Neosilurus hyrtlii	Hyrtl's Tandan	12.8-36	1-11.4	5.2-9.1	4-1,855	0.4-170
Oxyleotris lineolatus	Sleepy Cod	15-38	1-11	4.8-9.2	4-650	1-579
Hypseleotris klunzingeri *	Western Carp Gudgeon	8.4-31.7	0.6-12.8	4.8-9.1	19.5-5,380	0.5-65
Hypseleotris sp. 1 *	Midgley's Carp Gudgeon	8.4-31.2	0.3-19.5	4.4-8.9	51-4,123	0.1-331.4

* previously recorded from survey area

4.3 Fish Tolerance to Barriers

Many of Australia's native freshwater fish are known to be migratory and require free passage to sustain populations. However it is now recognised that all freshwater fish need to move freely between the various areas of their habitat, although the scales of movement are different between species. The movement of fish throughout Australian waterways is crucial for the survival of many native species, allowing for spawning and migration to new feeding grounds and habitats, especially during periods of high flow when Australian freshwater fish are most active.

More specifically fish migration behaviour can be classified into the following:

- Anadromous – fish live in the ocean mostly and breed in fresh water;
- Catadromous – fish live in freshwater, and breed in the ocean;
- Amphidromous – fish move between fresh and salt water during their life cycle, but not to breed; and
- Potamodromous – fish migrate and breed within freshwater only.

All fish collected in the 2011 survey are potamodromous and all species vary in their known dispersal rates within freshwater habitats. For example:

- Glassy Perchlet and Hyrtl's Tandan are known to exhibit upstream spawning migrations (Pusey *et al* 2004);
- Bony Bream and Spangled Perch are known to make general fast migrations to colonise other riverine habitats (*ibid*);

- Purple Spotted Gudgeon make small frequent small scale dispersion; (*ibid*);
- Eastern Rainbowfish exhibit upstream migration upon the commencement of the wet season (*ibid*); and
- Sleepy Cod make slow moving localised movement (*ibid*).

WBM Oceanics (2001) attributed the absence from the survey area of species that move between freshwaters and estuaries to the numerous artificial barriers downstream and within the Isaac River.

Historic river diversion works in the survey area have been designed to allow water to flow during high flow events, similar to that within the natural channels. As such, these are unlikely to have a major impact on the movement patterns of fishes. Within the larger catchment area, natural barriers during the dry season that are quickly overcome with the onset of the wet season represent an equivalent risk to the maintenance of species diversity.

4.4 Fauna Tolerance to Loss of or Changes to Habitat

The loss of habitat through increased sedimentation has the potential to greatly impact upon species diversity. Given the substrate in the catchment is largely coarse sand, there is potential for and evidence of major sediment mobilisation during high flow events. Evidence of erosion of stream banks through the removal of riparian vegetation, cattle grazing and natural hydraulics also adds to the risk of instream habitat loss. As previously highlighted, Sleepy Cod were restricted to a deep pool associated with a large snag and a railway crossing pillar. Concentrated flow through a culvert currently aids in the scouring of the pool, therefore, assisting in the retention of the pool habitat. During the survey, it was also noted few large snags existed within the pools of the Isaac River. These would typically assist in directing flow and therefore create refuge habitat. It is unknown whether this is naturally occurring or the result of stream management works.

Increased sedimentation may also impact upon benthic macroinvertebrates by smothering food sources and depleting microhabitat availability such as aquatic macrophytes. Doeg and Milledge (1991) suggested a threshold level exists where macroinvertebrates drift downstream as a response to increased suspended sediments. This can create secondary impacts upon fauna higher up the food chain. Increased sediment loads could also result in impacts to downstream aquatic and marine ecosystems although run-off from the EIS study area is expected to be a minor contributor to sediment load in the entire catchment. The significance of the loss of habitat structure to macroinvertebrates is also evident in the channelised Fisher Diversion (site 6) where the lowest macroinvertebrate taxa richness was observed.

Impact Assessment and Mitigation Measures

This Chapter discusses the potential direct and secondary impacts associated with the various phases of project life from construction, to operations, to decommissioning. A number of mitigation measures are proposed to maintain aquatic communities.

5.1 Construction Earthworks and Clearance of Vegetation

There will be selective clearance of vegetation and earthworks at the MIA, the Red Hill accommodation village, the road to the accommodation village, the conveyor route, the coal handling and preparation plant (CHPP), and across the underground mining footprint for the incidental mine gas (IMG) network. These works will expose soils, which can potentially lead to erosion and increased sediment loads into local streams.

Control of erosion and sediment loading in the waterways is essential to ensure the maintenance of aquatic ecological habitat structure. Controls should be implemented for all development, including construction of bridges, roads, tracks and the IMG pipelines, which impinge on waterways.

The following principles of erosion and sediment control should be applied:

- where practical, clean water flows should be diverted around disturbed areas;
- measures should be taken to minimise exposure of soils to erosive forces; and
- where erosion is unavoidable, devices should be installed to minimise release of sediment laden water from disturbed areas.

Erosion and sediment control plans should be developed prior to surface disturbance in any particular area. These plans should include an assessment of erosion risk at each location, and selection of appropriate diversion, erosion prevention and sediment capture methods. Current relevant erosion and sediment control guidelines should be utilised in preparation and implementation of erosion and sediment control measures.

Normal control measures should include limitation of vegetation clearance, use of sediment fences, and construction of stormwater diversion and containment structures prior to any substantial earthworks. Adjacent to sensitive areas such as stream lines, multiple levels of sediment control may be required to minimise sediment movement into water ways. Regular inspection and maintenance of sediment control works should be undertaken to ensure ongoing effectiveness.

If check dams or other sediment capture structures are installed on streams or drainage lines, these should be installed in accordance with the *Guideline - activities in a watercourse, lake or spring associated with mining operations* (DERM 2010).

The protection of the riparian zone outside of the intensive development zones is important to controlling bank erosion, and for the provision of allochthonous material that is expected to contribute to the function of the aquatic ecosystem. The main surface facilities of the Red Hill MIA, accommodation village and CHPP do not require clearing in riparian zones. Management of disturbance arising from construction of the bridge, associated pipelines and IMG drainage infrastructure, is discussed further in **Sections 5.2** and **5.3**.

Interference with aquatic passage through the EIS study area should be minimised wherever possible to allow migration and breeding of fishes during flow periods.

With these measures in place, marked changes in habitat structures and aquatic ecosystem characteristics are not expected to arise from vegetation clearing and earthworks activities.

5.2 Construction of Isaac River Crossings (Bridgeworks and Other Infrastructure)

A road bridge is to be constructed across the Isaac River above the main drive of the Red Hill Mine (RHM) that will also carry water pipelines and gas pipelines associated with the IMG management system. As is typical with bridge construction on ephemeral rivers, construction will take place in the dry season if possible. The bridge should be designed so that it does not markedly impede river flows or increase flood risk and, hence, will have minimal impact on fish passage. However, there may be some disturbance to the bed and banks of the river during construction which will need to be reinstated and stabilised.

Pipelines for gas and water and power lines may need to be buried under the river at one or two locations to be determined in the detailed design phase. Construction works would most likely be undertaken by open trench during the no-flow conditions, with the bed and banks stabilised and restored post-construction. Fish passage would, therefore, not be impacted.

There is a risk that should a flow event occur before stabilisation is complete, local erosion and increased sediment releases may occur. These impacts are likely to be temporary and would be considered to have a minor (cumulative) impact on water quality and downstream habitat as the volume of sediment that might be released is relatively small. No mitigation measures are proposed other than to complete stabilisation works or make good any local erosion in the event that a flow does occur before stabilisation is finalised.

Minor loss of habitat may occur during bridge construction. The impact would primarily be confined to a narrow corridor across the riparian zone that would need to be cleared and, depending on bridge design, may be replaced with parts of the bridge structure. No effects on macroinvertebrates are expected if construction takes place during low flows.

5.3 Incidental Mine Gas Drainage Infrastructure

The RHM underground expansion option will require extensive surface infrastructure across the underground mine footprint to drain and manage IMG to enable the safe and efficient operation of the underground mine. IMG management will involve a series of gas drainage wells and a second set of wells to remove goaf gas post mining.

The IMG management system will consist of a network of IMG drainage infrastructure comprising pipes, water pipes, access tracks, and wells and well pads. Once mining is complete, goaf gas drainage wells will be required.

There will be numerous crossings across smaller drainage lines by gas infrastructure. These will consist of an access track that will remain in place for the duration of gas drainage activities and the gas and water pipes. The pipes will be likely buried and will be constructed by open trench. Construction will take place during no flow conditions wherever possible.

Power will either be overhead or buried with the gas and water pipelines. Depending on the streamline crossed it may be necessary to install culverts to allow for vehicle access. Although waterway barrier works approval is not required for works on a mining lease, consideration will be given to the Queensland Government Code for Self Assessable Development, Minor Waterway Barrier Works Approvals – Part 3 (culverts) and Part 4 (bed level crossings) where relevant and practical.

Tracks and trenched crossings will be stabilised and monitored (inspected) and managed.

The gas drainage infrastructure and the gas wells will result in surface disturbance across the RHM footprint which may result in increased erosion and, hence, increase the potential for sediment release to waterways.

As the gas drainage infrastructure will be constructed up to 15 years ahead of mining the main focus during this stage should be to keep the streams as stable as possible, thus minimising habitat changes outside the immediate footprint of disturbance. Although there will be a large number of stream crossings, provided crossings are managed and stabilised, and fish passage is maintained on major streams, impacts should be localised to the crossing location and significant changes in aquatic ecosystems and fauna assemblages is not expected at a site or sub-catchment level.

5.4 Spills and Leaks of Fuels and Chemicals

Construction and operation will require the use of heavy machinery and the establishment of fuel and maintenance workshops and depots containing diesel and oil. Consequently, there is the potential for fuel and oil spills that could contaminate waterways within the EIS study area.

The likelihood of significant waterway contamination is considered to be low since bulk fuel storage areas will be appropriately sited and bunded, and fuel handling procedures will be observed.

Spills and leaks of fuels and chemicals within the Red Hill MIA, CHPP and accommodation village areas should be contained by stormwater management systems for these facilities. During early construction, before these stormwater systems are installed, erosion and sediment control systems should be used to capture spills. Prompt containment and clean up of spills to land will minimise likelihood of mobilisation of contaminants to waterways.

There is a risk of fuel or oil spills arising from the use and refuelling of heavy machinery outside of these areas, particularly associated with IMG management activities and also construction of the bridge across the Isaac River. Works in and around waterways have the highest potential to cause contamination, including bridge construction, river crossings, access road construction and riparian zone works. Constraining work in streams to dry periods for stream line and river crossings would further reduce the risk of spread of any contaminant spill within the aquatic ecosystem.

The risk of significant contamination is considered low since leaks are likely to be of small volume and dispersed across the linear infrastructure. During construction and installation of IMG management infrastructure, erosion and sediment control measures would assist in isolating areas of vehicle movement and machinery. Prompt containment and clean up of spills will also reduce the likelihood of mobilisation of contaminants to waterways.

During high flow events, contaminants may be transported into the Isaac River and Fitzroy River systems, although resultant concentrations are likely to be diluted well below the tolerance thresholds of fauna. Overall, with control measures in place, impacts on aquatic ecosystems on the site and downstream are expected to be negligible.

5.5 Subsidence

The proposed underground longwall mining is projected to result in subsidence of portions of the overlying ground surface. The degree of subsidence will vary but is predicted to average between three to five metres. A maximum of six metres has been predicted assuming a worst-case scenario.

5 Impact Assessment and Mitigation Measures

This will result in marked localised changes to surface drainage patterns and topography as described by Alluvium (2011). Changes may include avulsion, where stream channels alter to follow the alignment of the subsidence troughs, as well as bank erosion and upstream and downstream channel deepening. Ponds are expected to form, and some of these may be effectively permanent.

The introduction of deep pools through subsidence of the river bed will increase habitat availability for aquatic species in the short term. The pools are expected to provide additional and new refuge habitat for both macroinvertebrates and fish compared with current conditions and may therefore be considered a positive outcome of the project. No significant change in water quality is expected from current conditions. However, the pools may be more highly stratified than current pool refuges due to the predicted depth.

While, over time, the subsidence voids in the river are predicted to fill up with sediment, numerous deep subsidence voids would act as pools in areas outside of the main river channel if they are not drained. These areas would act as newly created aquatic habitat and provide refuge habitat for aquatic fauna during the dry season.

Subsidence trough ponding extents and volumes outside the Isaac River channel was assessed and indicated a possible 44 ponding areas larger than two hectares, of varying degrees of permanence. The subsidence troughs are estimated to range from less than 10 megalitre capacity up to a maximum of approximately 1,100 megalitres. The average capacity would be approximately 210 megalitres. The largest areas of potential ponding would be up to 40 hectares, and the average area would be approximately 12 hectares.

Ponding along the main Isaac River channel is predicted to infill reasonably quickly due to sediment load in the river system. Ponding along 12 Mile Gully and tributaries may be effectively permanent due to the smaller catchment and lower sediment loads. Destabilisation of the river bank and channel deepening upstream and downstream are also expected as a result of the subsidence. In contrast to the creation of new habitat, these changes would cause readjustment of habitat through sediment movement and potentially the short term loss of riparian habitat and energy inputs such as coarse particulate matter. The loss of energy inputs will be a local phenomenon that may lead to an adjustment of local faunal assemblages or abundances (e.g. in the newly created pools) since taxa dependent on energy inputs will be less favoured and subsequently impact on taxa higher in the food chain. Careful management of erosion and riparian vegetation will be required to minimise long term effects. A subsidence management plan should be prepared.

With the increase in water habitat from subsidence, the macroinvertebrate diversity is expected to be maintained and possibly enhanced through the opportunity for highly mobile taxa to colonise the pools.

Conversely, impacts of erosion, sediment movement and changes in riparian vegetation habitat and inputs may result in a reduction of refuge habitat and diversity of both fish and macroinvertebrates.

The deeper pools that will be created through subsidence may result in an increase in an abundance of Sleepy Cod (*Oxyleotris lineolatus*), a large predator. Sleepy Cod were observed to be restricted to the Isaac River at the Railway Crossing where deep pools existed. Pusey et al. (2004) indicate the loss of Purple Spotted Gudgeon (*Morgurnda adspersa*) from Blue Range Station in the Burdekin River occurred within two years of the appearance of Sleepy Cod. Sleepy Cod are known to have a considerably higher fecundity than Purple Spotted Gudgeon (ibid) and this can lead to competition for resources as well as higher predation rates by Sleepy Cod. Of note is that subsidence, particularly in

12 Mile Gully, is expected to produce steep walled pools and with the addition of high velocity flows, this may act as a barrier to the movement of Sleepy Cod, which unlike Purple Spotted Gudgeon, are believed to have their dispersion limited by such conditions. For example, Purple Spotted Gudgeon have been found above waterfalls, while Sleepy Cod have been restricted to below such structures. Aquatic ecosystem monitoring will assist in identifying whether imbalances in fish populations are occurring. Provided that stream channel erosion and bank stability is managed, subsidence is not expected to contribute to sediment loads in the Isaac River as sediment will tend to be trapped in the subsidence troughs.

5.6 Monitoring

Aquatic macroinvertebrate monitoring should be incorporated into the receiving environment monitoring program to provide for the assessment of changes in the aquatic ecosystem arising from mining and post-mining subsidence.

Monitoring should be undertaken at or near the cessation of seasonal flow on a regular basis during the life of the mine, having regard to access and safety considerations. In the wet-dry tropics Humphrey et al. (1990) have shown that this timing represents the period when biological diversity is highest and when the summation of all contaminant runoff effects would be best measured and any effects most pronounced.

Survey design will generally follow ANZECC/ARMCANZ (2000) guidelines including adequate control and impact sites to provide statistically significant comparisons.

Many taxa have shown tolerances to the in situ parameters measured beyond that recorded in published material. However, further investigation to assess the restriction of Sleepy Cod and Mayflies from the family *Leptophlebiidae* to the Isaac River is recommended. Although both taxa were rare, this may be associated with salinity and habitat structure and warrants further investigation. This will be incorporated into early monitoring events.

Water quality monitoring should be undertaken as part of the receiving environment monitoring program.

5.7 Decommissioning Phase

Rehabilitation of streams and riparian zones will assist in ensuring that impacts from proposed works are managed in such a way that maintains local ecological functionality. As part of the site rehabilitation, snag habitat and overhanging vegetation should be provided as these will add to the habitat quality for aquatic fauna. Stabilisation of soil through vegetative control throughout all non-operational zones should be completed to reduce the risk of potential unforeseen erosive events.

5.8 Residual Impacts

Residual impacts associated with the proposed project are likely to be associated with sediment infill of newly formed pools in the river bed caused by subsidence. During the life of the mine monitoring of fauna and water quality associated within these pools will provide information on the likely impacts of these processes and may lead to the need to translocate species away from the pools.

Subsidence is also likely to lead to more permanent refuge habitat on the floodplain. This is considered a positive residual impact that would aid in maintaining biodiversity.

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Appendix A Habitat Summaries

Site	Point source pollution	Mean| depth	Mean channel width	Substrate					
				boulder	cobble	pebble	gravel	sand	silt clay
1	tailings leak/cattle	0.5	15	20	20	0	0	30	30
2	cattle	0.4	3	0	0	0	5	80	15
3	mine/cattle	0.5	70	1	5	2	0	82	10
4	mine/cattle	0.7	80	0	0	0	0	95	5
5	cattle	0.5	70	0	0	0	0	95	5
6	cattle	0.5	8	0	0	0	0	5	95
7	cattle	0.3	6.5	0	0	0	0	5	95
8	cattle	0.6	6	0	5	5	15	35	50
9	cattle	0.7	9	2	0	1	15	67	15
10	cattle	0.3	1.5	0	0	0	0	97	3
11	cattle	0.8	4	0	5	10	2	3	80
12	cattle	0.3	30	0	0	0	0	100	0

Site	Riparian Vegetation						Trailing Bank	Overhanging Bank
	native	exotic	grass	trees <10	shrubs	trees >10		
1							moderate	nil
2							nil	nil
3	30	70	95	5	5	2	slight	slight
4	30	70	90	0	0		nil	nil
5	60	40	95	5	5	5	slight	slight
6	20	80	95	5	0		nil	nil
7	30	70	95	5	1	10	nil	nil
8	30	70	95	10	2	5	slight	nil
9							nil	nil
10	20	80	95	2	2	1	nil	slight
11	10	90	95	5	0	0	slight	slight
12	50	50	80	10	0	20	slight	moderate

B

Appendix B Site photographs

Upstream

Downstream

Plate 1 Site 1 Eureka Creek downstream of the Causeway

Upstream

Plate 2 Site 2 Eureka Creek

Upstream

Downstream

Plate 3 Site 3 Isaac River upstream Eureka Creek

Appendix B - Site photographs


Upstream


Downstream

Plate 4 Site 4 Isaac at railway crossing


Upstream


Downstream

Plate 5 Site 5 Isaac River near confluence with Platypus Creek


Upstream

Plate6 Site 6 Fisher Diversion upstream

Appendix B - Site photographs

 Upstream	 Downstream

Plate 7 Site 7 Goonyella Creek

 Upstream	 Downstream

Plate 8 Site 8 Fisher Creek

 Upstream	 Downstream

Plate 9 Site 9 Eureka Creek

Appendix B - Site photographs

Upstream

Plate 10 Site 10 Platypus Creek

Upstream

Downstream

Plate 11 Site 11 Ceil Creek

Upstream

Downstream

Plate 12 Site 12 Isaac River at Riverside

Appendix C Macroinvertebrate diversity

Taxa		1	2	3	4	5	6	7	8	9	10	11	12
Crustacea	*Palaemonidae*	50	40	130	4	50	0	35	177	0	125	48	110
	Parastascidae	0	0	0	0	0	0	0	1	0	10	1	0
Arachnid	*mite*	0	10	60	10	0	20	2	23	0	75	2	40
Annelida	*Oligochaete*	10	480	0	0	0	10	1	254	71	25	84	0
Mollusca	*Ancylidae*	0	30	0	0	0	0		15	14	5	4	0
	Gastropoda	0	0	0	0	0	10	0	0	0	0	0	0
	Planorbidae	0	0	0	0	0	0	0	8	0	0	0	0
Ephemeroptera	*Caenidae*	40	230	590	870	975	90	14	62	557	315	4	410
	Baetidae	60	130	220	820	2275	0	0	8	200	0	4	1300
	Leptophlebiidae	0	0	0	10	0	0	0	0	0	0	0	0
	Prosopistomatidae	0	0	0	0	25	0	0	0	0	0	0	0
Odonata	*Zygoptera (imm)*		0	40	60	100	0	0	0	143	0	4	20
	Coenagrionidae	60	0	0	0	0	0	0	0	0	0	0	0
	Epiproctophora (imm)	30	20	0	0	0	20	0	0	0	0	1	
	Gomphidae	0	0	20	30	25	0	0	0	0	5	0	10
	Libellulidae	0	0	0	0	0	0	0	0	2	0	0	0
	Macromiidae	0	0	0	20	25	0	0	0	0	0	0	0
Hemiptera	*Belostomatidae*	0	0	0	1	1	0	0	0	0	0	0	0
	Notonectidae	0	20	10	20	300	0	0	23	14	5	36	1
	Corixidae	190	40	30	140	25	60	0	15	14	40	0	10
	Veliidae	30	30	0	0	150	0	4	208	0	5	48	60
	Mesoveliidae	10	0	0	0	25	0	0	0	0	0	4	0
	Gerridae	10	0	30	30	50	0	2	0	14	0	8	20
	Pleidae	40	10	30	20	725	0	0	69	57	0	56	30
	Nepidae	6	1	0	5	25	0	0	8	1	2	2	3
Diptera	*Ceratopogonidae*	530	470	170	80	225	90	13	238	129	45	28	10
	Tanypodinae	480	300	100	670	1525	90	21	123	757	20	4	70
	Chironominae	770	950	2080	1440	1350	1580	44	92	1757	205	36	510
	Orthocladiinae	20	0	0	20	150	20	1	0	71	0	0	40
	Culicidae larvae	50	40	0	10	175	0	0	115	57	15	320	0
	Simuliidae (larvae)	100	0	0	10	200	0	0	0	43	0	0	60
	Tipulidae	0	0	0	0	50	0	0	0	29	0	0	0
	Tabanidae	60	0	0	0	25	0	0	0	0	0	0	0
	Empididae	0	10	0	0	0	0	0	0	0	0	8	0
	Psychodidae	0	0	0	10	0	0	0	0	0	0	4	0
	Stratiomyidae	10	0	0	0	0	0	0	0	0	0	0	0
	Ephydridae	10	0	0	0	0	0	0	0	0	0	0	0
	Dolichopodidae	0	0	0	0	0	0	0	0	71	0	0	0
Coleoptera	*Dytiscidae (adult)*	40	1	10	70	750	0	16	46	57	20	16	10
	Hydrochidae (adult)	10	0	0	0	50	0	2	23	0	0	20	30
	Hydraenidae (adult)	40	0	0	20	525	0	3	100	43	25	72	70
	Hydrophilidae (adult)	30	0	0	0	175	0	5	0	43	25	16	30
	Gyrinidae (adult)	0	2	0	0	75	1	0	0	29	0	0	40
	Noteridae	0	0	0	0	0	0	1	0	0	0	4	0

Appendix C - Macroinvertebrate diversity

Taxa		1	2	3	4	5	6	7	8	9	10	11	12
	Curculionidae (adult)	0	0	0	0	25	0	0	0	0	0	0	0
	Chrysomelyidae (	0	0	0	60	450	0	0	0	0	0	0	0
Trichoptera	*Leptoceridae*	40	30	250	150	925	60	6	0	871	20	4	150
	Ecnomidae	0	50	120	20	25	40	25	23	0	0	4	10
	Hydropsychidae	270	0	0	20	150	0	0	0	329	0	0	0
	Hydroptilidae	0	10	20	10	0	0	0	0	0	0	0	0

Appendix D Fish Diversity

Common Name	Species	1	2	3	4	5	6	7	8	9	10	11	12
Glassy Perchlet	*Ambassis agaassizi*	26	25	559	1		251	289	4	21	23	8	22
Bony Bream	*Nematalosa erebi*	19		4			48	219			7	1	23
Hyrtl's Tandan	*Neosilurus hyrtlii*	3			17	1		31			9	5	13
Purple Spotted Gudgeon	*Morgurnda adspersa*	4	15	11		3	22	2	14	18	4		
Eastern Rainbowfish	*Melanatonia splendida*	9	13	13	3		341	318	1	37	80	2	41
Sleepy Cod	*Oxyeleotris lineolata*				4								
Spangled Perch	*Leiopotherapon unicolor*	5	6	28	35		7	151	1	4	6	5	77

Appendix E Murray Darling Macroinvertebrate Salinity Tolerances

Taxa		Murray Darling Salinity Range (mg/L)	Murray Darling Maximum (mg/L)
Annelida	*Oligochaete*	180-58000	58000
Acarina	*mite*	82-19300	19300
Coleoptera	*Curculionidae* (adult)	5916	5916
Coleoptera	*Hydrochidae* (adult)	300-20900	20900
Coleoptera	*Gyrinidae* (adult)	400-14100	14100
Coleoptera	*Hydrophilidae* (adult)	100-149400	149400
Coleoptera	*Hydraenidae* (adult)	1455-14200	14200
Coleoptera	*Dytiscidae* (adult)	82-93000	93000
Crustacea	*Palaemonidae*	2000-40000	40000
Diptera	*Stratiomyidae*	100-4900	4900
Diptera	*Ephydridae*	80-117000	117000
Diptera	*Psychodidae*	213-3100	3100
Diptera	*Empididae*	281-19000	19000
Diptera	*Dolichopodidae*	3428	3428
Diptera	*Tipulidae*	82-5800	5800
Diptera	*Orthocladiinae*	82-7200	7200
Diptera	*Simuliidae*	281-6600	6600
Diptera	*Culicidae larvae*	100-11200	11200
Diptera	*Ceratopogonidae*	82-86000	86000
Diptera	*Tanypodinae*	82-59800	59800
Diptera	*Chironominae*	82-255000	255000
Ephemeroptera	*Leptophlebiidae*	82-3200	3200
Ephemeroptera	*Caenidae*	100-5500	5500
Ephemeroptera	*Baetidae*	82-5400	5400
Hemiptera	*Belostomatidae*	1500-5916	5916
Hemiptera	*Mesoveliidae*	75-5916	5916
Hemiptera	*Nepidae*	109-4100	4100
Hemiptera	*Gerridae*	3200	3200
Hemiptera	*Notonectidae*	100-30400	30400
Hemiptera	*Veliidae*	3200-39700	39700
Hemiptera	*Corixidae*	82-53800	53800
Hemiptera	*Pleidae*	400-3900	3900
Mollusca	*Planorbidae*	82-5916	5916
Mollusca	*Gastropoda*	82-124000	124000
Mollusca	*Ancylidae*	169-2240	2240
Odonata	*Libellulidae*	100-24600	24600
Odonata	*Coenagrionidae*	100-21000	21000
Odonata	*Epiproctophora (imm)*	82-24600	24600
Odonata	*Gomphidae*	82-5500	5500
Odonata	*Zygoptera (imm)*	100-37500	37500
Trichoptera	*Hydroptilidae*	135-5300	5300
Trichoptera	*Ecnomidae*	75-18500	18500
Trichoptera	*Hydropsychidae*	102-1885	1885
Trichoptera	*Leptoceridae*	82-38700	38700

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