APPENDIX O

Aquatic Fauna Assessment

CLIENTS | PEOPLE | PERFORMANCE

Vista Gold Australia Pty Ltd

Mt Todd Gold Project

Aquatic Fauna Study

May 2013

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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- *water quality data supplied by Vista Gold has been undergone appropriate QA/QC processes during the collection and processing of samples.*

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Executive Summary

Vista Gold Australia Pty Ltd (Vista Gold) is proposing to develop the Mt Todd Gold Project (the Project) consisting of the re-establishment, operation and rehabilitation of the Mt Todd Gold Mine. GHD conducted an aquatic fauna study to identify potential for impacts on the aquatic fauna and any required mitigation of those impacts.

Methods

Field sampling was undertaken in accordance with the Northern Territory AUSRIVAS sampling methodologies. The sampling methodology includes habitat, sediment and fish assessment along with macroinvertebrate sampling.

Sampling was conducted in the recessional flow period so as to capture the integrated effects of mine site runoff over the preceding wet season. This coincides with the optimal sampling time and is approximately four to six weeks after the last flushing (storm event) from wet season rains. This enables macroinvertebrates to recolonise stream habitats after disturbances from flooding.

Sites for the macroinvertebrate study were chosen to provide an assessment of the state of the aquatic environment in the footprint of the existing mineral leases. All sites were positioned to efficiently quantify existing conditions and detect impacts from future potential pollutants released from the Mt Todd Mine Site

Mt Todd Mine Site

A total of 6,520 macroinvertebrate specimens from 39 taxa were identified from three waterways during the 2011 investigation of the Minerals Leases. The Edith River and Stow Creek returned 33 taxa, while the Fergusson River returned 30 taxa.

The results demonstrate minimal impact on the Stow Creek and Edith River macroinvertebrate communities from, a long history of mine discharges.

The descriptive analysis of taxa diversity demonstrates that although there was a degree of variability in replicates for each site, the total numbers of families sampled at sites were consistent across the three waterways, regardless of their spatial relationship to existing discharge points.

The AUSRIVAS results show no discernible pattern in relation to the sites located upstream and downstream of the mine site. All sites returned an AUSRIVAS ranking of either band A or X, which indicates that the macroinvertebrate faunas are equal to (level A) or above (level X) what would be expected of a reference community at an un-impacted site in the Daly-Darwin region.

Background concentrations of iron, manganese and aluminium in sediment samples are relatively high across all sites, regardless of their location in relation to existing mine infrastructure. This is likely a function of local mineralisation and the macroinvertebrate communities of these waterways having presumably evolved and adapted to tolerate such concentrations.

The sediment samples demonstrate that metal contaminants from the mine are not being bound and retained by the sediment. The residual impact on the macroinvertebrate fauna after the initial first flush event is consequently likely to be minimal. Particle analysis indicates that the sediments have large particle sizes and minimal clay content (fines <63 µm).This configuration of particle sizes and low total organic carbon means that there are limited binding sites for metals.

The NT Government's previous biological sampling consistently failed to identify a significant impact from the mine discharge to the Edith River has. This may suggest one of two things. Either the discharge into Stow Creek and in turn Edith River is relatively benign, or the design of the monitoring failed to identify impact.

The inherent risk with sampling macroinvertebrate according to the NT AUSRIVAS program is that samples are taken during receding flow conditions (after the wet). Macroinvertebrate biodiversity is highest at this time, and has had time to respond to the flushing effects of the wet season. This contrasts with a potential impact from mine runoff and seepage that may be observable during the end of the dry season when the Edith River and Stow Creek are constricted to a series of refuge pools.

There has been no dry season sampling at the Mt Todd site. Impact from mine runoff and seepage is likely to be at its most observable during the end of the dry season. Dilution of contaminates by passing flow will be non-existent at this time. This would allow impacts to become apparent at the same time as the aquatic fauna would have reduced capacity to recolonise impacted pools.

Matters of National Significance

The Commonwealth protected matters search tool identified the study area as potential habitat for the freshwater crocodile (*Crocodylus johnstoni)* and freshwater sawfish (*Pristis microdon*).

Freshwater crocodile were observed during the course of the survey at the Mt Todd mine site. Freshwater crocodiles observed at the Mt Todd mine site were small (<1m) and are likely to be the young of the previous years' breeding. This indicates that suitable breeding habitat exists in the project area. This species is a listed marine species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and potential breeding habitat should be protected where in-stream works are required.

The freshwater sawfish has not been recorded as occurring in the Edith or Fergusson Rivers although it can be found in the broader reaches of the middle and lower Daly River. Given that the Edith River has been surveyed a number of times in relation to the mine operations, and that the Edith River is also popular recreational fishery, the lack of sawfish records is a strong indication that the Edith River does not constitute a significant habitat for this species.

1. Introduction

1.1 Project Overview

Vista Gold Australia Pty Ltd (Vista Gold) is proposing to develop the Mt Todd Gold Project (the Project) consisting of the re-establishment, operation and rehabilitation of the Mt Todd Gold Mine.

The Mt Todd Gold Mine site is located approximately 55 km north-west of Katherine and 250 km south of Darwin in the Northern Territory (NT).

1.1.1 Proposed Operations

Mt Todd mine site is a disturbed site previously mined for gold in the 1990s until the year 2000. Mining infrastructure such as tailing dam, waste rock dumps and remains of processing facilities remain on site.

Gold mining will be an open-pit truck and shovel operation, using large haul trucks, hydraulic shovels and front end loaders to transport materials to the crusher, stockpiles, Run of Mine (ROM) pad and waste dump. Extracted ore, approximately 17.8 million tonnes per annum (Mtpa), will be processed in an ore processing plant where it will be crushed, milled and then carbon in leach (CIL) leached followed by adsorption, desorption and recovery leading to gold dore (unrefined gold). Gold dore will be transported for onward secure shipment to a refinery.

Mining and associated operations will occur on primarily on Mineral Leases MLN 1070, MLN 1071 and MLN 1127, covering 5,365 ha. A small portion of EL 29886 will be inundated due to a raising of the raw water dam and a Special Purpose Licence will be applied for to accommodate this.

The Project, based on current known data, will have a life of around 19 years inclusive of construction, operations and closure. Construction is anticipated to commence in the first quarter of 2014 and take two years, including 6 months pre-production. The mine is scheduled to operate for a further 13 years. Closure and rehabilitation of the mine is expected to take four years.

1.1.2 Key Elements of the Project

The key elements of the Project are outlined below (Figure 1).

Mining and Mining Infrastructure

- extension of the existing Batman Pit from its current depth of 114m to approximately 588m and surface area of 40 hectares (ha) to approximately 137ha;
- expansion of the existing waste rock dump (WRD) from a height of 24m above ground level to approximately 350m above ground level (RL 470m), and a footprint of 70ha to approximately 217ha;
- construction of a Run of Mine (ROM) pad and ore stockpile;
- construction of an Ammonium Nitrate and Fuel Oil (ANFO) Facility;
- construction of heavy and light vehicle workshop and administration offices, and facilities comprising wash down area, tyre change facility, lube storage facility etc; and
- construction of haul roads and access roads.

Process Plant and Associated Facilities

- Ore Processing Plant capable of processing approximately 50,000 tonnes per day (tpd) of ore;
- processing and / or reclamation of the existing low grade ore (LGO) stockpile, and scats stockpile, and construction and processing of new LGO stockpile with a footprint of approximately 47ha;
- raising the existing tailings storage facility (TSF1) from 16m to 34m above ground level;
- construction of a new TSF2, approximately 300ha in area and up to 60m high (RL 175m);
- diversion of Horseshoe Creek and Stow Creek adjacent to TSF2 to provide flood protection;
- rehabilitation of the existing heap leach pad (HLP), if residual HLP material is not processed;
- chemical and reagent storage and handling facility; and
- process plant workshops, administration offices, control room etc.

Other Infrastructure

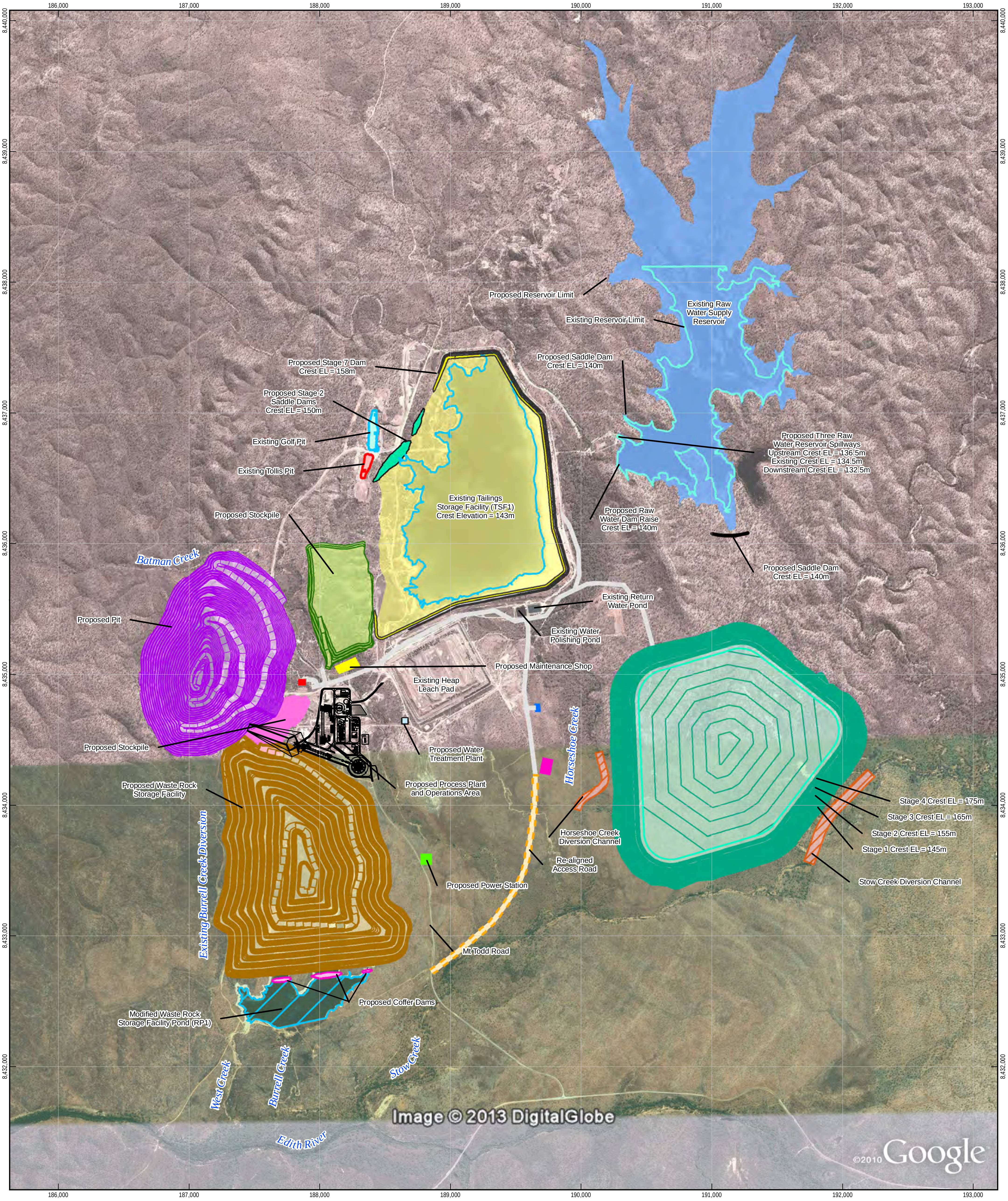
- gas fired Power Station, including re-routing of the existing gas pipeline;
- anaerobic treatment wetlands, approximately 10ha in area;
- a 2m high raising of the raw water dam (RWD) and an increase in the area of inundation;
- construction of saddle dams at the RWD and TSF1;
- water treatment plant;
- potential re-alignment of access roads;
- site wide drainage, sediment traps; and
- modification to existing fuel storage and distribution facility.

A surface water diversion west of TSF2 will direct Horseshoe Creek away from the new TSF2 footprint (Figure 2). The alignment for the diversion channel was determined to minimise excavation and the channel has been designed to meander to preserve natural conditions as closely as possible. The channel has been designed to accommodate a peak flow of approximately 182m^3/s comprising 100m^3/s of runoff from a 100 year, 24h storm event in the Horseshoe Creek catchment and 82m^3/s of overflow from the raw water supply dam. The channel will be lined with rip-rap to reduce scour and erosion, have a width and length of approximately 40m and 550m respectively, and have a nominal depth of 2.5m.

A surface water diversion along the south-eastern edge of TSF2 will direct Stow Creek away from the TSF2 footprint (Figure 3). The channel has been designed a peak flow of approximately 656m^3/s from a 100 year, 24h storm event in the Stow Creek catchment. The channel will be lined with rip-rap to reduce potential scour and erosion. The channel will have a width and length of approximately 60m and 850m respectively and a nominal depth of 4.2m.

The proposed diversions have been designed to meet required design criteria that include:

- the need to accommodate the highly variable flow regime associated with the wet and dry season;
- constraints imposed by the close proximity of the new tailings storage facility (TSF2);
- minimising the required level of excavation; and
- preserving the natural channel conditions as close as possible by maintain a meandering channel.



LEGEND

Process Plant	Power Plant	Explosives Magazine	TSF1 Existing Water Body	TSF2 Impounded Surface Area (Year 12)	Proposed Saddle Dam (Raw Water Dam)
Golf Pit	Proposed Haul Road	Diversion Channels	Proposed Saddle Dam	TSF2 Contours (Year 12)	Retention Pond 1
Tollis Pit	Re-aligned Access Road	Raw Water Dam Existing Water Body	TSF1	TSF2 Footprint (Year 12)	Batman Pit Footprint (Year 12)
Fuel Bays	Coffer Dams	Indicative Raw Water Dam	Low Grade Ore Stockpile Contours	Water Treatment Plant	Waste Rock Dump Contours (Year 10)
Proposed Maintenance Shop	ANFO Facility	TSF1 Contours	Low Grade Ore Stockpile	Batman Pit Contours (Year 12)	Waste Rock Dump Footprint (Year 10)

Stockpile

0 0.25 0.5 0.75 1
Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 53

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MT TODD

Vista Gold Australia Pty Ltd
Mt Todd Gold Project

Job Number 43-21801
Revision 0
Date 05 Jun 2013

Mt Todd General Facilities Arrangement

Figure 1

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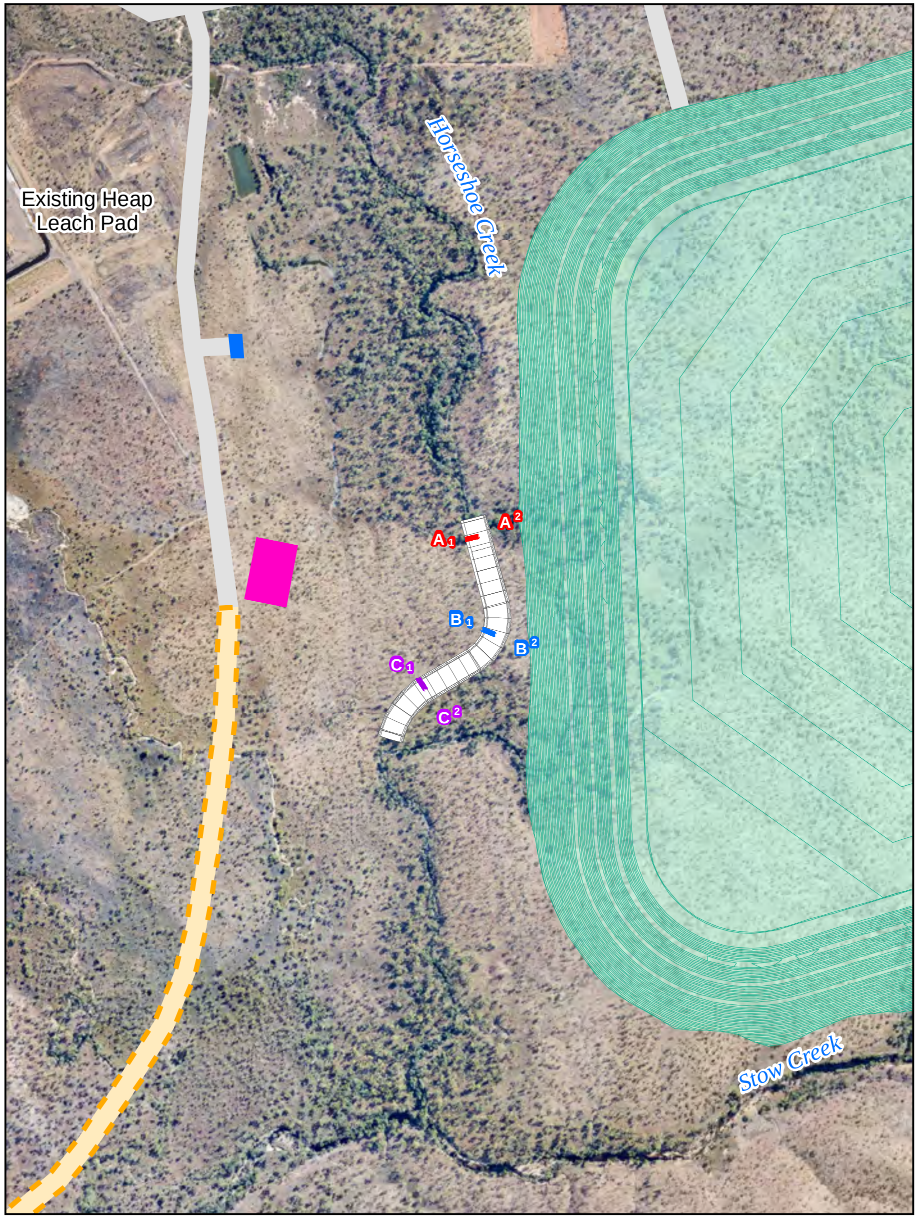
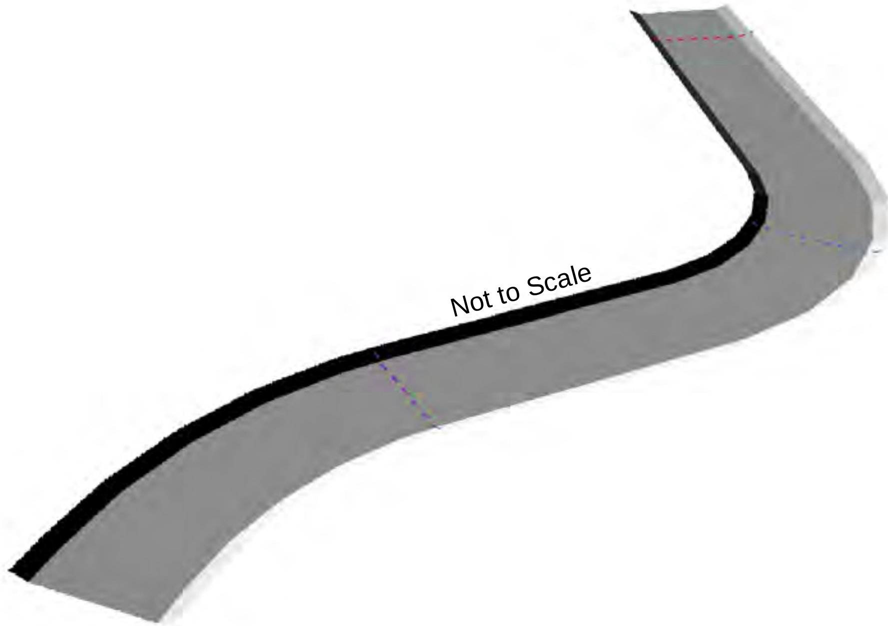
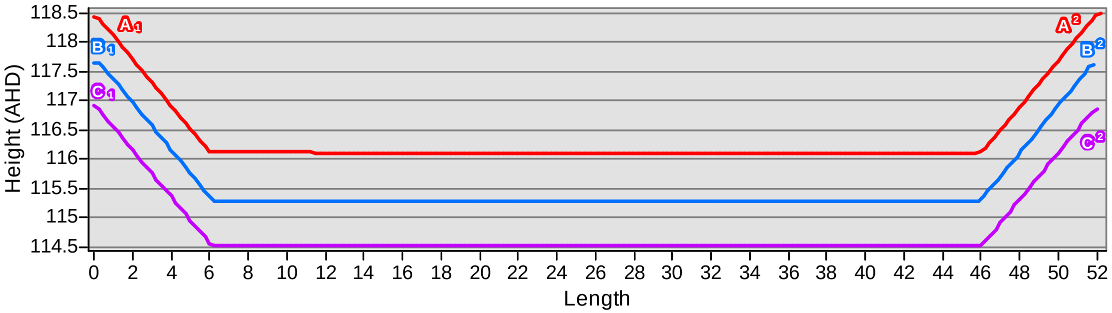
66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com.au

Data source: Tetra Tech - Process Plant, Golf Pit, Tollis Pit, Fuel Bays, Proposed Maintenance Shop, Power Plant, Realigned Roads, Proposed Haul Road, Coffer Dams, ANFO Facility, Explosives, Diversion Channels, Raw Water Dam Existing Water Body, Indicative Raw Water Dam, TSF1 Contours, TSF1 Existing Water Body, Proposed Saddle Dam, TSF1, Low Grade Ore Stockpile Contours, Low Grade Ore Stockpile, TSF2 Impounded Surface Area, TSF2 Contours, TSF2 Footprint, Water Treatment Plant, Batman Pit Contours, Proposed Saddle Dam (Raw Water Dam), Retention Pond 1, Batman Pit Footprint, Waste Rock Dump Contours, Waste Rock Dump Footprint, Stockpile (2013). Google Earth Pro - Imagery (Date extracted: 17/05/2013).
GHD - Creek Names (2011). Created by: CM





Horseshoe Creek Diversion Channel Cross Sections



Year 12 (all units in metres)

1:15,000 @ A4

0 100 200 300 400 500

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 53

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LEGEND

- Cross Section A
- Cross Section B
- Cross Section C
- Contours
- New Tailing Storage Facility (TSF2)
- ANFO Facility
- Explosives Magazine
- Proposed Haul Road
- Re-aligned Access Road

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Vista Gold Australia Pty Ltd
Mt Todd Gold Project

Horseshoe Creek
Diversion Channel

Job Number	43-21801
Revision	0
Date	29 May 2013

Figure 2

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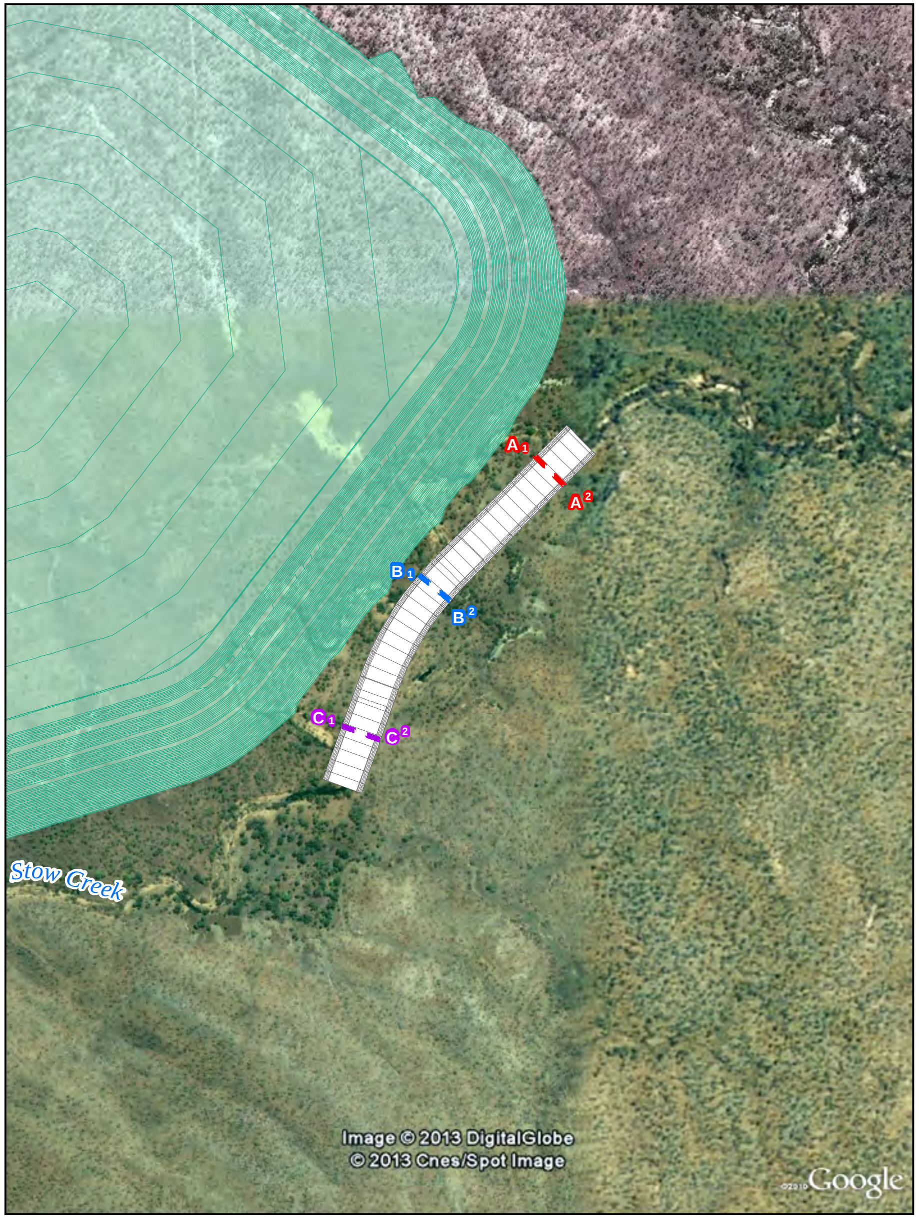
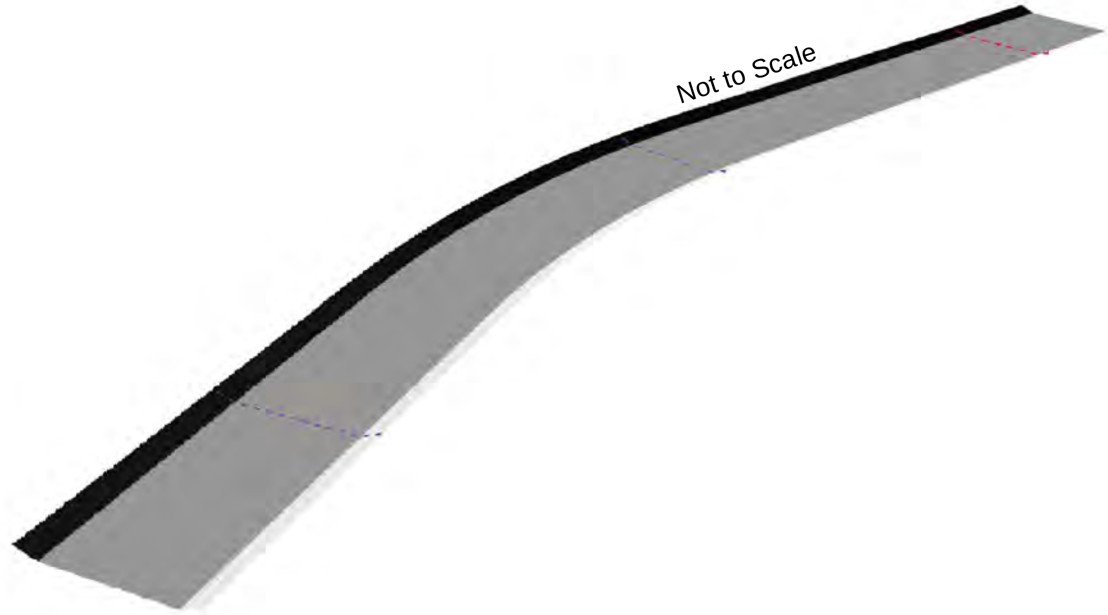
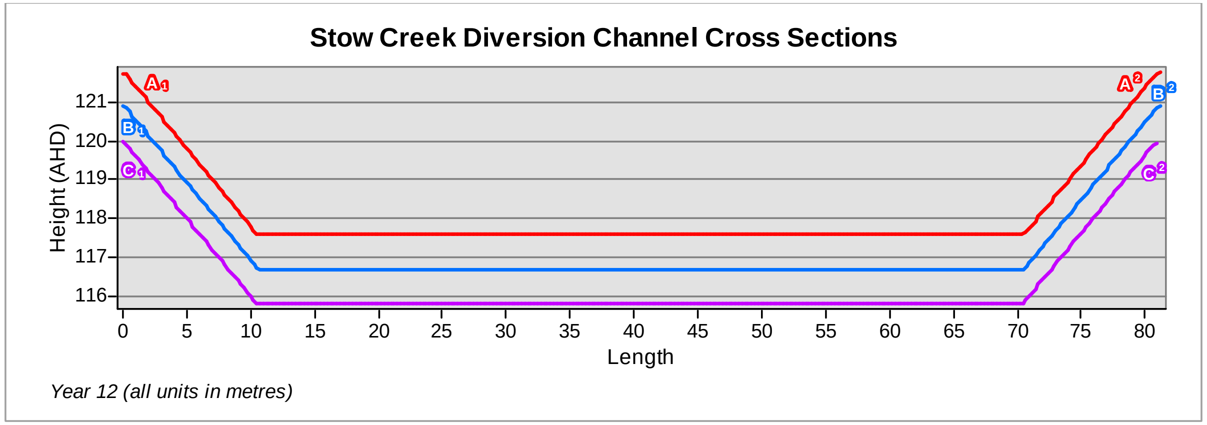
66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com.au

Data source: Vista Gold - Imagery (2012). Tetra Tech - TSF2, ANFO Facility, Explosives, Proposed Haul Roads, Re-aligned Access Road (2013). GHD - Cross Sections, 3D Model (2013). Created by: CM







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0 100 200 300 400 500

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 53

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LEGEND

- Cross Section A
- Cross Section B
- Cross Section C
- Diversion Channel Contours
- Tailing Storage Facility 2 Contours
- Tailing Storage Facility 2 (TSF2)

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Vista Gold Australia Pty Ltd
Mt Todd Gold Project

Job Number	43-21801
Revision	0
Date	29 May 2013

Stow Creek
Diversion Channel

Figure 3

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66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com.au

Data source: Vista Gold - Imagery (2012). Tetra Tech - TSF2, ANFO Facility, Explosives, Proposed Haul Roads, Re-aligned Access Road (2013). GHD - Cross Sections, 3D Model (2013). Created by: CM

1.2 Recent History

1.2.1 Waste Discharge Licence

Vista Gold originally accepted responsibility for Waste Discharge Licence (WDL) 135 on 1 January 2007. The licence was originally granted to the NT's Department of Primary Industries, Fisheries and Mines under Section 74 of the *Water Act 1992.* On the 5 February 2013, Vista Gold received a Waste Discharge Licence (WDL 178-2) from the Northern Territory Environment Protection Authority (EPA). The WDL outlines environmental requirements for protection of the Edith River from mine water discharges.

1.2.2 Commonwealth Referral

Vista Gold submitted a referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). The project was determined to be a controlled action due to the potential to have significant impact on listed threatened species and communities (sections 18 and 18A) and listed migratory species (sections 20 and 20A).

1.2.3 Northern Territory Regulators

The project was referred by the NT Department of Resources (DoR) on 21 April 2011 to the EPA (formerly NRETAS) for environmental assessment. In August 2011, the NT Minister for Natural Resources, Environment and Heritage determined that the Project requires formal assessment under the NT *Environmental Assessment Act 1982* (EA Act), at the level of an EIS. It will be assessed under an accredited assessment process between the NT and Commonwealth Governments.

The main concerns associated with the aquatic fauna of the Mt Todd mining area are related to:

- Acid and metalliferous drainage (AMD) in several of the retention pond areas; and
- Exposure of sulphide minerals in the mine's waste rock to air and water resulting in liberation of heavy metal ions such as zinc and copper, and sulphates into the retention ponds.

1.3 Specialist Study Objectives

This study aims to:

- describe the aquatic fauna in the project footprint and downstream of the mine site;
- discuss potential impacts from discharging mine water to the Edith River;
- evaluate the potential impacts of the proposed diversion of Horseshoe and Stow Creek; and
- identify mitigation measures to reduce potential impacts.

Previous studies of the aquatic fauna of the area are reviewed, sampling for water and sediment quality is carried out, and the aquatic fauna is described, results are evaluated, potential impacts assessed and possible mitigation proposed for impacts with high levels of risk.

2. Previous Studies

2.1 Water Quality

Potential sources of polluted surface mine water entering the Edith River from 2003 to 2008 included:

- discharge of Stow Creek into the Edith River;
- controlled siphon discharge from RP1; and
- discharge from West Creek, which receives overflow from RP1 via a spillway.

Stow Creek receives water intermittently from the ephemeral Batman Creek and Horseshoe Creek that run through the mine site. The creeks have historically received overflow and seepage from several mine site sources during heavy rainfall, including TSF1, retention ponds and HLP (Enviro Tech 2010).

Government monitoring has identified copper and zinc concentrations as two of the 'problem' contaminants for surface water in the Mt Todd area. High concentrations of these elements have deleterious effects on macroinvertebrate populations.

Variable water quality results were obtained over the 2003-2007 sampling period (Enviro Tech 2010). Parameters including copper, cadmium and zinc consistently exceeded the ANZECC (2000) 95% species protection water quality guidelines. The reference site concentrations of metals often exceeded the impact site levels. Site specific concentrations of dissolved copper and zinc over the 2003-2008 sampling period are presented in Figure 4 and Figure 5 respectively. The ANZECC Guideline species protection concentrations for each metal are presented on the graphs to allow comparison with the observed levels. The patterned bars in the figures highlight reference sites on the Fergusson River.

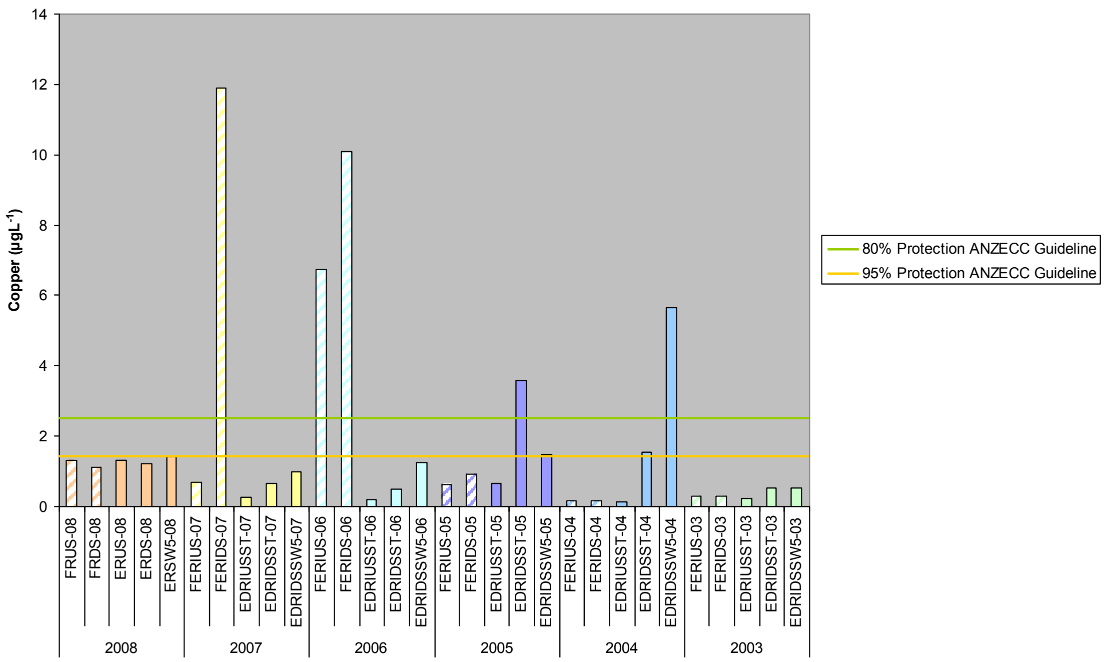


Figure 4 Levels of copper found at the macroinvertebrate sampling sites during sampling periods (patterned bars indicate reference sites) (Data sourced Enviro Tech 2010).

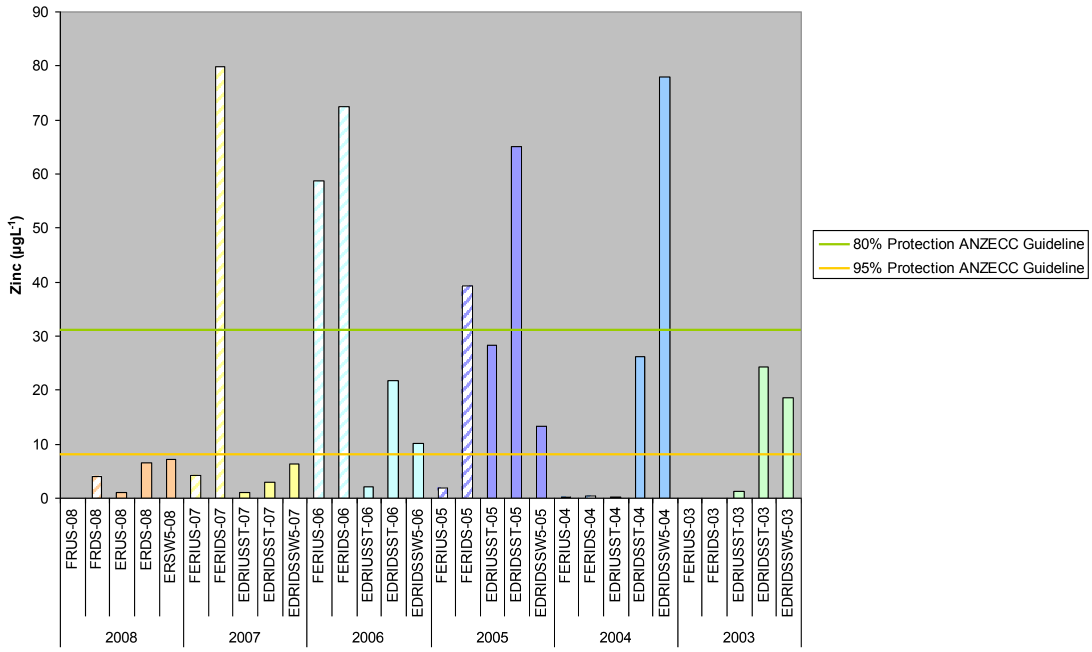


Figure 5 Levels of zinc found at the macroinvertebrate sampling sites during sampling periods (patterned bars indicate reference sites) (Data sourced Enviro Tech 2010).

Sampling during 2006 and 2007 (Enviro Tech 2010) had dissolved copper and zinc concentrations significantly higher at the reference waterway than in the receiving waterway. The levels substantially exceeded the ANZECC 80% species protection guidelines. The measured elevations may indicate that the Fergusson River site is unsuitable as a reference site. Impacts on the Edith River may not be detected if the Fergusson River reference site measurements are used as the sole reference.

2.2 Macroinvertebrates

Macroinvertebrates were monitored by ERIS and Enviro Tech Monitoring between 2003 and 2010 according to the NT AUSRIVAS framework. The data was provided by Vista Gold at the commencement of the project. The monitoring was designed to detect impacts of mine discharge waters on the surface water biota of the Edith River.

The sampling program from 2003-2010 used a reference/impact site comparison whereby the similarity in community composition of reference sites was compared to that of the community compositions of potential impact sites. The rationale of this comparison was that an impact is detected if the percentage similarity between up and downstream reference sites in higher than that of the up and downstream impact sites. Conversely, if the impact sites have a higher percentage similarity than the reference locations, then no impact is detected. Previous reports have not measured the statistical significance of differences. Interpretations of results make the assumption that differences between two points on the Fergusson River are similar to the difference between two points a similar distance apart on the Edith River.

The sites selected and included in the similarity calculations for the latest reporting period (2008) were:

- Edith River Upstream of Stow Creek Confluence (ERUS);
- Edith River Downstream of Stow Creek Confluence (ERDS);
- Edith River Downstream of Site SW4 (ERSW4);
- Fergusson River Upstream (FRUS); and
- Fergusson River Downstream (FRDS).

Samples were sub-sampled at a laboratory with only a portion of the total macroinvertebrates identified. Actual macroinvertebrate abundances were extrapolated from the percentage identified. The macroinvertebrates were generally identified to family level. Several families were taken to genus and even species level with no systematic resolution within orders defined in the report i.e. families were identified to the same level of resolution.

A Bray-Curtis similarity matrix was generated after transforming the data using a 4^{th} root transformation. The 2008 report included the similarity matrices for the five sites previously mentioned from 2003 to 2008.

The matrices compared percentage similarity pair-wise between the three Edith River sites and the two Fergusson River sites. The reference site similarity was subsequently compared with the Edith River similarities and a decision made as to whether an impact was detectable or not.

The 2008 report detected no impact from the mine site. This was based on the reference sites being less similar to one another than were the Edith River sites. The statistical methodology indicated that an impact was detected only once during the entire history of the sampling program. This was in 2004 when an 85.5% similarity was calculated for the reference sites and 72% (ERUS-ERDS), 66.8% (ERSW4-ERUS) and 74.4% (ERSW4-ERDS) for the impact site locations.

2.3 Fish

Surveys of fish in the Edith River (detailed in 2.3.2 and 2.3.3) have identified a relatively diverse fish fauna in and around the Mt Todd Mine site. However, limited data is available for Stow Creek.

2.3.1 EPBC Protected Matters Search Tool

The Commonwealth Department of SEWPAC's online Protected Matters Search Tool (PMST) was used by GHD (22/2/2011) to identify potential matters of national environmental significance, as defined under the EPBC Act.

This search tool returns an Environmental Report that contains flora and fauna species listed in one or more provisions of the EPBC Act, and is based upon the predicted distribution of flora and fauna species and/or their habitat. This means that the PMST may predict the potential occurrence of a species or its habitat in an area even though there may be no documented records. Information was downloaded on 16 June 2011 in the form of an Environmental Report. Listed species likely to be associated with the river and riparian habitats are provided in Table 1.

Table 1 EPBC Listed Species

Scientific Name	Common Name	EPBC Status
Pristis microdon	Freshwater sawfish	Vulnerable
Crocodylus johnstoni	Freshwater crocodile	Listed Marine

2.3.2 EPA Supplied Data

The EPA fauna database does not contain fish data. Data on the presence of other aquatic species in the mineral leases are provided in Table 2.

Table 2 EPA Species List for Mt Todd Mine Site

Scientific Name	Common Name
Amphibia	
Platyplectrum ornatus	Ornate Burrowing Frog
Crinia bilingua	Bilingual Froglet
Litoria australis	Giant Frog
Litoria bicolor	Northern Dwarf Tree-frog
Litoria caerulea	Green Tree-frog
Litoria coplandi	Copland's Rock Frog
Litoria inermis	Peters' Frog
Litoria meiriana	Rockhole Frog
Litoria nasuta	Rocket Frog
Litoria pallida	Pale Frog
Litoria rothii	Roth's Tree-frog
Litoria rubella	Red Tree-frog
Litoria tornieri	Tornier's Frog
Litoria wotjulumensis	Wotjulum Frog
Rhinella marina	Cane Toad
Reptiles	
Crocodylus johnstoni	Freshwater Crocodile
Elseya dentata	Northern Snapping Turtle
Emydura victoriae	Short-necked Turtle

2.3.3 Mt Todd Fish Survey 2008, Mine Evaluations – Authorisations & Evaluations Division

The most recent fish survey was in 2008 in response to the possible toxicity of mine discharge to Edith River (Welch 2009). Fish were surveyed during the mid-dry season on the 5th- 6th August, a period when pools had formed in the river channel and fish were concentrated in a small area facilitating sampling.

Two sites were sampled on Edith River; one upstream and one downstream of the mine. The upstream site was located approximately 1 km upstream of the Edith River-Stow Creek confluence at the bridge crossing of the Edith Falls Road. The downstream site was located downstream of the Retention Pond 1 discharge point and the Edith River-Stow Creek confluence (i.e. downstream of all mine site influence).

The sites were chosen to maximise similarities in fish habitats, although this was constrained to some extent by the accessibility of boat launching locations. Both sites were 50 – 80 m long pools that had similar depths and widths. A total of 17 fish species were recorded during the survey, including 14 at the upstream site and 7 at the downstream site. Fish species sampled are detailed in Table 3.

Table 3 Species Sampled (Welch 2009)

Species	Common Name	Abundance Upstream	Abundance Downstream
Ambassis agrammus	Sail-fin glassfish	1	
Amniataba percoides	Banded grunter	1	
Anodontiglanis dahli	Toothless catfish	1	
Arius sp.	Fork-tailed catfish	(1)	
Craterocehalus stercusmuscarum	Fly-specked hardyhead	(2)	1
Glossamia aprion	Mouth almighty	1	
Hephaestus fuliginosus	Sooty grunter	(2)	4
Lates calcarifer	Barramundi	4 (1)	
Leiopotherapon unicolor	Spangled grunter	1	2
Megalops cyprinoides	Tarpon		4 (20)
Melanotaenia australis	Western rainbowfish	15 (100+)	35 (100+)
Mogurnda mogurnda	Purple-spotted gudgeon		1
Nematolosa erebi	Bony bream	2	
Neosilurus ater	Black catfish		1
Oxyeleotris lineolata	Sleepy cod	1	
Strongylura kreffti	Long tom	(1)	
Syncomistes butleri	Butler's grunter	4	
Total No. Species		**14**	**7**

Note: Counts shown in brackets are from visual observations.

Tissue analyses indicated that concentrations of some metals were higher in fish tissues collected at the site downstream than those collected upstream of the mine, particularly in liver tissue (Welch 2009). The downstream concentrations were not substantially higher. Welch (2009) stated that it indicated a potential influence from the mine.

2.3.4 Mt Todd Gold Project, Edith River Aquatic River Survey April 1992

In 1992 AGC Woodward-Clyde conducted an aquatic survey in the vicinity of the Mt Todd mine on behalf of Zapopan NL. The objectives of the study were to describe the freshwater environment of the Edith River in the general vicinity of the then proposed water off take for the mine and the weir area for the Mt Todd water supply.

A total of eleven fish species were recorded from three sites near Mt Todd, with fourteen fish species recorded at Edith Falls. The most frequently recorded species from the three Mt Todd sites were the 'redtailed' rainbowfish (*Melanotaenia australis*) and barred grunter (*Syncomistes butleri*).

Ryan (1992) summarised previous studies including one on Horseshoe Creek (Martin 1990). Table 4 provides a collective summary of the fish species caught in, and around, the Mt Todd Mine site.

Table 4 Summary of Species Recorded in Previous Surveys (Ryan 1992)

Scientific Name	Common Name	Fergusson R. (1)	Edith R. near Mt Todd (2)	Horseshoe Ck. (3)	Edith Falls (2)
Megalops cyprinoides	Tarpon				
Anodontiglanis dahli	Toothless catfish				
Nematolosa erebi	Bony bream	x	x		x
Arius sp.	Fork-tailed catfish	x	x		
Arius midgleyi	Shovel nose catfish	x	x		
Neosilurus ater	Black catfish				x
Neosilurus hyrtlii	Hyrtles catfish			x	x
Neosilurus sp	false spine catfish	x			
Strongylura kreffti	Long tom	x	x		x
Craterocehalus stercusmuscarum	Fly-specked hardyhead	x	x		x
Craterocehalus stramineus	Strawman	x			
Melanotaenia australis	Western rainbowfish	x	x	x	x
Melanotaenia exquisite	Exquisite rainbowfish				x

Scientific Name	Common Name	Fergusson R. (1)	Edith R. near Mt Todd (2)	Horseshoe Ck. (3)	Edith Falls (2)
Lates calcarifer	Barramundi	x			
Ambassis macleayi	Reticulated glassfish		x		x
Ambassis agrammus	Sailfin glassfish	x	x	x	x
Hephaestus fuliginosus	Sooty grunter	x	x		x
Leiopotherapon unicolor	Spangled grunter	x	x	x	x
Amniataba percoides	Banded grunter	x	x	x	x
Syncomistes butleri	Butler's grunter		x		x
Glossamia aprion	Mouth almighty	x	x		x
Toxotes charareus	Common archerfish	x	x		
Liza alata	Diamond mullet	x			
Mogurnda mogurnda	Purple-spotted gudgeon				x
Oxyeleotris lineolata	Sleepy cod				
Glossogobius giurus	Flathead goby	x			x
Total No. of Species	**27**	**17**	**14**	**5**	**16**

Sources: [1] Midgley (1980), Allen (1989); [2] Martin and Goodfellow (1988); [3] Martin (1990)

2.4 Horseshoe Creek Water Quality and Flows

Seepage from TSF1 currently makes its way into Horseshoe Creek (HSC). Earth Systems (2011) reported that areas of visible seepage were identified on the western bank of the creek. This seepage area extended for approximately 20 metres and had an estimated flow rate of a few litres per minute. They also found that water quality data for a sample collected from HSC at location HSC-10 is characterised by high sulfate (1,230 mg/L), thiocyanate (30.8 mg/L), and high ammonia concentrations (14.1 mg/L NH_3-N).

Earth Systems (2011) found that field water quality data collected along Horseshoe Creek show a general trend of increasing EC moving south along HSC, with EC values increasing from 30 µS/cm up hydraulic gradient of the TSF to 2,200 µS/cm further downstream (down hydraulic gradient of the TSF). Some areas of ponded water occur along Horseshoe Creek. Horseshoe Creek has visible Fe-precipitates.

There is an existing gauging station located on Horseshoe Creek which monitors continuous flow, electrical conductivity and pH. Records for this gauging station date back to 17/12/2008 (Envirotech Monitoring 2012). Demonstrated in Figure 6, this figure shows a strong relationship between flow and electrical conductivity where low flow periods directly correspond with high conductivity levels, providing further evidence that seepage has an influence on Horseshoe Creek.

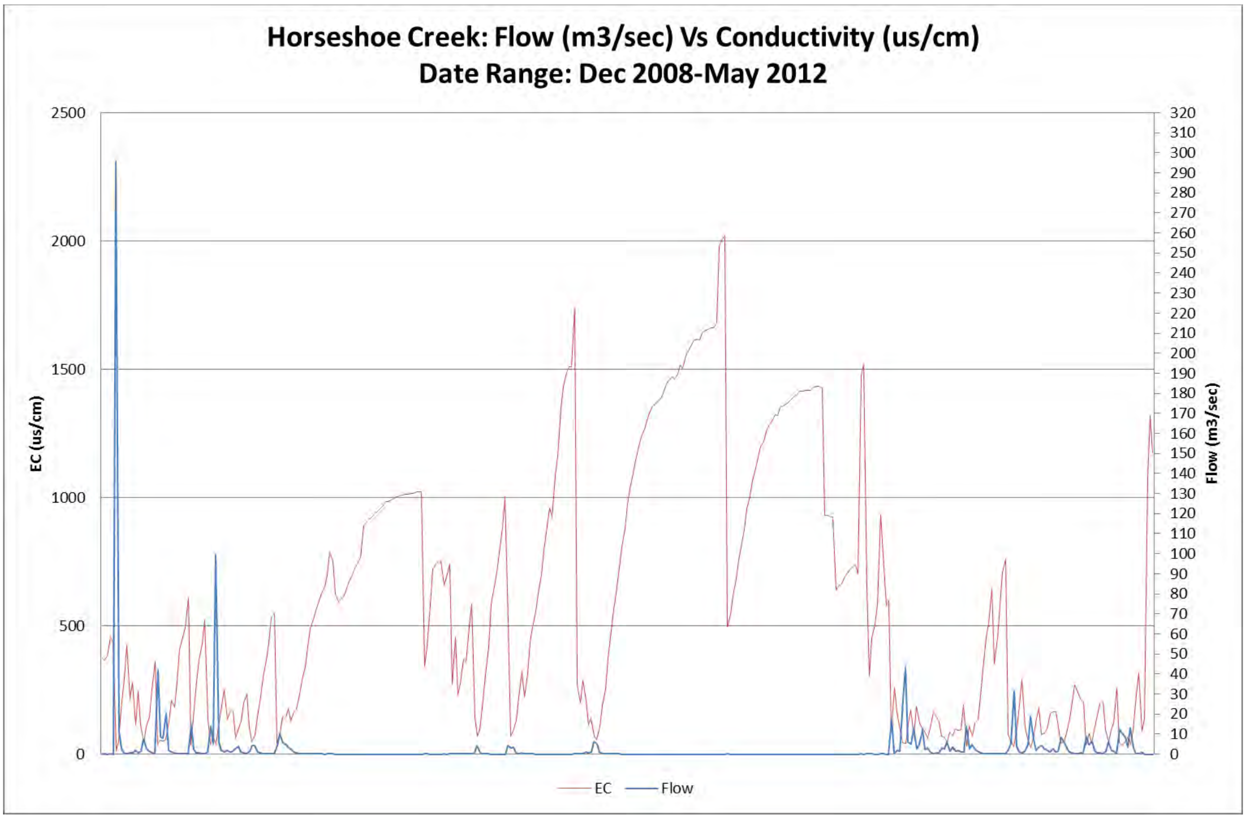


Figure 6 Horseshoe Creek SW11 Gauging Data (Daily Average)

3. Survey Methods

3.1 Sample Sites

Sampling sites have been split into two groups:

- Water and Sediment Quality, Habitat and Macroinvertebrates Survey; and
- Fish Survey.

3.2 Water and Sediment Quality, Habitat and Macroinvertebrates Survey

3.2.1 Introduction

Sites for water, sediment, habitat and macroinvertebrate sampling were chosen to provide an assessment of the state of the aquatic environment in the footprint of the mineral leases and adjacent waterways. Sites were positioned to efficiently quantify existing conditions and allow for detection of impacts from future potential pollutant sources.

Sites sampled included those sampled during 2003-2008 monitoring programs and additional sites. Use of new and previously used sites allows for use of the longer term monitoring data and provides improved capacity to detect potential impacts.

Sites were located on the following waterways:

- **Edith River:** The Edith River rises at an elevation of 257 m and ends at an elevation of 81.8 m where it merges with the Fergusson River, dropping approximately 175 m over its 69.1 km length.

  The Edith River is the largest waterway in the immediate vicinity of the mine and has been the recipient of mine overflow waters via Stow Creek and West Creek. It has received licensed discharge from RP1. The river has been intensively sampled because it is the end receiving environment for the majority of the Mt Todd Mine Site catchment.

- **Fergusson River:** The Fergusson River rises at an elevation of 296 m and ends at an elevation of 54.1 m, merging with the Daly River, dropping approximately 242 m over its 144 km length.

  Several creeks and rivers flow into the Fergusson River. The five longest tributaries are: Edith River, Wandie Creek, Cullen River, Driffield Creek and Bondi Creek.

  This River has been used as a reference waterway for the Edith River. It sampled as part of this investigation to provide continuity of available data;

- **Stow Creek:** Stow Creek rises at an elevation of 275 m and ends at an elevation of 116 m were it flows into the Edith River, dropping approximately 159 m over its 25.1 km length. The Mt Todd Mine Site is located at the bottom end of Stow Creek, with approximately 5 km of creek frontage through the existing mineral leases. The confluence of Stow Creek and Edith River are in the boundary of the mineral leases.

  This waterway sporadically receives water from the ephemeral Batman and Horseshoe Creeks that run through the Mt Todd Mine Site. According to the 2010/11 Water Management Plan (WMP) for the mine, large rainfall events can result in overflow from the RP2 and RP5 catchments into Batman Creek, and from the mine's RP7 tailings dam into Horseshoe Creek.

Ephemeral waterways of interest that were dry and could not be surveyed included:

- **Burrell Creek:** This is the discharge location for the controlled release of mine water from the waste rock retention pond (RP1). It feeds directly into the Edith River. Water can only be released in a controlled manner from RP1 when appropriate water levels are reached in the Edith River;
- **West Creek:** This small ephemeral creek discharges directly into the Edith River. It is the direct receiving environment for RP1 site spillway, which can spill in an uncontrolled manner during heavy rainfall events;
- **Batman Creek:** This is a small ephemeral creek that can potentially receive runoff from the mines various facilities during the wet season. The creek flows directly to Stow Creek; and
- **Horseshoe Creek:** This is a small ephemeral creek that can potentially receive runoff from the mine's various facilities during the wet season. It flows directly to Stow Creek. Horseshoe Creek also receives good water quality flow from the raw water dam during high flow periods.

3.2.2 Site Details

The locations of sites are detailed in Table 5.

Table 5 Site Details

Site	Details	Rationale
SC1 SC2 SC3	Three Stow Creek sites upstream of its confluence with Horseshoe Creek.	These sites act as an upstream reference for two sites further downstream
SC4	Stow Creek site downstream of its confluence with Horseshoe Creek.	This site was established to indicate whether the health of the creek is affected by water input from Horseshoe Creek;
SC5	Stow Creek site downstream of its confluence with Batman Creek.	This site was located to indicate whether the health of the creek is affected by water input from Batman Creek and can be used to differentiate between the input effects of Horseshoe and Batman Creeks.
ERUS	Edith River site upstream of its confluence with Stow Creek.	This site was located to represent upstream reference conditions in Edith River for comparison with downstream sites
ERDS	Edith River site downstream of its with Stow Creek.	This site was located to detect change as a result of discharge from Stow Creek
ERSW4	Edith River site downstream of the RP1 discharge location and West Creek confluence.	This site was located to detect change to the Edith River macroinvertebrate community following both controlled and uncontrolled discharge from these two point sources;
FRUS FRDS	Fergusson River reference sites.	These sites will be used for reference comparisons to similar sites from the Edith River and provide temporal change comparisons between the waterways.

Each site was sampled for water quality and macroinvertebrates, with sediments sampled at the Stow Creek and Edith River sites. The locations of the sites are presented in Table 6 and Figure 7, with reference photographs of each site provided following.

Two reference sites on the nearby Fergusson River that were sampled previously were also sampled (Figure 8). The configuration of replicated exposed (subject to a potential source of contaminants) and reference sites (not subject to a potential sources of contaminants) enables formal statistical comparisons of measured variables to be made between sites of the different exposure types over time.

Table 6 Site Coordinates

Site	Latitude	Longitude
SC1	14.14671	132.14693
SC2	14.15298	132.14260
SC3	14.15592	132.12948
SC4	14.15520	132.12810
SW3/SC5	15.16057	132.11936
ERUS	14.17172	132.11923
ERDS	14.17005	132.11233
ERSW4	14.17140	132.10354

Detailed habitat descriptions for each individual survey site are provided in Appendix A.

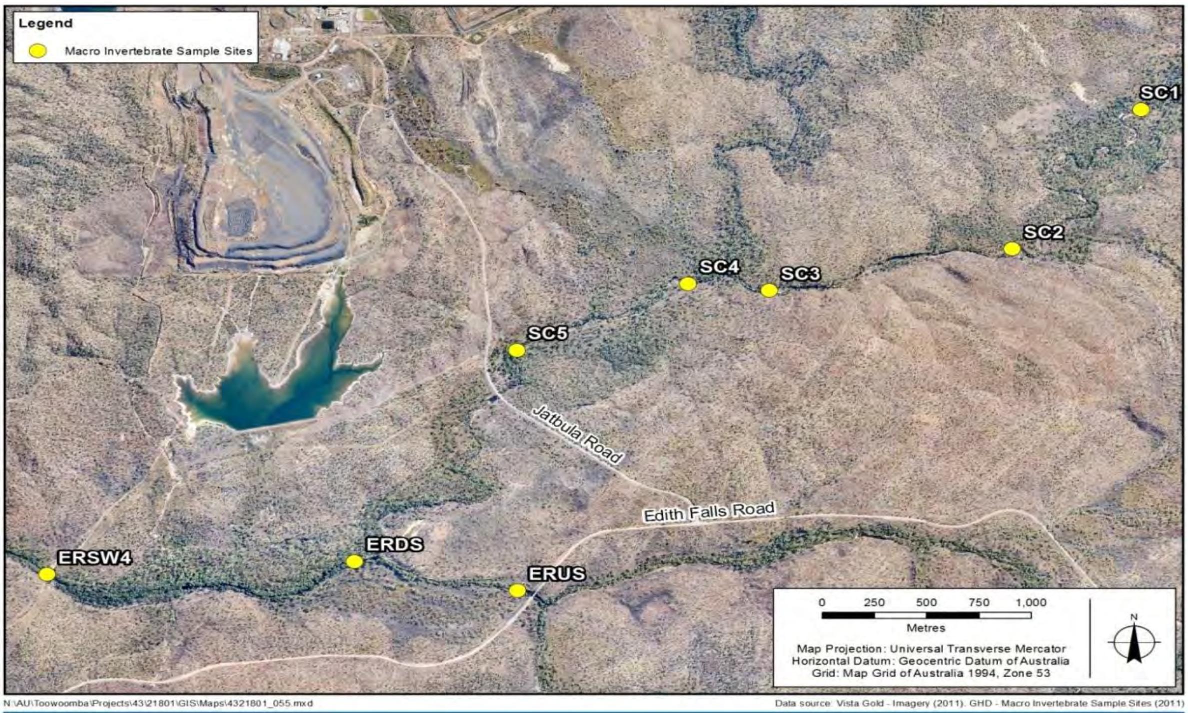
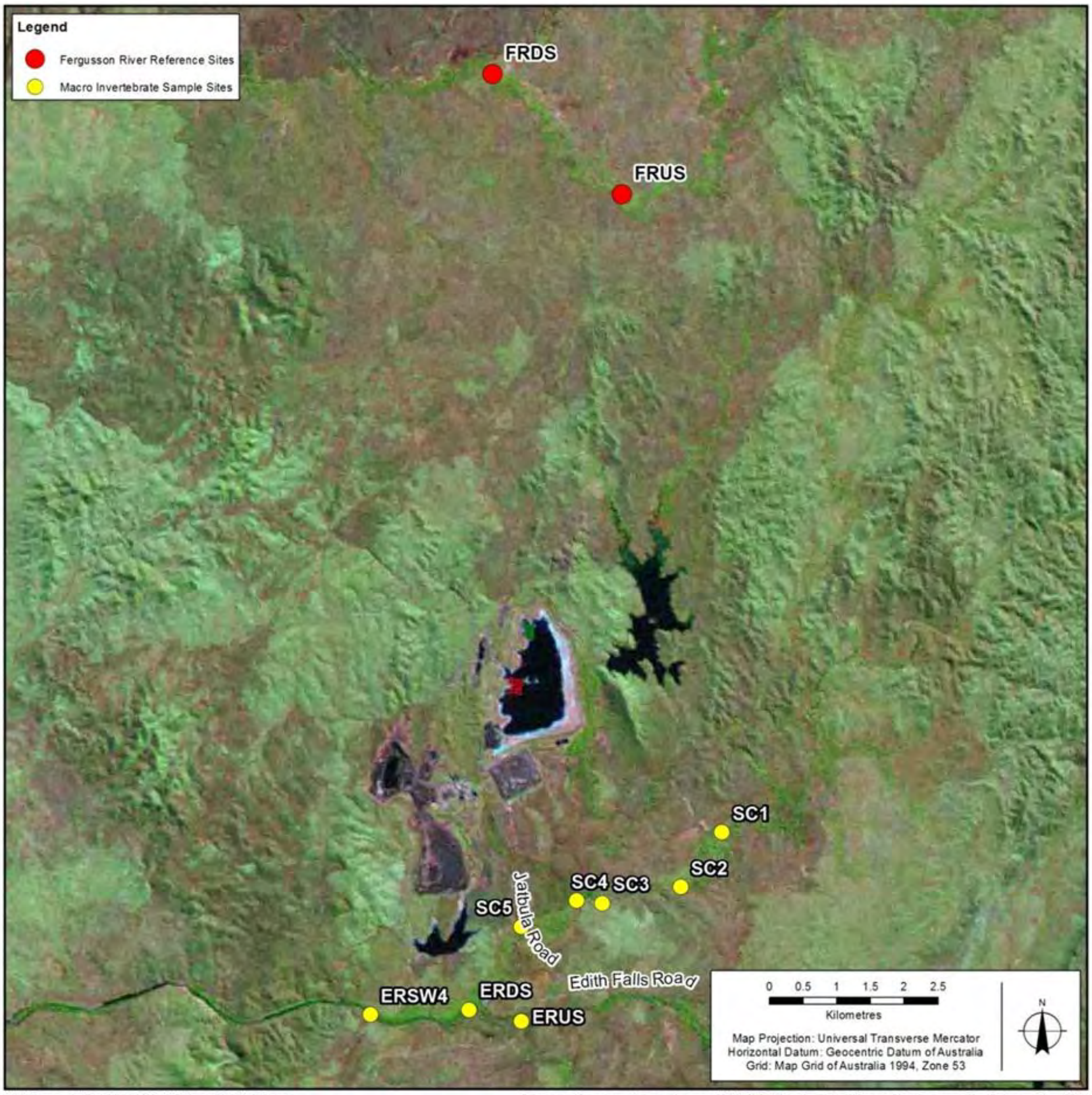


Figure 7 Mt Todd Macroinvertebrate Sample Sites



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Data source: Geoscience Australia - Imagery (2011). GHD - Macro Invertebrate Sample Sites, Fergusson River Reference Sites (2011)

Figure 8 Fergusson River Reference Sites (in context with Mt Todd)

Stow Creek - Mt Todd Sample Sites

Stow Creek 1 (SC1)

Photo 1 SC1 Downstream View

Photo 2 SC1 Upstream View

Stow Creek 2 (SC2)

Photo 3 SC2 Downstream View

Photo 4 SC2 Upstream View

Stow Creek 3 (SC3)

Photo 5 SC3 Downstream View

Photo 6 SC3 Upstream View

Stow Creek 4 (SC4)

Photo 7 SC4 Downstream View

Photo 8 SC4 Upstream View

Stow Creek 5 (SC5)

Photo 9 SC5 Downstream View

Photo 10 SC5 Upstream View

Edith River - Mt Todd Sample Sites

Edith River Downstream (ERDS)

Photo 11 ERDS Downstream View

Photo 12 ERDS Upstream View

Edith River Upstream (EDUS)

Photo 13 ERUS Upstream View

Photo 14 ERUS Downstream View

Edith River Surface Water Site (ERSW4)

Photo 15 ERSW4 Upstream View

Photo 16 ERSW4 Downstream View

Fergusson River - Mt Todd Sample Sites (Reference Sites)

Fergusson River Upstream (FRUS)

Photo 17 FRUS Downstream View

Photo 18 FRUS Upstream View

Fergusson River Downstream (FRDS)

Photo 19 FRDS Downstream View

Photo 20 FRDS Upstream View

3.3 Fish Survey

Sampling was designed to supplement and update past survey data (Midgley 1980; Allen 1989; Martin and Goodfellow 1988: Martin 1990; Ryan 1992; Welch 2008). The historic data was collected for Edith River, Fergusson River and Horseshoe Creek. There was no data on the fish fauna of Stow Creek.

Four sites were surveyed during the 2011 assessment. These were:

- Three sites on Stow Creek (FS1, FS2 & FS3); and
- One site on the Edith River (FE1).

The location of these sites is presented in Figure 9.

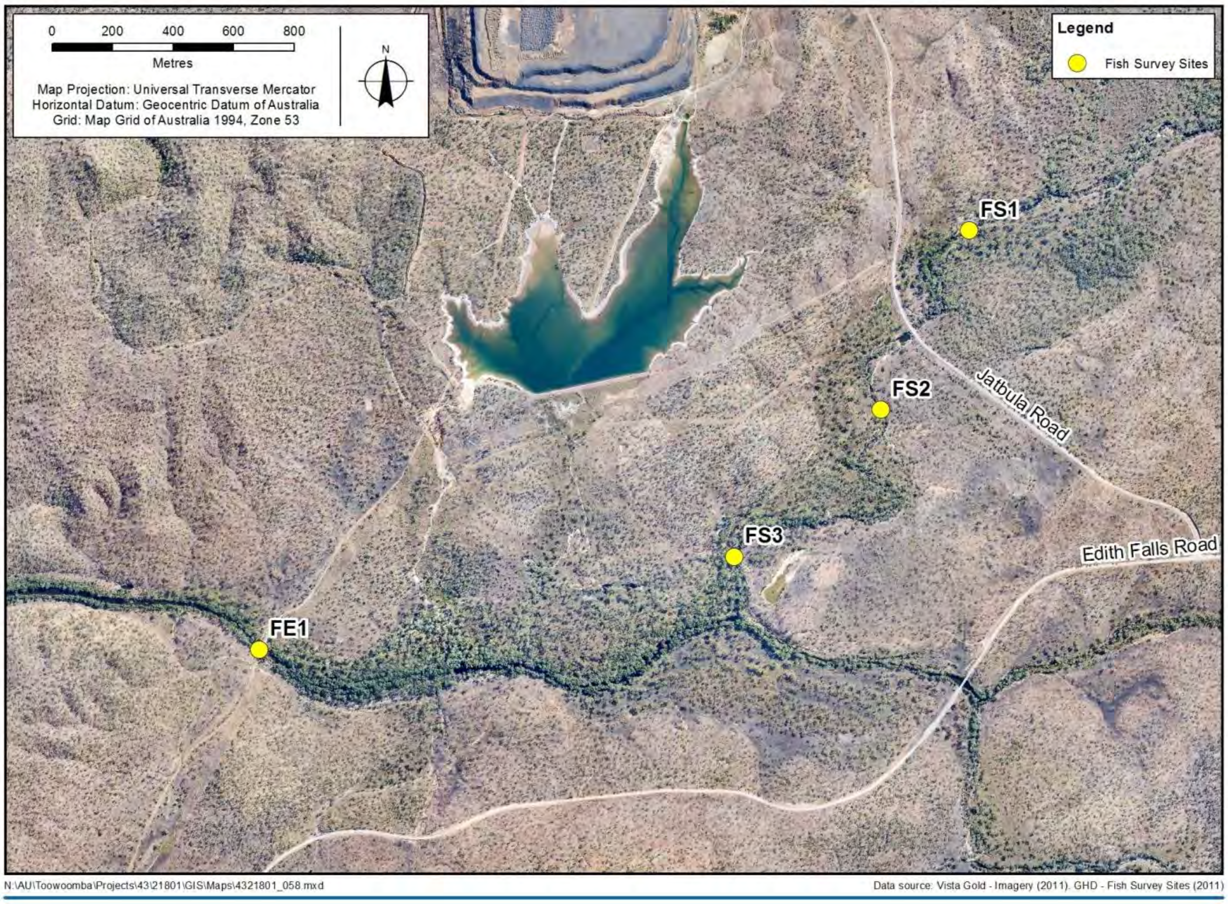

Figure 9 Fish Survey Sites Mt Todd (March 2011)

3.4 Survey Timing

3.4.1 Water and Sediment Quality, Habitat and Macroinvertebrates

Sampling was conducted in the period of recessional flow. The optimal sampling time is approximately four to six weeks after the last flushing (storm event) from wet season rains. By this time the macroinvertebrates have recovered from possible impacts from contaminated water in ponds during the dry season, and had the opportunity to re-colonise stream habitats following disturbances from flooding.

The Mt Todd Mine Site was sampled on the 2nd to the 6th of May 2011 i.e. during the late wet-recessional flow period of 2010-2011. There were adequate to good flow conditions at all sites at the time of sampling. The 2010-2011 wet season was particularly wet, with high flood flows experienced in the greater Daly River catchment.

3.4.2 Fish Survey

The fish survey was completed in on the 2nd to the 6th of May 2011.

3.4.3 Inspection of Horseshoe Creek and Stow Creek

Horseshoe Creek was inspected during the dry season on the 16th May 2011.

3.5 Sampling Methods

Sampling methods for water and sediment quality, habitat assessment, macroinvertebrates and fish conform to the requirements of the NT AUSRIVAS sampling methodologies.

3.5.1 *In-situ* Water Quality Sampling

Field measurements of water temperature, pH, electrical conductivity, dissolved oxygen and turbidity were performed at all sites using a calibrated TPS 90-FL multi-parameter water quality meter. Water quality measurements were taken at the halfway point of the 100 m reach. Water quality monitoring data are presented in GHD 2013.

3.5.2 Sediment Quality Sampling

A single composite of three sediment grabs were collected at each of the Edith River and Stow Creek sites. Samples were taken from 'edge' habitat using a sediment grab and subsequently homogenised to form the final sample. Labelled jars were filled and placed in chilled eskies for transport to a National Association of Testing Authorities (NATA) accredited laboratory.

Sediments were analysed for:

- Particle size distributions;
- Dissolved metals using a weak acid (1M HCl) digest method; and
- Total organic carbon.

Particle size distribution was analysed at each site to demonstrate the binding potential of sediments and to highlight any correlations between contaminant level and particle size.

Sediment quality data were analysed to determine the degree of contamination and potential impact (comparison of values against published national guidelines) on Stow Creek and the Edith River. The analyses aim to assist in providing an understanding of the relationship between environmental conditions and macroinvertebrates.

3.5.3 Habitat Assessments

Habitat assessments were conducted over a 100 m reach at each site, 50 m upstream and downstream of the central macroinvertebrate sampling point. Data input into the NT AUSRIVAS habitat sheets included the assessment of several habitat variables, including stream width, substrate type and presence of any snags or macrophytes.

3.5.4 Macroinvertebrate Sampling

There is one annual sampling period for the Darwin-Daly regional models, namely the early dry season. Macroinvertebrate responses at this time integrate the effects of wet season water quality events while maximum biodiversity is also captured during this period. Both of these factors provide an appropriate basis for comparing sites in the AUSRIVAS framework (Lamche and Gisela 2007).

Samples were collected at the mid-point of each of the 100 m reach used for sampling. Three 10 m long edge sweep samples were taken at each site using a 250 micrometre (µm) sweep/dip net with an opening of 250 x 250 mm. The samples were sieved to remove large detritus and stored in 70% ethanol for transportation to the laboratory for identification and enumeration.

Subsamples of the macroinvertebrates were kept for laboratory identification. The subsamples contained a minimum of 3% of a total sample.

Macroinvertebrates were identified to family level using the keys recommended by Hawking (1999) with the exceptions of Oligochaeta (Class), Acarina (Order) and Chironomidae (Sub-Family). Adults and larvae for each beetle family were combined for the AUSRIVAS model input.

The raw macroinvertebrate data for the Mt Todd Mine Site are presented in Appendix B.

3.5.5 Fish Sampling

A quantitative assessment of the fish community was not possible. There was a recent sighting of a large crocodile in the area. This restricted the access for setting nets and biased the sampling to shallow (<1 m) habitats.

All fish surveys were undertaken under NT Fisheries Special Permit No 2010/S17/3224 Fish species were identified, measured and counted in the field and returned to the water at the site of capture.

Fyke nets were used as the primary method for fish sampling. Fyke nets are constructed of a series of hoops that covered in webbed netting. Fish enter the fyke net through a lead funnel then enter into one of two or more internal funnels. The internal funnels prevent fish from re-entering the lead funnel and swimming out of the net once they are caught. The cod end (net end) is tied off above the waterline so that air breathing animals have refuge.

Two large mesh single-wing fyke nets, two small mesh single-wing fyke nets and two dual-wing fyke nets were deployed at each site:

- Large mesh fyke nets have a central wing (8 m x 0.65 m) attached to the first supporting hoop (diameter = 0.65 m) with a stretched mesh size of 20 mm; and
- Small mesh fyke nets have a central wing (8 m x 0.65 m) attached to the first supporting hoop (diameter = 0.65 m) with a stretched mesh size of 20 mm.

Polarised lenses were used to enhance visibility of in-stream objects from above. A species presence/absence approach was adopted to overcome the difficulty of tracking and counting fish and the risk of repetitively counting individuals.

3.6 Statistical Analysis of Macroinvertebrate Data

3.6.1 Characterisation Using Three Families Highly Sensitive to Contamination

The number of ETO families is a metric assessing the proportion of the sensitive taxa Ephemeroptera, Trichoptera Odonata (mayflies, caddisflies and dragonflies) in the total macroinvertebrate assemblage. The number of ETO families provides insight into the sensitivity to contamination of taxa in a sample.

3.6.2 Characterisation of Communities Using Breadth of Tolerance of Environmental Conditions

Each macroinvertebrate family has been assigned a "grade number" between 1 and 10, with 1 indicating organisms with a high tolerance of a range of environmental conditions. Scores can be calculated with or without abundance weighting. The SIGNAL scores were calculated using an abundance weighting. A more detailed description of this method can be found in Chessman (2003).

The resulting score provides a simple assessment that gives an indication of the condition of a site. For easier interpretation, SIGNAL scores and the number of types of macroinvertebrates were graphed using a biplot. The resulting biplot is placed into context using a quadrant diagram that divides the results into:

- High values of both SIGNAL scores and number of macroinvertebrate species;
- Lower SIGNAL scores and high diversity of macroinvertebrate species;
- High values of SIGNAL but few macroinvertebrate species; and
- Low values of both SIGNAL scores and number of macroinvertebrate species.

The quadrant boundaries were set according to boundaries suggested for the Northern Territory. The schematic presented in Figure 10 summarises the SIGNAL output interpretations.

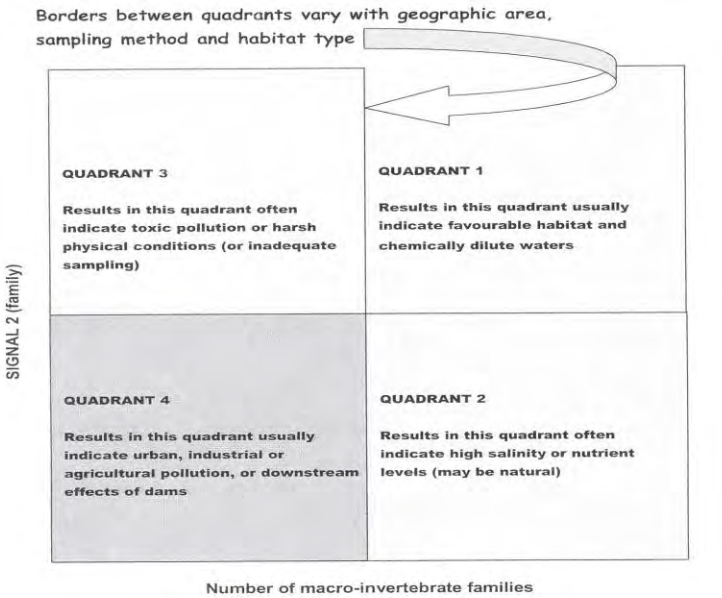

Figure 10 Signal Outputs

3.6.3 Comparison of Communities with the Theoretical Reference Community

The AUSRIVAS model predicts the macroinvertebrate communities expected to occur (E) at test sites in the absence of an impact. A comparison of the invertebrates expected to be collected with those actually collected (O) provides a measure of biological impairment at the test sites. The predicted taxa list provides a 'target' community to measure the success of remediation measures and provides an indication of the type of impact a site is experiencing (e.g. absence of Leptophlebiidae may indicate an impact from trace metal input).

The OE50 score stated in Table 7 is the ratio of the observed to expected number of taxa with a probability of 50% or greater of occurring. This OE50 score is the major output score used in the NT to assess the health of the macroinvertebrate community at the test site. To simplify interpretation of the OE50 score and to aid management decisions, a banding scheme is used representing different levels of biological condition. The banding thresholds vary for each AUSRIVAS model and are shown for the Darwin-Daly regional models in Table 7.

Table 7 Band Thresholds for the Darwin-Daly Region Model

Band	Family level model OE50	Description
X	>1.18	Above Reference
A	0.82-1.18	Similar to reference
B	0.45-0.81	Significantly impaired
C	0.07-0.44	Severely impaired
D	<0.07	Extremely Impaired

3.6.4 Multivariate analyses

Abundance data from the community results were analysed using multivariate procedures from the PRIMER (v6) software package (Clarke & Gorley 2006). These were used to:

- describe pattern among the data on the assemblages sampled using ordination. The bases of these analyses were Bray-Curtis similarity matrices performed on log(X+1) transformed data. The ordination method used was Multi-Dimensional Scaling (MDS) (Clark and Warwick 2001). Ordinations were depicted as two-dimensional plots based on the site by site similarity matrices; and
- compare faunas of exposed versus reference site groupings (Analysis of Similarity (ANOSIM) – effectively an analogue of the univariate ANOVA) to determine whether these were significantly different from one another. The ANOSIM test statistic compares the observed differences between groups (exposure type) with the differences among replicates in the groups. The test is based on rank similarities between samples in the underlying Bray-Curtis similarity matrix. The degree of separation between groups is denoted by the R-statistic, where R-statistic > 0.75 = groups well separated, R-statistic > 0.5 = groups overlapping but clearly different, and R-statistic < 0.25 = groups barely separable. A significance level < 5% = a significant effect/difference.

3.7 Horseshoe and Stow Creek Diversions

The existing diversion of Horseshoe Creek and the area of the proposed diversion of Horseshoe Creek were traversed and records taken of the general morphology and habitat characteristics of the creek. These records included stream width, slopes of banks, stream substrates, and presence of roots, logs and snags.

Stow Creek sample site SC1 and SC2 have been used to characterise the proposed diversion reach on Stow Creek.

4. Results

4.1 Sediment Quality

Sediment quality was assessed against ANZECC interim sediment quality guideline trigger values (ANZECC & ARMCANZ 2000) (Table 8). No values exceeded the guideline trigger values.

Table 8 Sediment Quality Data (Metals – Weak Acid Digest)

Parameter	SC1	SC2	SC3	SC4	SC5	ERSW4	ERDS	ERUS	ANZECC ISQG -low
% Moisture	20	19	19	15	18	22	22	24	
pH	5.9	6.3	6.2	6.3	6.1	6.7	6.8	5.9	
%TOC	0.19	0.094	0.28	0.046	0.043	0.12	0.16	< 0.005	
Metals (mg/kg)									
Aluminium	2,200	1,500	1,000	760	1,000	1,200	940	990	25,519*
Cadmium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.5
Chromium	< 5	< 5	< 5	8.7	< 5	< 5	5.4	< 5	80
Cobalt	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	-
Copper	< 5	< 5	< 5	< 5	< 5	26	< 5	< 5	65
Iron	14,000	9,000	6,100	9,700	6,400	7,200	8,500	12,000	-
Lead	6.7	< 5	< 5	< 5	13	< 5	< 5	< 5	50
Manganese	41	36	18	44	18	79	130	20	460**
Mercury	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.15
Nickel	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	21
Silver	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	1
Zinc	6.4	< 5	< 5	6.9	9.8	24	9.2	< 5	200
Particle Size (%)									
>2000 µm	2.7	2.1	0.1	30	13	0.3	1.1	0.3	
1000-2000 µm	2	4	0.7	12	3.6	2.1	8.8	0.8	
500-1000 µm	9.8	14	38	33	30	8.3	38	21	
250-500 µm	32	30	39	14	23	37	20	28	
125-250 µm	38	42	16	8.3	24	24	5.8	14	
63-125 µm	6.5	2.5	3.7	2.7	1.5	2.3	3	4.9	
<63 µm	9.3	6.2	2.4	< 0.1	5.7	26	24	31	

**Ingersoll et al. 1996, **Persaud et al. 1992*

4.2 Macroinvertebrate Results

4.2.1 Total Number of Taxa

A total of 6,520 macroinvertebrate specimens from 39 taxa were identified from three waterways during the 2011 investigation. Edith River and Stow Creek returned 33 taxa, while the Fergusson River returned 30 taxa.

Figure 11 lists the macroinvertebrate orders that dominated the community assemblage at each site. This figure is a combined total of each of the three replicates. Community composition varied across the three waterways. The Fergusson River and Edith River communities were relatively similar with Triochoptera and Coleoptera taxa dominating the community assemblage. Trichoptera taxa are generally regarded as pollution sensitive and the high representation of these taxa in Edith and Fergusson River indicates that the water quality and habitat are of good quality.

Trichoptera and Coleoptera taxa were present in Stow Creek although Dipteran taxa dominated the community. Dipterans are known to have a wide tolerance to pollution. The high representation of these taxa in Stow Creek indicates a possibly higher level of impact to this waterway.

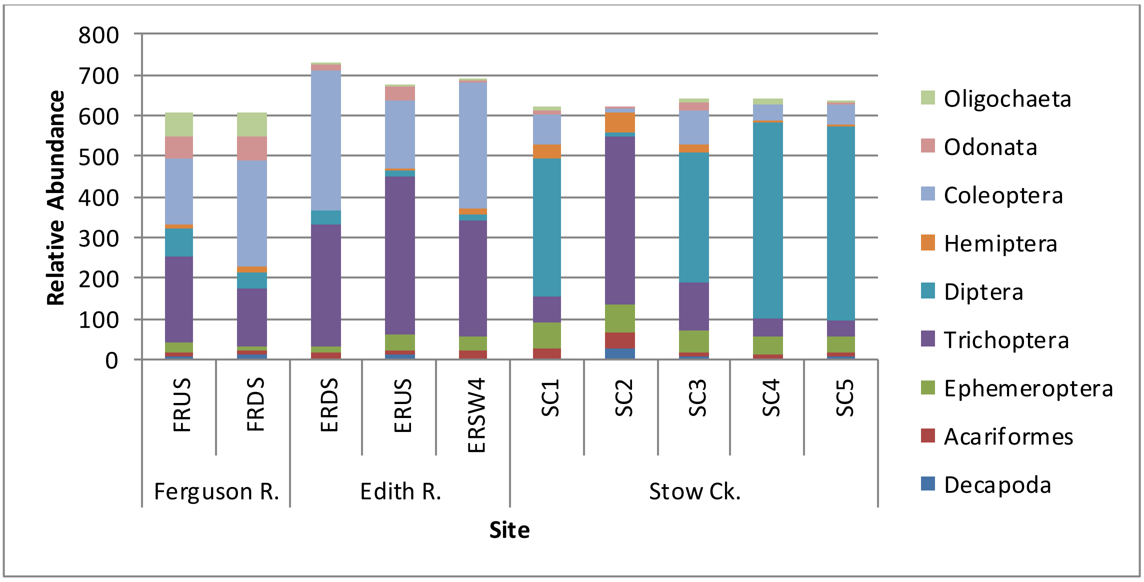

Figure 11 Relative Abundance of Macroinvertebrate Taxa

Figure 12 depicts the number of taxa sampled per replicate and Table 9 provides the combined total of taxa sampled at each site.

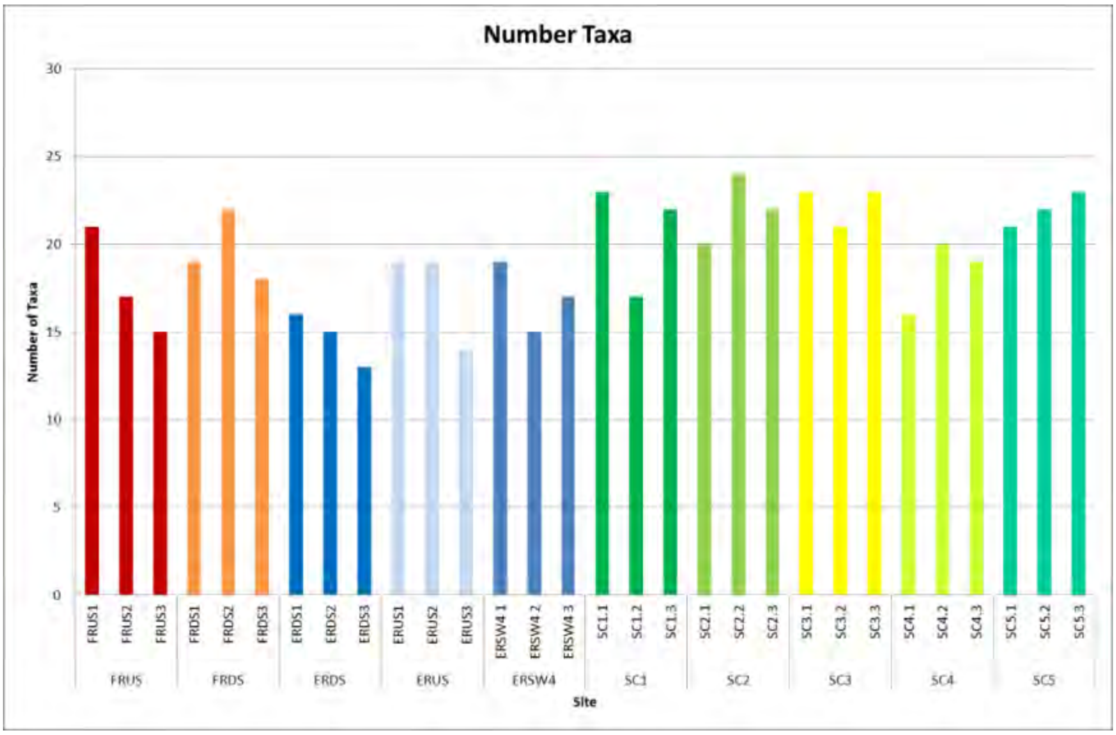

Figure 12 Overall Number of Taxa Sampled During 2011 Survey

Table 9 Combined Total Number of Taxa per Site

Site	Total Number of Taxa
FRUS	23
FRDS	28
ERUS	26
ERDS	18
ERSW4	24
SC1	30
SC2	26
SC3	30
SC4	24
SC5	27

The total number of taxa sampled at each site ranged between 18 and 30 respectively. Site ERDS which is located immediately downstream of the Stow Creek confluence with the Edith River returned the lowest overall number of taxa. The number of taxa recovers further downstream at site ERSW4.

The macroinvertebrate communities in Stow Creek were generally more diverse than the Edith and Fergusson River. There was an immediate decrease in diversity downstream of the Horseshoe Creek confluence with Stow Creek (SC4) indicating that the input from Horseshoe Creek may have a localised impact on Stow Creek.

4.2.2 Characterisation using three families highly sensitive to contamination

The ETO ratio of the macroinvertebrate data indicate that the diversity of disturbance sensitive taxa across all sample sites was relatively consistent (Figure 13) with the ratio varying between 0.33 and 0.44 (Table 10).

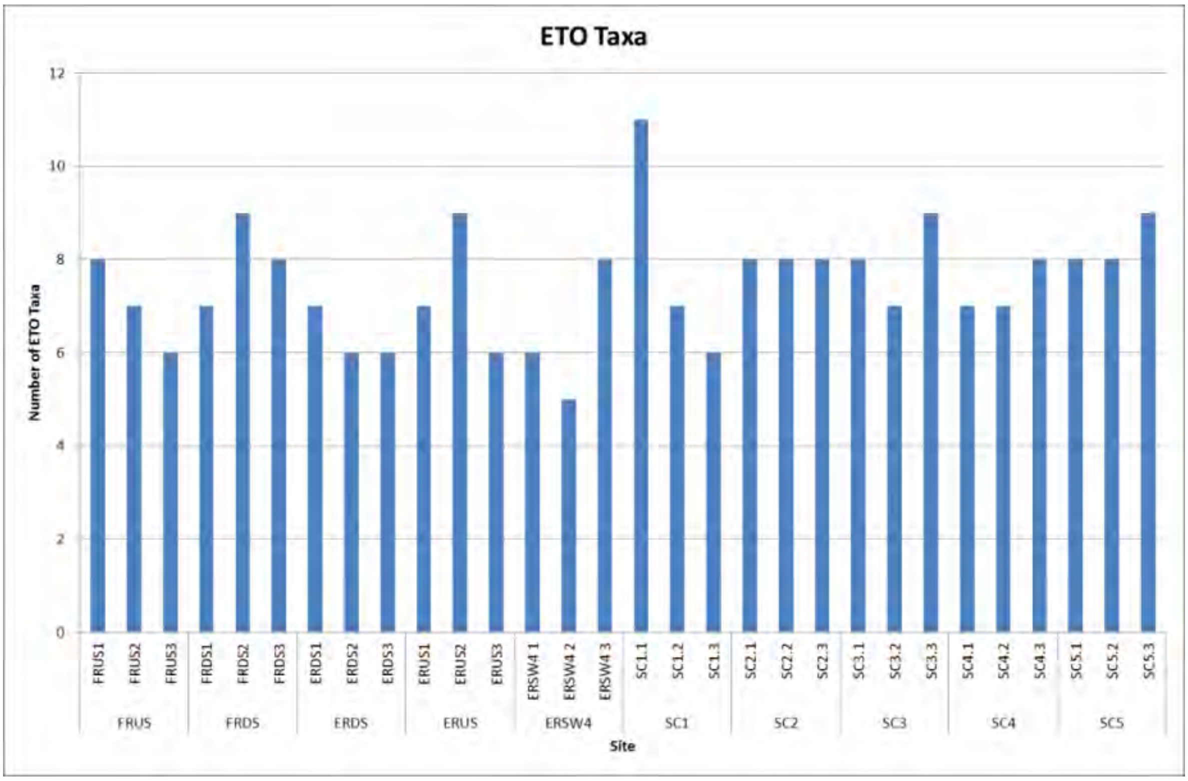

Figure 13 Overall Number of ETO Taxa Sampled During 2011 Survey

Table 10 Combined Total Number of ETO Taxa per Site

Site	ETO Taxa	Total Taxa	ETO Ratio
FRUS	9	23	0.39
FRDS	11	28	0.39
ERDS	8	18	0.44
ERUS	11	26	0.42
ERSW4	9	24	0.38
SC1	11	30	0.37
SC2	9	26	0.35
SC3	9	30	0.30
SC4	8	24	0.33
SC5	9	27	0.33

4.2.3 Characterisation of Communities Using Breadth of Tolerance of Environmental Conditions

The SIGNAL 2 analysis indicates that the macroinvertebrate habitat and water quality is of good condition with all sites falling on the cusp of Quadrant 1 and 2 (Figure 14).

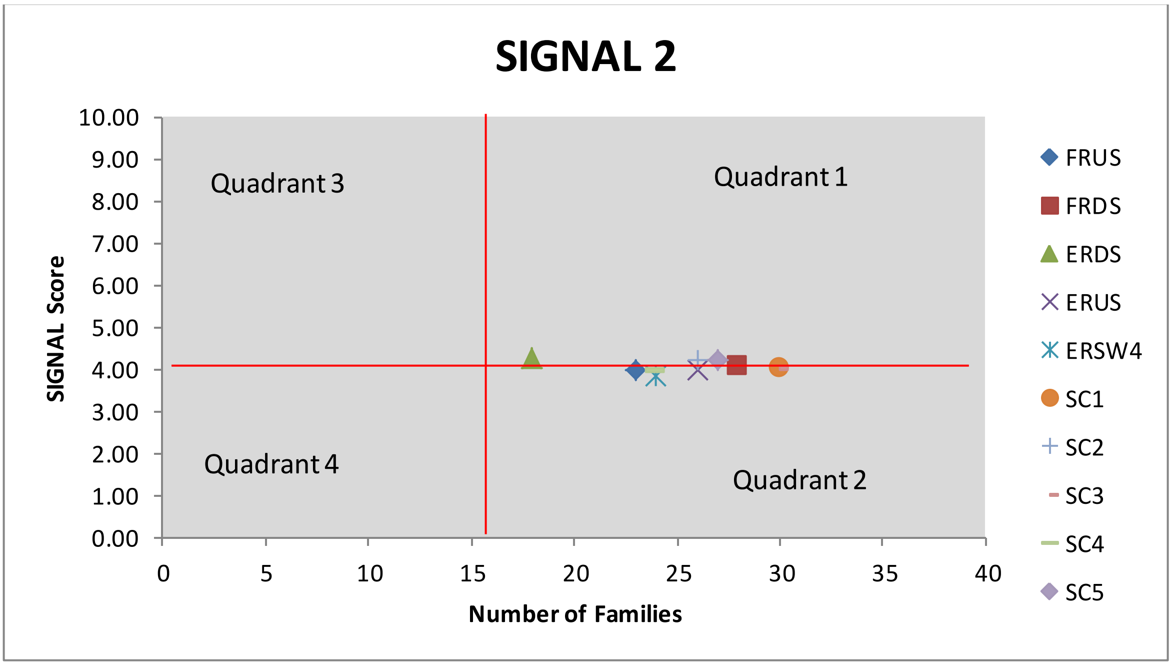

Figure 14 SIGNAL 2 Biplot for Mt Todd Sample Sites.

Samples in Quadrant 1 have relatively high diversity and SIGNAL 2 score, which suggest that the sample was collected from an area with high habitat diversity and an absence of toxic chemicals and harsh physical conditions.

Quadrant 2 represents samples with low SIGNAL 2 scores and a high diversity of macroinvertebrates. Samples that fall into this quadrant generally have elevated levels of turbidity, salinity or nutrients, which can be due to natural or human influenced factors.

4.2.4 Comparison of Communities with the Theoretical Reference Community

AUSRIVAS compares the expected (E) number of taxa to the actually observed (O) number of taxa at each site (section 4.3.4). The AUSRIVAS system only considers taxa that were calculated to have a probability of 50% or greater of occurring at a test site. The OE50 score is therefore the ratio of the observed to expected number of taxa with a probability of 50% or greater of occurring. This OE50 score is the major output score used in the NT to assess the health of the macroinvertebrate community at the test site.

The AUSRIVAS model indicates that the edge habitat of most sites fall in band A (Table 11). Band A indicates that macroinvertebrate communities are "Similar to Reference", or in a range of central 80% of reference sites used to create the model. This indicates that the sampled sites contained the expected number of families in the range found at 80% of the reference sites.

Two sites fell in AUSRIVAS band X. These were FRDS and SC2. Band X represents sites more biologically diverse than reference and constitutes an observed over expected ratio greater than the 90^{th} percentile of reference sites used to create the model.

Table 11 AUSRIVAS O/E Ratio for Edge Sites Sampled

AUSRIVAS	O/E Ratio	Band
FRUS	1.11	A
FRDS	1.19	X
ERDS	1.03	A
ERUS	1.07	A
ERSW4	0.95	A
SC1	1.16	A
SC2	1.19	X
SC3	1.15	A
SC4	1.15	A
SC5	1.15	A

Note: Band threshold for the Darw in-Daly region models.

4.2.5 Similarity of Faunas

Multivariate Analyses and MDS Ordinations are shown in Figure 15 and Figure 16.

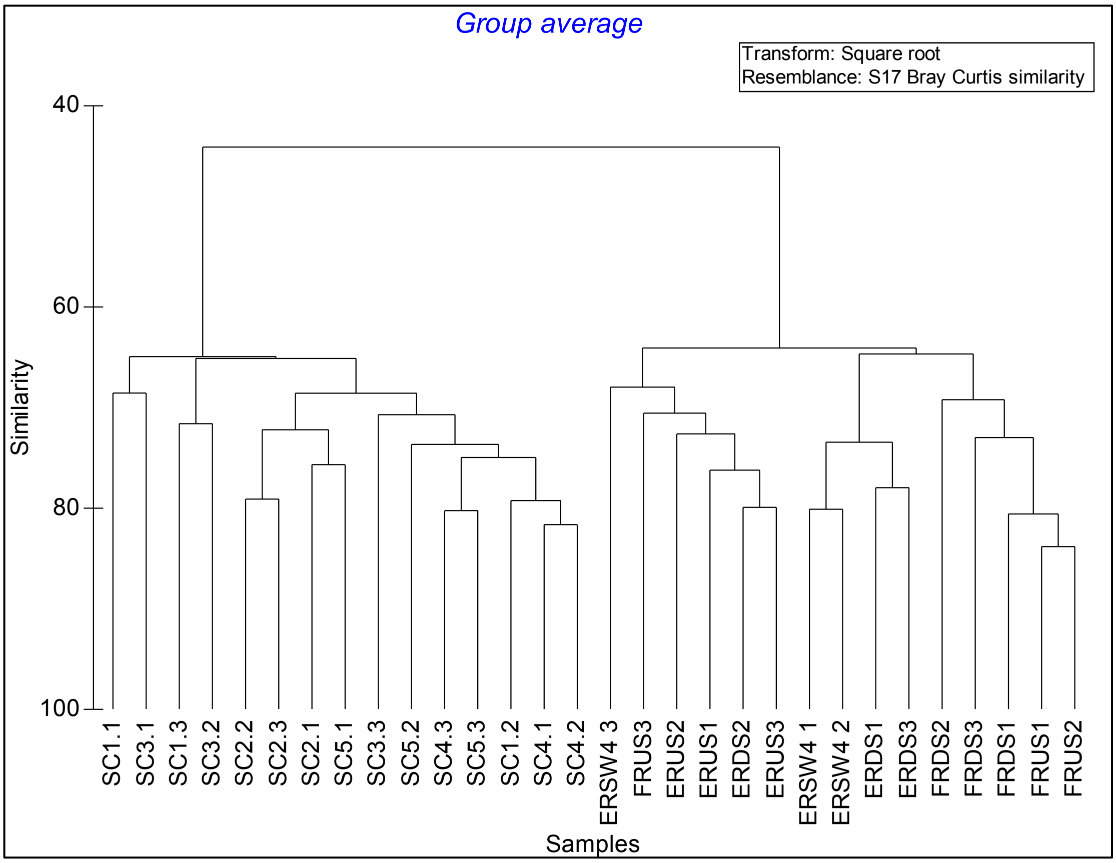

Figure 15 Cluster Analysis of Mt Todd Sample Sites

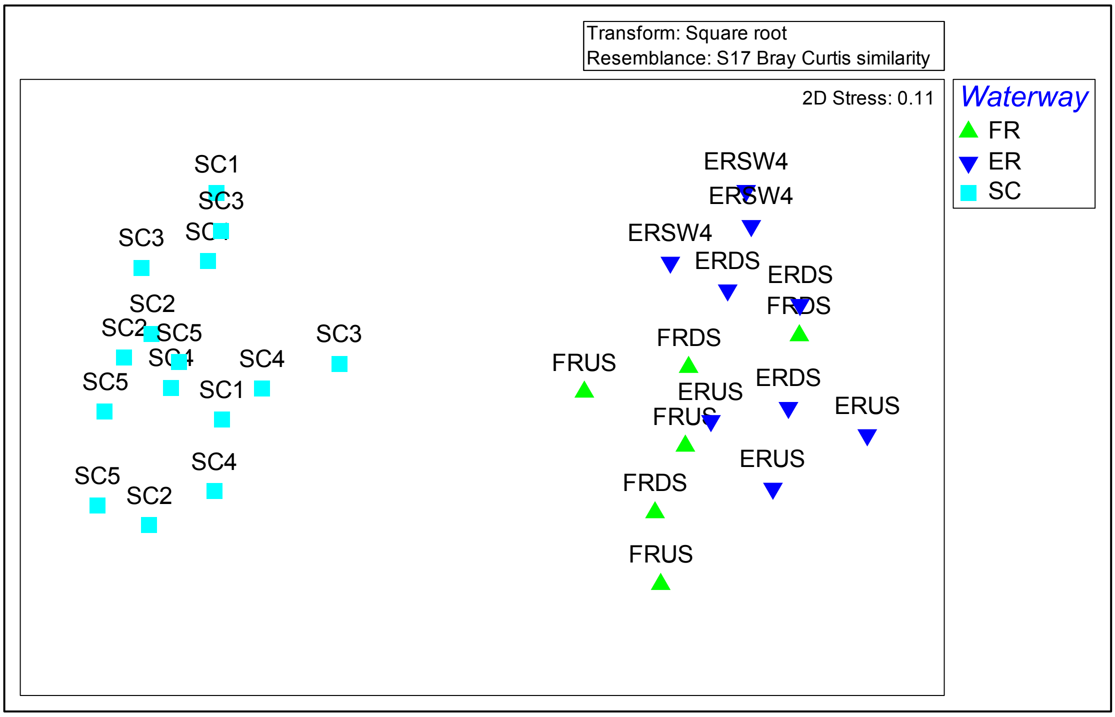

Figure 16 MDS Analysis of Mt Todd Sample Sites

The cluster and MDS analyses of the macroinvertebrate data from each site indicate that:

- macroinvertebrate fauna of Stow Creek is distinctly different from those sampled at the Edith and Fergusson Rivers;
- communities of the Edith and Fergusson River Sites are similar in composition and abundance;
- no distinct separation between Edith River upstream and downstream sites indicating that the input from Stow Creek has had a minimal long term impact on the Edith River; and
- no distinct grouping of replicates sites in Stow Creek, indicating that point source inputs were not observable in the macroinvertebrate data at the time of the survey.

Waterways

A pairwise Analysis of Similarity of the macroinvertebrate communities between each waterway indicates a significant difference between the macroinvertebrate communities. The differences between Stow Creek and Edith River or Ferguson River are greater than between the Edith River and Ferguson River communities. The data is detailed in Table 12.

Table 12 ANOSIM Model Output (Waterways Comparison)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >=Observed
FR, ER	0.433	0.2**	5,005	999	1
FR, SC	0.983	0.1**	54,264	999	0
ER, SC	0.995	0.1**	1,307,504	999	0

** Denotes significant difference between communities

Edith River

A pairwise Analysis of Similarity of the faunas in Edith River upstream and downstream indicates no significant difference between the macroinvertebrate communities upstream and downstream of known point source inputs. The data is detailed in Table 13.

Table 13 ANOSIM Model Output (Orientation to Discharge Comparison)

Pairwise Tests					
Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >=Observed
FRUS, FRDS	0.037	50	10	10	5
ERDS, ERUS	0.451	5.1	84	84	4
SC/US, SC/DS	0.006	44	5,005	999	439

** Denotes significant difference between communities

4.3 Fish

Eight fish species were identified from Stow Creek and 9 species from Edith River. Overall a total of 14 fish species were sampled from both the Edith River and Stow Creek combined. Full detailed of species are provided in Table 14.

Site FE1, sampled from the Edith River returned the greatest diversity with 9 fish species.

Table 14 Fish Survey Results

Species	Common Name	Survey Sites			
		Stow (FS1)	Stow (FS2)	Stow (FS3)	Edith (FE1)
Melanotaenia australis	Western rainbowfish	7	4		17
Ambassis agrammus	Sailfin glassfish	3			
Strongylura kreffti	Longtom		1		1*
Anguilla bicolor	Indian Shortfin Eel				1
Amniataba percoides	Barred grunter	2		3	3
Hephaestus fuliginosus	Sooty grunter	1			
Syncomistes butleri	Butlers grunter			1	
Glossamia aprion	Mouth almighty			3	
Lates calcarifer	Barramundi				1*
Craterocehalus stercusmuscarum	Flyspecked hardyhead				2
Neosilurus hyrtlii	Hyrtls catfish		32		
Neosilurus ater	Black catfish				2
Anodontiglanis dahli	Toothless catfish				1
Neosilurus sp	False-spined catfish				1
Total Fish Species	**14**	**4**	**3**	**3**	**9**
Crocodylus johnstoni	Freshwater crocodile.	1	2*		
Elseya dentata	Northern snapping turtle	1			
Emydura victoriae	Short-necked turtle			2	3

Note: *Denotes visual observation

4.4 Horseshoe Creek Diversion

Horseshoe Creek is an ephemeral system that flows during the wet season and reduces to a series of pools during the dry season. At the time of the survey, the waterway had dried to a series of pools. It was unsuitable for sampling macroinvertebrate.

The creek line downstream of the raw water storage overflow had steep earthen banks with some exposed roots at the water's edge. Fallen trees with collected organic litter extended from the edge to well into the stream. The principal in stream habitats were rock cobble substrate (80%) and 20% sand silt. Horseshow Creek lacks sand beds/bars such as occur in Stow Creek and the Edith River. It is unlikely to provide nesting habitat for the freshwater crocodile.

The channel varies in width from approximately 3 to 10 m, with depths from 0 m (dry sections) to greater than 2 metres in the holes. The width of the stream between the tops of the banks varied along the stream from 10 to 40 metres.

Photo 21 Horseshoe Creek existing upstream diversion

Photo 22 Location of proposed diversion

4.5 Stow Creek Diversion

Stow Creek rises at an elevation of 275 m and ends at an elevation of 116 m were it flows into the Edith River, dropping approximately 159 m over its 25.1 km length. The Mt Todd Mine site is located at the bottom end of Stow Creek, with approximately 5 km of creek frontage through the existing mineral leases. The confluence of Stow Creek and Edith River are in the boundary of the mineral leases.

The 800 m reach of Stow Creek that is proposed to be diverted was not part of the original scope of works when the aquatic field assessment was undertaken in 2011. As such a detailed habitat survey of the impact reach was not conducted.

The 2011 investigation did have two sites (SC1 and SC2) located within the proposed impact reach. These were assessed as control sites for the ongoing monitoring of mine associated discharges to Stow Creek. Information recorded from these sites has been used to extrapolate the potential habitat values lost as a result of the TSF2 construction and diversion.

The channel width at these sites varied from 5 to 15 m in width and depth between 5 cm to pools over 1.5 m. The habitat matrix at these sites was complex, with riffle, pool and back water habitat. The substrate consisted of a combination of sand, pebble and bedrock. Undercut banks, organic debris, including large snags were abundant at both sites. The reach has a high sinuosity with large sand deposits on the inside bends of meanders. Given that a number of juvenile freshwater crocodiles were observed within Stow Creek, and the presence of sand bars, there is a potential that nesting habitat exist in the reach to be diverted.

Unlike Horseshoe Creek, Stow Creek can be considered to provide high value aquatic habitat and the reach to be impacted by the proposed diversion works is currently not impacted by existing mine operations. Given that the 2011 survey was completed at the commencement of the dry season, the survey was unable to determine extent of dry season refugia habitat therefore it is difficult to speculate on how much (if any) refugia habitat loss may be lost as a result of the TSF2 constructions and associated diversion.

5. Discussion

5.1 Sediment Quality

Controlled discharge from RP1 is the largest contributor of mine water to the Edith River. Water has been released to the Edith River to maintain the holding capacity of RP1 during the wet season. The discharge is controlled by siphon pump. A minor drain, West Creek, delivers mine water to the Edith River only after substantial rainfall causes RP1 to overflow. Its flows include water diverted from the western side of the Waste Rock Dump via the Western Diversion Drain, and overflow from the RP1 spillway.

Uncontrolled discharge from RP1 (via the spillway) to West Creek has occurred during past heavy rainfall events. Uncontrolled discharge occurs via Horseshoe Creek and Stow Creek to the Edith River during periods of wet-season base flow (roughly January to May).

Most of the mine water making up the discharge originates from a number of sources on-site:

- Seepage from the low grade ore (LGO) stockpile, the Plant and the heap leach pad (HLP) is flushed to Batman Creek and then Stow Creek;
- Tailings Dam seepage and underflow as well as some seepage from the HLP is flushed into Horseshoe Creek and then Stow Creek; and
- Some seepage from the Tailings Dam occurs directly into Horseshoe Creek along the eastern Tailings Dam wall.

The sediment quality of the Edith River has been largely unaffected by past discharges. This may be because sediments in the Edith River below the upstream site and in the Stow Creek sites have large particle sizes and minimal clay content (fines <63 µm).This configuration of particle sizes and low TOC (total organic carbon) provides few binding sites (usually organic compounds such as humic acids) for metals. Metals would tend to remain in the system rather than absorb to these types of sediments (Simpson *et al*. 2005).

5.2 Macroinvertebrate Communities

Numerous studies have demonstrated the dynamics of contaminant transfer from source to sink in river systems (e.g. Macklin, 1996; Miller, 1997; Hudson- Edwards *et al*. 1999, 2001). Metals have long residence in riverine sediments and metal-contaminated sediments may act as major sources of future contamination and pose an ongoing long-term risk to the environment. Depositional river environments and their sediments are spatially and temporally complex in morphology and distribution. It must be expected that contaminants carried by, and stored in river and floodplain sediment will exhibit similar complexity.

The descriptive analysis of taxa diversity demonstrates that although there was a degree of variability in replicates for each site, the total number of families sampled at the site level were relatively consistent across the three waterways.

The macroinvertebrate results demonstrate that despite the long history of mine discharges to Stow Creek and the Edith River, there is minimal long term impact on the macroinvertebrate communities of Stow Creek and the Edith River.

Analysis of the invertebrate community composition data indicated a significant difference between the macroinvertebrate communities at Stow Creek and those at the Edith and Fergusson Rivers. This was supported by the MDS analysis grouping all Stow Creek sites separate from the Edith River and Fergusson River sites. Dipteran taxa were most dominant in Stow Creek. The chironomid sub family Chironominae was the most abundant dipteran taxa. Although these were present in the Edith and Fergusson Rivers these comprised less than 10% of the fauna at each these locations. Some chironomids are known to be tolerant of metal pollution (e.g. see Norris *et al*. 1982).

The consistency of community structure of sites upstream of the mine' influence (SC1, SC2) with these sites downstream of the mine (SC3, SC4, SC5) indicates that differences observed between Stow Creek and the Edith and Fergusson Rivers are most likely habitat related (i.e. it is driven by catchment wide influences rather than point source input from the mine).

Trichopteran taxa dominated the community composition in the Edith and Fergusson Rivers. The abundance of Trichoptera was almost exclusively attributed to members of the family Leptoceridae, which is known to be tolerant of metal contamination (Norris *et al*. 1982). The similarity of the community at upstream and downstream sites on the Edith and Fergusson Rivers suggests that catchment scale factors maybe determining the observed community structure.

No index demonstrated a pattern of increasing or decreasing values from upstream to downstream from the mine.

The AUSRIVAS results show no discernible difference between upstream and downstream of the mine. All sites returned an AUSRIVAS ranking of either band A or X, indicating that the macroinvertebrate faunas are equal to (A), or above reference populations (X) sampled for the Daly-Darwin model.

5.3 Fish

The data allow little inference about the potential impact of the mine on the fish fauna. Fish would have been capable of moving between the sample sites at the time of the study. The results were also limited by the presence of large crocodile slides at the Mt Todd Mine Site. This largely restricted the sampling to shallow areas. This has an influence on the species encountered during the survey. The deeper reaches of waterways are likely to contain a higher number of species than was recorded during the survey of the Mt Todd Mine Site.

The only species sampled during the current survey that had not been recorded as part of previous surveys on the Edith River was the Indian Shortfin Eel (*Anguilla bicolor*). In Australia, this species is known only from the coastal drainages of the Kimberly region (WA) where it is not common (Allen *et al.* 2003). The presence of this species in the greater Daly River catchment is an anomaly.

The EPBC protected matters search tool identified the study area as potential habitat for both the freshwater crocodile (*Crocodylus johnstoni)* and freshwater sawfish (*Pristis microdon*).

Freshwater crocodile were observed at the Mt Todd Mine Site during the course of the surveys. The freshwater crocodiles that were observed at the Mt Todd Mine Site were small (<50 cm) and likely young of the year juveniles. This indicates that suitable breeding habitats exist in the project area. This species is a listed marine species under the EPBC Act. Potential breeding habitat should be protected where in-stream works are required.

Freshwater sawfish are known to occur in the greater Daly River catchment, mostly in larger middle and lower Daly River reaches. There are no recorded sightings in the Edith or Fergusson Rivers.

6. Discussion of Potential Impacts

6.1 Mt Todd Mine Site

This report describes the aquatic fauna and general sediment characteristics of Stow Creek and the Edith and Fergusson Rivers in the vicinity of the Mt Todd Mine. Previous biological sampling of the Edith River has consistently failed to identify a significant impact from the mine discharges.

The inherent risk with sampling macroinvertebrate according to the NT AUSRIVAS program is that samples are undertaken during receding flow conditions. Macroinvertebrate responses at this time integrate the effects of wet season water quality events at the time of maximum diversity.

Impact from mine runoff and seepage is likely to be at its most observable during the end of the dry season when the Edith River and Stow Creek constrict to a series of refuge pools. During this time the dilution of contaminates by passing flow will be non-existent and ability of aquatic fauna to recolonise impacted pools will be reduced as a function of cease flow conditions.

The data demonstrate that any impacts that may have occurred in the past were short term or transient. This is likely due to a number of factors.

The Edith River and Stow Creek upstream of the mine site can be considered as pristine waterways, flowing directly out of Nitmiluk National Park. This provides a rich population source for recolonisation following impact events. Dispersal movements are an important activity in the ecology of aquatic macroinvertebrates, and can happen by active movement among stream patches, drift and adult emergence (Smock 1996). Dispersal movements (active or passive) can occur in response to several factors (Smock 1996), with water flow acting as an energetically efficient mechanism for movement.

Several studies have demonstrated that rates of macroinvertebrate colonisation of new substrates differ among taxa and are affected by the physical characteristics of the substrate (e.g. Smock 1996). Downstream movement is considered one of the more important ways of colonisation in streams, occurring primarily by drift, but also from movement along the sediment (Waters 1972; Williams and Hynes 1976). Upstream movement along the sediment occurs in species exhibiting positive rheotaxis (Bishop and Hynes 1969; Humphries 2002). Colonisation can occur from the subsurface or hyporheic zone (Smock 1996; Olsen and Townsend 2005). Aerial colonisation is important in all streams with oviposition by winged adult insects the primary mechanism of colonisation (Benzie 1984; Reich and Downes 2003 a, b). There is a high likelihood that short-term stochastic impacts are masked by rapid recolonisation.

Sediment samples demonstrate relatively high background concentrations of iron, manganese and aluminium across all sites surveyed, regardless of their location in relation to the existing mine infrastructure. This is likely a function of the local mineralisation. In turn the macroinvertebrate communities are likely to have evolved and adapted to tolerate these concentrations.

The sediment samples demonstrate that metal contaminants from the mine are not being bound and retained by the sediment, thus the residual impact on macroinvertebrate fauna after the initial first flush event is minimal. Particle size analysis indicates that the sediments have large particle sizes and minimal clay content (fines <63 µm). This configuration of particle sizes and low TOC means that there are relatively few binding sites for metals.

It is possible that a combination of the factors previously discussed combine with frequent pulse flow events during the wet season to effectively flush the system of contaminants and allow for recolonisation.

Further assessment to establish the fate of contaminants, including the assessment of transport, deposition and uptake of contaminates within the greater Daly River Catchment is required.

6.2 Potential AMD Impacts

AMD at the Mt Todd site has the potential to impact the aquatic environment through two main pathways. These are point source and diffuse source. The management of point source inputs can be largely managed through engineering design and treatment of which a number of controls have been built into the system to address these.

There is a large amount of acid producing rock in the Mt Todd tenement and the general movement of groundwater is toward the Edith River. Diffuse sources of AMD (i.e. groundwater seepage) such as these are difficult to predict and manage. It is the ongoing management of diffuse AMD during mine operation and closure that has the greatest potential to impact the aquatic environment, especially during low flow conditions.

The makeup of mine drainage is a complex of elements that interact to cause a variety of effects on aquatic life. It is difficult to separate the individual components of the impacts. Toxicity is dependent on discharge volume, pH, total acidity, and concentration of dissolved metals.

pH is the most critical component. The lower the pH, the more severe the potential effects of mine drainage on aquatic life. The overall effect of mine drainage is also dependent on the flow (dilution rate), pH and alkalinity or buffering capacity of the receiving stream. High concentrations of bicarbonate and carbonate ions in the receiving stream provide a high buffering capacity that protects aquatic life from the adverse effects of acid mine drainage (Kimmel, 1983).

Acid metalliferous drainage with elevated metals concentrations discharging into headwater streams or lightly buffered streams can have a devastating effect on aquatic life. Secondary effects such as increased carbon dioxide tensions, oxygen reduction by the oxidation of metals, increased osmotic pressure from high concentrations of mineral salts, and synergistic effects of metal ions also contribute to toxicity (Parsons, 1957). Physical effects such as increased turbidity from soil erosion and smothering of the stream substrate with precipitated metal compounds may occur (Parsons, 1968; Warner, 1971).

Macroinvertebrates are often used as indicators of water quality because of their limited mobility, relatively long residence times, and varying degrees of sensitivity to pollutants. Unaffected streams generally have a variety of species with representatives of all insect orders, including a high diversity of insects in the taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT taxa). Like many other potential pollutants, mine drainage can cause a reduction in the diversity and total numbers, or abundance, of macroinvertebrates and change community structure, such as lower the percentage of EPT taxa.

Moderate pollution eliminates the more sensitive species (Weed and Rutschky, 1971). Severely degraded conditions are characterised by dominance of taxa such as earthworms (Tubificidae), midge larvae (Chironomidae), cranefly larvae (Tipulidae), caddisfly larvae (Trichoptera), and non-benthic insects like predaceous diving beetles (Dytiscidae) and water boatmen (Corixidae) (Nichols and Bulow, 1973; Roback and Richardson, 1969; Parsons, 1968) that are pollution tolerant. These tolerant organisms may be present in unpolluted streams, becoming dominant following impact.

Fish are often used as indicators of pollution. However, at the Mt Todd mine site they are not as useful as macroinvertebrates because of their greater mobility. Fish may temporarily swim through a non-lethal impacted area or away from a discharge of intermittent duration.

6.2.1 pH

Most organisms have a well-defined range of pH tolerance. If the pH falls below the tolerance range, death will occur due to respiratory or osmoregulatory failure (Kimmel, 1983).

Low pH disturbs the balance of sodium and chloride ions in the blood of aquatic animals. At low pH, hydrogen ions may be taken into cells and sodium ions expelled (Morris et al., 1989). Mayflies are one of the groups of aquatic insects more sensitive to low pH whereas caddisflies are generally less sensitive to low pH. Mayflies and stoneflies that normally live in neutral water experience a greater loss of sodium in their blood when exposed to low pH than do acid-tolerant taxa whose sodium uptake is only slightly reduced by low pH (Sutcliffe and Hildrew, 1989).

Acid waters typically have fewer species and a lower abundance and biomass of macroinvertebrates than near-neutral pH waters. Animals are affected by interruption of food chains and the direct effects of low pH levels. Macroinvertebrates are often grouped by their feeding habits. The faunas of low pH streams are usually composed of shredders (organisms that eat leaves that fall into the stream), collectors (organisms that filter or gather particles of organic matter from the water), and predators. Low pH tends to eliminate species that feed on algae (scrapers or grazers).

Low pH may inhibit growth of bacteria which help break down leaves making them more digestible. These observations led early investigators to theorize that low pH levels reduced the food sources for invertebrates, thereby indirectly reducing their numbers. More recent studies have shown that direct effects of low pH on aquatic life are more critical than indirect effects on food sources (Rosemond et al., 1992).

The primary causes of fish death in acid waters are loss of sodium ions from the blood and loss of oxygen in the tissues (Brown and Sadler, 1989). Acid water increases the permeability of fish gills to water, adversely affecting gill function. Ionic imbalance in fish may begin at a pH of 5.5 or higher, depending on the tolerance of the species. Severe anoxia will occur below pH 4.2 (Potts and McWilliams, 1989). Low pH that is not directly lethal may adversely affect fish growth rates and reproduction (Kimmel, 1983).

6.2.2 Metals

Heavy metals can increase the toxicity of mine drainage and act as metabolic poisons. Iron, aluminium, and manganese are the more common heavy metals that can compound the adverse effects of mine drainage. Heavy metals are generally less toxic at neutral pH.

Trace metals such as zinc, cadmium, and copper, which may be present in mine drainage, are toxic at extremely low concentrations and may act together to suppress algal growth and affect fish and benthos (Hoehn and Sizemore, 1977). Some fish are tolerant of low pH, but the addition of metals decreases that tolerance.

Precipitated iron or aluminium hydroxide may form in streams receiving mine discharges with elevated metals concentrations. Ferric and aluminium hydroxides decrease oxygen availability as they form. The precipitate may coat gills and body surfaces, smother eggs, and cover the stream bottom, filling in crevices in rocks, and making the substrate unstable and unfit for habitation by benthic organisms (Hoehn and Sizemore, 1977).

Aluminium

Aluminium rarely occurs naturally in water at concentrations greater than a few tenths of a milligram per litre. Higher concentrations can occur as a result of drainage from mines, acid precipitation, and breakdown of clays (Hem, 1970). The chemistry of aluminium compounds in water is complex. Aluminium combines with organic and inorganic ions and can be present in several forms. Aluminium is least soluble at a pH between 5.7 and 6.2. Aluminium tends to be in solution (Hem, 1970; Brown and Sadler, 1989) and bioavailable at pHs above and below this range.

Most information on the effects of low pH and aluminium on aquatic life is based on studies of acid precipitation, such as those summarised in Haines (1981), Morris et al. (1989), and Mason (1990). Aluminium has a more adverse effect on stream aquatic life than the three major metals in acid mine drainage. Addition of aluminium ions compounds the effect of low pH by interacting with hydrogen ions, further decreasing sodium uptake, and increasing sodium loss in blood and tissues. High calcium concentrations generally reduce rate of influx of hydrogen ions into the blood and so reduce mortality and the sub-lethal effects of low pH and elevated aluminium. Streams most susceptible to degradation from elevated aluminium usually have low concentrations of calcium.

Stream investigations globally have indicated that a combination of pH less than 5.5 and dissolved aluminium concentration greater than 0.5 mg/L will generally eliminate all fish and many macroinvertebrates. Several genera of stoneflies, caddisflies, and true flies (particularly in the family Chironomidae) are tolerant of low pH and high dissolved aluminium. Mayflies are the aquatic insects most affected by a combination of low pH and acidic water. Aluminium is most toxic to fish at pH between 5.2 and 5.4 (Baker and Schofield, 1982).

Streams with precipitated aluminium usually have lower numbers and diversity of invertebrates than streams with low pH and high dissolved aluminium. Precipitated aluminium coats the stream substrate, causing slippery surfaces and difficulty for insects to maintain position in the current. Aluminium precipitate can be directly toxic to macroinvertebrates and fish. Rosemond et al. (1992) stated that deposition of aluminium hydroxide particles on invertebrates blocks surfaces important for respiratory or osmoregulatory exchange. Aluminium precipitate eliminates most of the filter feeders, such as Hydropsychid caddisflies, which normally comprise a major portion of total stream macroinvertebrates. Precipitated aluminium can accumulate on fish gills and interfere with their breathing (Brown and Sadler, 1989).

Iron

Iron is a common component of mine drainage. It can have a detrimental effect on aquatic life. Like aluminium, iron can be present in several forms and combines with a variety of other ions. The impact on aquatic ecosystems from mine drainage containing elevated iron is complex. Little animal life may be found in streams with the lowest pH (under 3.5) and elevated dissolved iron concentrations. Dipterans, and aquatic worms will be present if the pH rises slightly. With further increases in pH, a more diverse assemblage of macroinvertebrates may be present, although total numbers may be lower than in nondegraded streams. Wiederholm (1984), Letterman and Mitsch (1978), and Moon and Lucostic (1979) presented results of research on the effects of mine drainage and elevated iron on aquatic life.

Iron precipitates at a pH greater than 3.5 and does not re-enter solution at higher pH. Because iron can form precipitates at a lower pH than aluminium and can be present in streams with pH less than 4.5, separating the effect of iron from the effect of low pH is difficult. Precipitation of ferric hydroxide may result in a complete blanketing of the stream bottom, adversely affecting both macroinvertebrates and fish (Hoehn and Sizemore, 1977). The severity is dependent on stream pH and the thickness of the precipitate. Generally, the effect of precipitated iron is less severe in alkaline conditions. Many fish and macroinvertebrates are tolerant of iron precipitate in alkaline water. Total numbers and diversity are usually lower than in unaffected streams.

Koryak et al. (1972) found that ferric hydroxide greatly diminished total biomass of benthic organisms and limited fish populations in streams with survivable pH levels. The caddisfly genus *Hydropsychidae*, which is generally sensitive to low pH, can live in alkaline streams with iron precipitate. Hydropsychid caddisflies are tolerant of iron precipitate and pH less than 5.0. Mayflies are generally more tolerant of alkaline mine drainage than acid mine drainage.

Manganese

Manganese, another metal that is widely distributed in mine drainage can be present in a variety of forms, compounds and complexes with organic compounds. Manganese is difficult to remove from discharges because the pH must be raised to above 10.0 before manganese will precipitate. Manganese, therefore, is persistent and can be carried for long distances downstream of a source of mine drainage. Less information is available on the effects of elevated manganese concentrations on aquatic life than the effects of iron and aluminium. Perhaps this is because manganese in mine drainage is usually associated with other metals which may have a more deleterious effect or mask the effect of the manganese. Manganese discharge limits have traditionally been based on aesthetical (discoloration) effects of manganese at concentrations as low as 0.2 mg/L supplies rather than effects on aquatic life.

6.3 Diversion Channel

The potential impact of the proposed Project on the geomorphic characteristics of the waterways are discussed throughout the assessment and summarised in this section. The main impacts of the diversion on Horseshoe and Stow Creek are:

- Changes in the overall character of the watercourse
- Fish passage restrictions; and
- Loss of habitat.

6.3.1 Changes in the Character of the Watercourse

Horseshoe Creek

The geomorphic characteristics, and hence the flow characteristics of the waterway, will be altered as a result of the diversion. A surface water diversion channel will be constructed to the southwest of TSF2 to divert the existing Horseshoe Creek away from the toe of the embankment to prevent erosion of the facility. Rip-rap will be used to line the diversion channel to prevent erosion (Tetra Tech 2012). The channel has been designed to accommodate a peak flow of approximately 182 m^3/s comprising 100 m^3/s of runoff from a 100 year, 24 hour storm event in the Horseshoe Creek catchment and 82 m^3/s of overflow from the existing raw water supply dam.

This results in an average stream velocity of 2.0 m/s with an average shear stress of 68.10 N/m^2. This is likely to present a barrier to upstream fish movement and scour benthic communities, however given that this is a 1 in 100 year event, the low frequency of occurrence is unlikely to result in a significant impact.

Modelling shows that natural sections of channel in the mine area already experience high velocity during extreme flood events. Diversions will involve the protection of the channel against existing flow velocities in excess of 2 m/s to prevent erosion. Protection is not intended to increase the existing velocity of the channel.

The detail of the modelling is commensurate with available topographic information and has relied on a 1-D model which represent flow conditions at specific intervals along the river reach and is therefore only a sample of hydraulic conditions. More detailed modelling at lower 'normal' flow conditions would be valuable to assess the associated hydraulic impacts on fish passage

Stow Creek

A surface water diversion along the south-eastern edge of TSF2 will direct Stow Creek away from the TSF2 footprint. The channel will have a width and length of approximately 60 and 850 m respectively and a nominal depth of 4.2 m. Rip-rap will be used to line the channel. The channel has been designed to accommodate a peak flow of approximately 656 m^3/sec from a 100 year, 24 hour storm event in the Stow Creek catchment.

Flow characteristics are controlled by the amount of flow entering a reach, its cross section area, channel bed gradient and roughness. The diversion may change the rate of flow entering the downstream reach for flows in excess of existing bank-full discharge (higher flows are now contained rather than dissipating over the floodplain). However, this change in flow is likely small given the opportunity for higher flows to break-out of the channel over remaining reaches upstream

The diversion channel within Stow Creek could have a significant impact on the greater Stow Creek catchment if fish passage is not considered in the design. The diversion reach is located at the bottom end of the catchment and as such there is approximately 20 km of river upstream that may inaccessible by migrating fish if sufficient depth, velocity and resting habitat are not provided in the diversion design for regular flow events. This is even more important considering that the Stow Creek catchment is located largely within the Nitmiluk National Park and that restricted fish passage coupled with dry season drying events could significantly alter the composition of the aquatic ecosystem within the greater Stow Creek catchment.

The hydraulic modelling that has been undertaken for the diversion channel only addresses the 100 year, 24 hour storm event. There has been no modelling undertaken to investigate 'normal' flow periods through the diversion channel. Flow modelling should be completed under a number of higher frequency flow scenarios to determine if the diversion channel provides conditions sufficient to meet criteria presented in Table 15. The cross section area may need to change but this could involve a composite cross section shape leaving the natural cross section of the channel unchanged whilst increasing the channel area at higher flow depths. The roughness of the channel will change however appropriate materials could be incorporated into the design to achieve the requirements for fish passage and habitat creation.

Table 15 Guidelines for providing fish passage in fishways, channels and regulators. Adapted from (Mallen-Cooper, 2001)

Fish Size	Maximum Water Velocity to allow passage
Fish < 80mm	0.15 m/sec
Fish > 100mm	0.30 m/sec
Fish > 150mm	0.45 m/sec
Fish > 250mm	0.75 m/sec
Fish Type	**Minimum Water Depth to allow passage**
Small native fish	<0.3 m
Small & medium sized fish. May exclude some adult fish.	0.4 m
Will pass most native fish	0.7 m
Will pass all native fish	1 m
Fish Type	**Width of channel to allow passage**
Will pass almost all native fish	1.5 m
Will pass all native fish	2.0 m

6.3.2 Loss of Habitat

Construction of diversion channels will result in a loss of complex, in-stream habitat. Riparian vegetation plays an integral role in creating and maintaining the stability of newly constructed channels and providing habitat. There is always a risk that a large flow event, in excess of the design storm event could occur in the diversion before riparian vegetation has become established to the point where it resists large flows. Contingency should be considered for maintenance following a large flow event early in the life of the diversion.

A revegetation plan should be developed to suit the physical characteristics and requisite environmental values of the waterway. Further analysis during detailed design should determine the necessity, degree and timing for establishment of vegetation along the diversion. Ground cover should be established as a minimum using existing topsoil material containing seed stock.

Large woody debris should be placed or fixed into the diversion channel to provide habitat and channel 'roughness' that will assist with breaking up the flow profile. This would allow fish and other aquatic species to find and navigate low flow paths.

Large woody debris provides important habitat use by a number of aquatic and terrestrial organisms. Uses include shelter from high current velocities, shade, feeding sites, spawning sites, nursery areas for larvae and juvenile fish, territory markers and refuge from predation

In general, the types of snags that provide habitat for fish also provide habitat for other aquatic and terrestrial organisms. Submerged wood, with a complex surface structure of grooves, splits and hollows, provides space for colonisation by a range of invertebrates, microbes and algae. Some invertebrates feed directly on the wood while others graze the biofilm.

Large woody debris contributes to development of other habitat types by their impact on channel structure. The main types of habitat formed depend on orientation and stream power (Table 16). Scour pools formed by large woody debris spanning the channel are particularly important for wildlife, especially in streams that regularly dry out. These pools provide the only habitat available for aquatic species when flow ceases and are a source of recruitment for re-colonisation when normal flow returns.

Table 16 Potential Habitat Development as a Result of Large Woody Debris Orientation

Orientation to flow	Habitat Form(s)	
	Upstream	Downstream
Parallel	Scour pool	Bar/island
Angled	Combination pool/bar	Combination pool/bar
Perpendicular – on bed	Depositional zone	Scour pool
– above bed	Scour pool	Scour pool

7. Impact Mitigation

7.1 Mine Runoff

Impacts of mine runoff are likely to be greatest if first flush events are not actively managed by pollution abatement and/or treatment programs. The high water temperatures of receiving water bodies in the seasonally wet tropics reduce the capacity to assimilate runoff with a high oxygen demand (Erskine *et al.* 2003). Runoff with high oxygen demand can cause hypoxic and/or anoxic conditions that produce fish kills. This occurs even though tropical Australian fish are tolerant of low oxygen concentrations (Townsend *et al*. 1992; Townsend 1994; Pidgeon 2001).

Every effort should be employed to minimise the causes of acid generation. The mineralogy and other factors (particle size, reactivity of NP and presence of oxidisers) that influence AMD formation are highly variable. Accurate prediction of future acid generation is difficult. Concern has arisen over the lag time between waste emplacement and observation of an acid drainage problem. With acid generation, there is no general method to predict its duration or to predict when acidic drainage will commence. There are historical, and now modern, mining examples of long-term AMD generation requiring active treatment in perpetuity. AMD is the greatest potential impact to the aquatic fauna.

The impact to the aquatic environment should be negligible providing AMD is appropriately managed and contained on site. The management of AMD is described in Chapter 12, AMD.

Monitoring should be undertaken to assess the impact from mine drainage. This is detailed in Section 8.

7.2 Diversion Channel Design

The Horseshoe Creek and Stow Creek diversion channels have the potential to impact resident aquatic fauna during construction and operation.

The aims in designing a diversion are for the channel and the existing creek to perform in a similar ways and be stable in the long term. To achieve this, the channel:

- Needs to operate as part of a self-sustaining stream system promoting nutrient processing, ecological connectivity and sediment storage and transport;
- Avoid the use of artificial grade control structures or other structures that likely to require maintenance beyond life of mine;
- Include natural, locally and regionally occurring geomorphic and habitat features; and
- Needs to establish a state of dynamic equilibrium (equal rates of sediment erosion and deposition) with adjoining sections of the creek.

The design of the proposed diversion incorporates the following:

- Construction of composite cross section shape leaving the natural cross section of the channel unchanged whilst increasing the channel area at higher flow depths ;
- A diversion channel bank batter slope of 1:3 (v:h). This design was adopted as a preliminary assumption based on limited geotechnical information, with the intention of refining these channel bank batter slopes as the design process progresses;

- A stream bed grade similar to that of the natural waterway, which is achieved by designing sufficient length and cross sectional area in the diversion alignment and incorporating meanders of adequate geometry where appropriate; and
- A receiving channel assessed for its capacity to carry the revised flows and to meet in-channel flow velocities where flows from tributaries and overland flows are redistributed.

It is expected that a design using these principles will assists in creating a morphologically stable channel requiring minimal management in the short to medium term and no ongoing management following mine closure.

7.3 Construction of Diversion Channel

7.3.1 Construction Site Management

Objectives

- Develop and implement a system to manage entry and exit from the site to ensure that works do not extend outside the contract site.

Controls

Table 17 Construction of Diversion Channel: Controls

Specific Requirement
Delineate a clearing envelope. Disturbance will not occur outside of this area.
Clearly define site entry and exit points. All traffic should use these points to access the site.

7.3.2 Scheduling of works

Objectives

- Minimise risk of worksite inundation resulting in increased sedimentation; and
- Minimise construction impacts on in-stream fauna (e.g. migrating fish).

Controls

Table 18 Construction of Diversion Channel: Scheduling

Specific Requirement
Schedule construction during periods of low flow and low rainfall.
If heavy rain is falling, or is predicted to fall, construction works should be postponed until water levels have returned to 'normal' background levels.

7.3.3 Sediment Management

Objectives

- Prevent erosion and sedimentation of waterways; and
- Minimise the amount of sediment lost during construction.

Controls

Table 19 Construction of Diversion Channel: Sediment Management

Specific Requirement
Avoid stockpiling sediments along existing and proposed drainage lines.
Cover stockpiles when not being actively used.
Keep vehicles to well-defined tracks and roads.
Divert storm water away from disturbed areas.
Conduct excavation in stages to minimise ground exposed to erosion.
Install temporary erosion control measures such as sedimentation fences, diversion drains and sediment traps.
Existing crossings should be used to move equipment across the waterway. If there is no crossing and the stream must be crossed, machinery should be carefully 'walked' across the stream.
Temporary crossings should be entirely removed when works have finished.
The flow should be diverted and the works site isolated When excavating the channel .

7.3.4 Contamination Prevention

Objectives

- Prevent contamination of waterways.

Controls

Table 20 Construction of Diversion Channel: Contamination Prevention

Specific Requirement
If a spill occurs, immediate steps should be taken to stop it migrating to a waterway.
The spill should be reported to the appropriate authorities as soon as possible.
Hazardous substances should be kept out of the waterway.
Hazardous substances should be kept in a designated, bunded storage facility.
Refuelling, top-ups and oil checks should be done well away from the waterway.
All equipment should be inspected and repaired regularly to prevent oil and other fluid leaks.
Dirt and mud should be removed from all equipment before entering the works site to avoid transferring weeds and disease.
Wash-down water is not to enter waterways.

7.3.5 Site Rehabilitation

Objectives

- Stabilise and rehabilitate banks, streambeds and other areas disturbed during construction.

Controls

Table 21 Construction of Diversion Channel: Site Rehabilitation

Specific Requirement
The site should be rehabilitated when the works have finished.
Temporary erosion control measures, such as geo-textile silt fences, diversion ditches, sediment traps and temporary seeding with fast growing annuals, should be used to control erosion at the works site.
Temporary erosion controls should remain in place until long-term erosion control methods are established and functioning.
Long-term measures should be used to control erosion at the works site. Suitable measures include slope stabilisation, revegetation, soil coverings, rip-rap and armouring, check dams, sediment traps, brush barriers and vegetation filters.
The measures used should be inspected and maintained regularly to make sure they are effective.

8. Monitoring Program

Under the existing Waste Discharge Licence (WDL) macroinvertebrate monitoring is required. The mine sites Water Management Plan (WMP) highlights the principal potential contaminants to Mt Todd surface waters as nitrate, sulphate, phosphorus, aluminium, cadmium, copper and zinc.

The monitoring plan takes into account the location of potential sources of impact, the large inputs of rain during the wet season and the necessary level of statistical power to detect change in macroinvertebrate communities.

Several improvements to the integrity of some of the mine's water storage and retention facilities were achieved. The main risk of future uncontrolled mine water inputs is a large rainfall event leading to overflow from several facilities into surrounding waterways eventually discharging to Edith River. Controlled discharge occurs from the mine's waste rock retention pond (RP1) during periods of heavy rainfall in the wet season and during the dry season to create capacity for the upcoming wet season.

Methods from previous surveys, including the multivariate analysis technique, will be retained with the addition of several macroinvertebrate data analysis tools (SIGNAL, AUSRIVAS, ANOVA). Additional sites will increase the statistical power of the analyses.

In light of the findings from the incumbent assessment, sampling should focus on targeting refugia pools during the dry season to investigate to potential of groundwater seepage impacting the aquatic fauna. To date there has been no dry season investigation at this site. Sites should be located upstream and downstream of known discharge locations.

Water quality will continue to be monitored at the time of sampling to provide data for interpretation of macroinvertebrate results.

8.1 Site Selection

8.1.1 Rationale

Site selection has been based on Edith River locations with potential point source influences from the mine. Sites sampled in previous macroinvertebrate sample events are retained to allow use of existing data. Several sites are added to the previous sampling plan to increase the robustness and statistical significance of the program, for example there is an additional Edith River upstream site.

The three point sources leading directly into Edith River are described below. Additional description of these sites can be found in Chapter 10, Surface Water.

Stow Creek

This waterway is a tributary of the Edith River, receiving water sporadically from the ephemeral Batman and Horseshoe Creeks that run through the Mt Todd Mine Site. According to the Water Management Plan (WMP) for the mine, a large rainfall event can result in overflow from the RP2 and RP5 catchments into Batman Creek, and from the mine's RP7 tailings dam into Horseshoe Creek. A third potential input source outlined in the WMP is from the HLP moat spilling into Stow Creek during heavy rain.

RP1 controlled discharge location (Burrelll Creek)

This is the discharge location for the controlled release of mine water from the waste rock retention pond (RP1). According to WDL requirements, water from this pond can only be released in a controlled manner when appropriate water levels are reached in Edith River.

West Creek

This creek discharges directly into the Edith River and is the direct receiving environment for the RP1 site spillway, which can spill in an uncontrolled manner during heavy rainfall events.

RP3 controlled discharge

Treatment of water within RP3 is being discharged (under WDL conditions) to Batman Creek. Batman Creek flows into Stow Creek and then into Edith River. This controlled discharge only occurs once appropriate water levels are reached in Edith River and suitable chemistry (predetermined) is achieved.

8.1.2 Site Selection

The sample site locations for macroinvertebrates take account of the listed sources of potential pollutants and provide for appropriate impact analyses:

The following sample sites take account of the listed sources of potential pollutants and provide for appropriate impact analyses:

- Two sites upstream of the confluence of Stow Creek and Horseshoe Creek: *These sites will used as an upstream reference for the two sites further downstream;*
- One site downstream of the confluence of Stow Creek and Horseshoe Creek: *This site will be used to indicate whether the macroinvertebrate health of the creek is affected by water input from Horseshoe Creek;*
- A site downstream of the confluence of Stow Creek with Batman Creek: *This site will be used to indicate if the macroinvertebrate health of the creek is affected by water input from Batman Creek and can be used to differentiate between the input effects of Horseshoe and Batman creeks;*
- Two sites upstream of the confluence of Stow Creek on Edith River: *These sites will provide upstream reference conditions in Edith River for comparison with downstream sites. Historically only one upstream site has been sampled; two sites were selected for this survey to improve the power of detection of impacts;*
- One site downstream of the Stow Creek confluence on the Edith River: *This site will be used in conjunction with the two upstream Edith River sites to detect change as a result of discharge from Stow Creek;*
- One site downstream of the RP1 discharge location and West Creek confluence: *This site will be used to detect change to the Edith River macroinvertebrate community following both controlled and uncontrolled discharge from these two point sources;*
- One site by Stuart Bridge, several kilometres downstream from all influences: *This site will be used to assess impacts on the Edith River further from the general mine area;* and
- Two reference sites on the nearby Fergusson River that were sampled previously: *These sites will be used for reference comparisons to similar sites from the Edith River and provide temporal change comparisons between the waterways.*

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Appendix A

Site Descriptions: Mt Todd Mine Site

Stow Creek

Stow Creek 1 (SC1)

Downstream View	Upstream View
Site Location	Site SC1 is located on Stow Creek, approximately 3.28 km upstream of the confluence with Horseshoe Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and some evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 10 to 15 metres and from 1 to 1.5 metres in depth. The width of the stream between banks was 50 m. At the time of sampling flow conditions in the stream were low.
Riparian Zone and Bank Composition	The riparian zone was >20 wide on the left bank and >2 metres wide on the right bank. Vegetation cover of the river was 6-25 % and dominated by shrubs and vines (70 %). A couple of large gum trees (>10 m) were observed on the left bank. All riparian vegetation observed was native with some evidence of fires. The creek banks at the sampling location were earthen on both sides. Bank stability appeared to be poor. The following erosion signs were observed: (left bank) bare ground above water mark, tree roots exposed and slumping banks; (Right bank) bare ground above water mark, tree roots exposed and gully erosion.
Floodplain Characteristics	The floodplain for this creek extended for approximately 70 metres between levees, with the levee bank 3 meters above the water surface.
Available Habitat	In the reach, edge habitat comprised steep bare eroded earth banks, shallower earth banks with exposed tree roots, and pebbly beach deposits. Occasional large collected deposits of organic litter were also observed. In the stream principal habitats comprised macrophytes (40%) with snags forming a further 20% on a sand/silt (90%) substrate.

Stow Creek 2 (SC2)

Downstream View	Upstream View
Site Location	Site SC2 is located on Stow Creek, approximately 1.58 km upstream of the confluence with Horseshoe Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 5 to 8 metres and from 5 to 30 centimetres in depth. The width of the stream between banks was 15 m. At the time of sampling flow conditions in the stream were moderate.
Riparian Zone and Bank Composition	The riparian zone was >50 wide on the left bank and >50 metres wide on the right bank. Vegetation cover of the river was 5 % and dominated by native grasses. All riparian vegetation observed was native with no evidence of fires. The creek banks at the sampling location were earthen on both sides with some embedded cobbles. Bank stability appeared to be poor, with evidence of slumping. The following erosion signs were observed: (left bank) bare ground above water mark, gully erosion, slumping banks; (Right bank) bare ground above water mark, gully erosion, and slumping banks.
Floodplain Characteristics	The floodplain for this creek extended for approximately 30 metres between levees, with the levee bank 2 meters above the water surface.
Available Habitat	In the reach, edge habitat comprised steep earth banks with cobbles and occasional exposed roots In the stream principal habitats comprised a gravel / rock (100%) substrate.

Stow Creek 3 (SC3)

Downstream View	Upstream View
Site Location	Site SC3 is located on Stow Creek, approximately 0.28 km upstream of the confluence with Horseshoe Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 2 to 4 metres and from 5 to 50 centimetres in depth. The width of the stream between banks was 40 m. At the time of sampling flow conditions in the stream were low.
Riparian Zone and Bank Composition	The riparian zone was >50 wide on the left bank and >50 metres wide on the right bank. Vegetation cover of the river was 26-50 % and dominated by shrubs and vines (40 %). All riparian vegetation observed was native with no evidence of fires. The creek banks at the sampling location were earthen with dense roots on both sides. Bank stability appeared to be moderate. The following erosion signs were observed: (left bank) bare ground above water mark; (Right bank) bare ground above water mark, tree roots exposed, gully erosion, and slumping banks.
Floodplain Characteristics	The floodplain for this creek extended for approximately 40 metres between levees, with the levee bank 3 meters above the water surface.
Available Habitat	In the reach, edge habitat comprised earth banks with dense tree roots. In the stream principal habitats comprised on a gravel / rock (90%) substrate with approximately (20%) riffles.

Stow Creek 4 (SC4)

Downstream View	Upstream View
Site Location	Site SC4 is located on Stow Creek, approximately 0.53 km downstream of the confluence with Horseshoe Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 5 to 7 metres and from 10 to 50 centimetres in depth. The width of the stream between banks was 20 m. At the time of sampling flow conditions in the stream were moderate.
Riparian Zone and Bank Composition	The riparian zone was >50 wide on the left bank and >50 metres wide on the right bank. Vegetation cover of the river was 6-25 % and dominated by small trees (<10m) (70 %). All riparian vegetation observed was native with no evidence of fires. The creek banks at the sampling location were earthen on both sides with some embedded cobbles and large root masses. Bank stability appeared to be good with the only erosion signs observed being some slumping on the right bank.
Floodplain Characteristics	The floodplain for this creek extended for approximately 20 metres between levees, with the levee bank 2 meters above the water surface.
Available Habitat	In the reach, edge habitat comprised earth banks with exposed roots of large trees at the water's edge. Fallen trees with collected organic litter extended into the stream from the edge. In the stream principal habitats comprised macrophytes (5%) and snags (5%) on a gravel / rock (90%) substrate with approximately (60%) riffles.

Stow Creek 5 (SC5)

Downstream View	Upstream View
Site Location	Site SC5 is located on Stow Creek, approximately 1.44 km downstream of the confluence with Horseshoe Creek, approximately 100 m upstream of the Jatloula Road Bridge.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 10 to 15 metres and from 10 to 50 centimetres in depth. The width of the stream between banks was 30 m. At the time of sampling flow conditions in the stream were low.
Riparian Zone and Bank Composition	The riparian zone was 30 wide on the left bank and 30 metres wide on the right bank. Vegetation cover of the river was 51-75 % and dominated by small trees (<10m), shrubs and vines 70 %). All riparian vegetation observed was native with some evidence of fires. The creek banks at the sampling location were earthen with dense roots on both sides. Bank stability appeared to be good with no significant erosion signs observed.
Floodplain Characteristics	The floodplain for this creek extended for approximately 30 metres between levees, with the levee bank 4 meters above the water surface. [Simon to add more detailed descriptions]
Available Habitat	In the reach, edge habitat comprised Steep earth banks overgrown with trees and shrubs. Fallen trees with collected organic litter extended into the stream from the edge. In the stream principal habitats comprised macrophytes (5%) and snags (10%), with the remainder on a sand /silt (90%) substrate with approximately (10%) riffles.

Edith River

Edith River Downstream (ERDS)

Downstream View	Upstream View
Site Location	Site ERDS is located on Edith River, approximately 0.75 km downstream of its confluence with Stow Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 16 to 45 meters, and from 0.5 to 1.6 meters in depth. The width of the stream between banks varied along the study site between 75 and 140 meters. At the time of sampling flow conditions in the river were low.
Riparian Zone and Bank Composition	The riparian zone was approximately 10 m on the left bank and >50 m on the right bank. Vegetation cover of the river ranged between 5-45% and was dominated by a range of small trees and shrubs (<5 m) and larger trees (>15 m). All riparian vegetation observed was native with no evidence of recent fires. The creek banks at the sampling location were earthen on both sides with some embedded cobbles. Bank stability appeared to be good.
Floodplain Characteristics	The floodplain for this river can be characterised as a broad valley.
Available Habitat	In the reach, edge habitat comprised steep earth banks with exposed roots of large trees at the water's edge. Fallen trees with collected organic litter extended into the stream from the edge. In the stream, principle habitats comprised macrophytes (90%) and snags (45%) and sand/silt substrates (95%) with no riffles.

Edith River Upstream (EDUS)


Upstream View


Downstream View

Site Location	Site EDUS is located on the Edith River, approximately 0.55 km upstream of its confluence with Stow Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' forestry with no evidence of human impact and no evidence of fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 5 to 15 meters, and from 0.3 to 1.5 metres in depth. The width of the stream between banks varied along the study site between 130 and 200 metres. At the time of sampling flow conditions in the river were low to almost no flow.
Riparian Zone and Bank Composition	The riparian zone was approximately 10 m on the left bank and 25 m on the right bank. Vegetation cover of the river was between 10 – 50% and was dominated by a range of small trees and shrubs (<10 m) and a few larger trees (>10 m). All riparian vegetation observed was native with no evidence of fires. The creek banks at the sampling location were earthen on both sides with some embedded cobbles. Bank stability appeared to be good, but some areas indicated some minor erosion of the bank.
Floodplain Characteristics	The floodplain for this river can be characterised as a broad valley
Available Habitat	In the reach, the edge habitat comprised steep to shallow earth banks with some exposed roots of large trees at the water's edge. Fallen trees with collected organic litter extended well into the stream from the edge. In the stream, principle habitats comprised macrophytes (95%) and either sand/silt (45%) or gravel/rock substrates (55%) with some riffles (10-60%).

Edith River Surface Water Site (ERSW4)

Upstream View

Downstream View

Site Location	Site ERSW4 is located on the Edith River, approximately 1.4 km downstream of its confluence with Stow Creek.
Surrounding Land Use	The land use on both sides of the creek at the sampling site consisted entirely of 'native woodland' forestry little evidence of human impact. There was no evidence of fires between the river channel and the levee banks.
Stream Dimensions & Flow	The channel varied in width from approximately 4 to 25 metres, and from 0.3 to to depth greater than 1.5 metres. At the time of sampling flow conditions in the river were low to moderate, with riffles present at the shallower areas of the study site.
Riparian Zone and Bank Composition	The riparian zone was approximately 15 m on the left bank and 50 m on the right bank. Vegetation cover of the river ranged between 10 – 40% and was dominated by a range of small trees and shrubs (<8 m) and a few larger trees (>15 m). All riparian vegetation observed was native with no evidence weed infestation. The creek banks at the sampling location were mostly earthen on both sides with some embedded cobbles, and some rock bars running into the water. Bank stability appeared to be good.
Floodplain Characteristics	The floodplain for this river can be characterised as a broad valley.
Available Habitat	In the reach, edge habitat comprised steep to shallow earth banks with some exposed roots of large trees at the water's edge. Also present were rocky banks. Fallen trees with collected organic litter extended well into the stream from the edge. In the stream, principle habitats comprised macrophytes (90%) and either sand/silt (70%) or gravel/rock substrates (30%) with few riffles (up to 30%).

Fergusson River

Fergusson River Upstream (FRUS)

Downstream View

Upstream View

Site Location	Site FRUS is located on the Fergusson River, approximately 20km northeast of the mine site.
Surrounding Land Use	The land use on both sides of the creek at the sampling site is 'native woodland' with no evidence of human impact and no evidence of recent fires beyond the levee banks.
Stream Dimensions & Flow	The channel sampled varied in width from approximately 7 to 20 meters, and from 1 to depths greater than 2 metres. The width of the stream between the top of the banks varied along the study site between 45 and 80 metres. At the time of sampling flow conditions in the river were low.
Riparian Zone and Bank Composition	The width of the riparian zone ranged from 25m on the left bank and 10m on the right bank. Vegetation cover of the river ranged between 10 – 40% and was dominated by a mix of small trees and shrubs (<4m) and a few larger trees (>20m). All riparian vegetation observed was native with no evidence of fires or weed infestation. The creek banks at the sampling location were mostly steep and earthen on both sides with some embedded cobbles, and some rock facades running into the water. Bank stability appeared to be good.
Floodplain Characteristics	The floodplain for this river can be characterised as a broad valley.
Available Habitat	In the reach, edge habitat comprised of steep earth banks with some exposed roots at the water's edge. Fallen trees with collected organic litter extended well into the stream from the edge. In the stream, principle habitats comprised snags (80%) and sand/silt substrate (80%) with a macrophytes (25%).

Fergusson River Downstream (FRDS)

	
Downstream View	Upstream View

Site Location	Site FRUS is located on the Fergusson River, approximately 22km northeast of the mine site.
Surrounding Land Use	The land use on both sides of the creek at the sampling site consists entirely of 'native woodland' with no evidence of human impact and no evidence of recent fires beyond the levee banks.
Stream Dimensions & Flow	The channel width varied in from approximately 6 to 22 metres, and depth ranged between 0.5 to depths greater than 2 metres. The width of the stream between the tops of the banks varied between 30 and 50 metres. At the time of sampling flow conditions in the river were moderate.
Riparian Zone and Bank Composition	The riparian zone was approximately 50m on the left bank and 15m on the right bank. Vegetation cover of the river was between 0 - 30% and was dominated by a range of small trees and shrubs (<3m) and a few larger trees (>15m). All riparian vegetation observed was native with no evidence of fires. The creek banks at the sampling location were mostly steep and earthen on both sides with some embedded cobbles, and some rock facades running into the water. Bank stability appeared to be good.
Floodplain Characteristics	The floodplain for this river can be characterised as a broad valley.
Available Habitat	In the reach, edge habitat comprised steep earth banks with some exposed roots of large trees at the water's edge. Fallen trees with collected organic litter extended well into the stream from the edge. In the stream, principle habitats comprised snags (60%) and sand/silt substrate (60%), some with a gravel/rock bed substrate (40%).

Appendix B

Raw Macroinvertebrate Data (Mt Todd)

Mt Todd Mine Site:
Edith River

Class	Order	Family	Sub-Family	FRUS1	FRUS2	FRUS3	FRUS	FRDS1	FRDS2	FRDS3	FRDS	ERDS1	ERDS2	ERDS3	ERDS	ERUS1	ERUS2	ERUS3	ERUS	ERSW4 1	ERSW4 2	ERSW4 3	ERSW
Crustacea	Decapoda	Palaemonidae		4	4	4	**12**	4	4	4	**12**	4	4		**8**	4	4	4	**12**			4	**4**
	Acariformes	Suborder Oribatida								1	**1**					6			**6**				
		Suborder Prostigmata		6	6	6	**18**		6	6	**12**	6	6	6	**18**	6	6	6	**18**	6	6	6	**18**
Insecta	Ephemeroptera	Baetidae		5	5	5	**15**	5	5	5	**15**	5	5	5	**15**	5	5	5	**15**	5	5	5	**15**
		Caenidae		4	4	4	**12**	4		4	**8**	4	4	4	**12**	4	4	4	**12**	4	4	4	**12**
		Leptophlebiidae							8		**8**	8	8	8	**24**	8	8	8	**24**				
	Trichoptera	Hydroptilidae							4	4	**8**									4	4	4	**12**
		Ecnomidae		4	4		**8**	4	4		**8**			4	**4**		4		**4**				
		Leptoceridae		6	6	6	**18**	6	6	6	**18**	6	6	6	**18**	6	6	6	**18**	6	6	6	**18**
		Hydropsychidae		6			**6**			6	**6**												
	Diptera	Chironomidae	Chironominae	3	3	3	**9**	3	3	3	**9**		3	3	**6**	3	3	3	**9**	3	3	3	**9**
			Tanypodinae	4	4	4	**12**	4	4		**8**	4	4		**8**	4		4	**8**				
			Orthocladinae			4	**4**		4		**4**					4			**4**				
		Ceratopogonidae		4	4	4	**12**	4	4		**8**	4	4	4	**12**		4	4	**8**	4		4	**8**
		Empididae																					
	Hemiptera	Pleidae							2		**2**						2		**2**	2			**2**
		Corixidae		2			**2**	2			**2**	2		2	**4**					2	2	2	**6**
		Veliidae		3			**3**		3		**3**									3			**3**
		Mesoveliidae																		2		2	**4**
		Notonectidae						1			**1**						1		**1**				
		Gerridae																					
	Coleoptera	Dytiscidae		2	2	2	**6**	2	2	2	**6**	2	2	2	**6**	2	2	2	**6**	2	2	2	**6**
		Hydrochidae		4	4		**8**	4	4	4	**12**	4	4	4	**12**	4	4	4	**12**	4	4	4	**12**
		Hydrophilidae		2	2	2	**6**	2	2	2	**6**					2	2		**4**	2	2		**4**
		Georissidae		4			**4**													4	4		**8**
		Hydraenidae		3	3		**6**	3	3	3	**9**	3	3		**6**	3			**3**	3	3		**6**
		Noteridae		4			**4**	4		4	**8**										4		**4**
		Elmidae		7	7	7	**21**	7	7	7	**21**	7	7	7	**21**	7	7	7	**21**	7	7	7	**21**
		Cuculionidae														2			**2**				
	Odonata	Protoneuridae				4	**4**										4		**4**				
		Isostictidae															3		**3**			3	**3**
		Hemicorduliidae		5	5		**10**	5		5	**10**					5			**5**			5	**5**
		Libellulidae							5		**5**	5			**5**		5		**5**	5			**5**
		Gomphidae		5	5	5	**15**	5	5	5	**15**	5	5	5	**15**	5	5	5	**15**			5	**5**
Oligochaeta				2	2	2	**6**	2	2	2	**6**	2	2		**4**	2	2	2	**6**	2	2	2	**6**

Mt Todd Mine Site:
Stow Creek

Order	Family	Sub-Family	SC1.1	SC1.2	SC1.3	SC1	SC2.1	SC2.2	SC2.3	SC2	SC3.1	SC3.2	SC3.3	SC3	SC4.1	SC4.2	SC4.3	SC4	SC5.1	SC5.2	SC5.3	SC5
Decapoda	Atyidae												1	1								
Ephemeroptera	Baetidae		15	3	5	23	8	3	2	13	16	2	6	24	4	4	5	13	11	1	10	22
			3	4		7			2	2	5	1	6	12	3	6	3	12		5	2	7
	Caenidae		13	15	10	38	17	3	6	26	20	1	10	31	11	15	7	33	4	2	10	16
	Calamoceratidae												1	1								
	Ceratopogonidae		13	7	22	42	7	19	25	51	5	38	14	57	4	7	10	21	13	7	21	41
Diptera	Chironomidae	Chironominae	44	97	45	186	93	83	68	244	31	49	72	152	140	94	125	359	120	128	85	333
		Tanypodinae	49	27	33	109	9	37	34	80	19	48	29	96	22	26	48	96	11	23	45	79
		Orthocladinae		2	1	3	10	13	12	35	3	6		9			3	3	6	3	3	12
	Corixidae		19	1	3	23	1	4	2	7		6	2	8		3		3	1		3	4
	Cuculionidae																					
	Culicidae																					
Coleoptera	Dytiscidae		5		8	13		3	4	7	1	6		7		1	3	4	1		1	2
	Ecnomidae		3	7	1	11	3	4	9	16	0	2	11	13	2	1	1	4	0	5	1	6
	Elmidae				1	1	5	1	5	11	2	1		3	5	5		10	1	1		2
	Empididae			1		1	2	3	2	7	2		2	4	1	1		2	2	6	3	11
	Georissidae				5	5		2	1	3	3			3						1		1
	Gerridae		1		1	2																
	Gomphidae		1			1																
	Hemicorduliidae		4	2	2	8	4	6	4	14	3	3	11	17	1		1	2	3	1	1	5
	Hydraenidae		1	3	15	19		5	1	6	4	7	14	25		4	3	7	1	6	14	21
	Hydrochidae		1	3	8	12	0	5	8	13	4	10	15	29	3	6	2	11	1	10	6	17
	Hydrophilidae		4			4	2	3		5	3	3	2	8	1	3	2	6		3	1	4
	Hydropsychidae						6	9		15			1	1					18	1	1	20
Trichoptera	Hydroptilidae		3	2	1	6	10	6	1	17	3	0	2	5	7	4	1	12	0	1	0	1
	Isostictidae		1			1					2		2	4								
	Leptoceridae		6	28	13	47	9	2	0	11	71	10	14	95	11	11	5	27	2	2	8	12
	Leptophlebiidae		2			2	3	4	2	9						5	1	6	2		2	4
	Libellulidae																					
	Mesoveliidae		4		1	5					4	2	6	12			1	1				
	Noteridae				4	4						1	4	5						1		1
	Notonectidae																					
	Palaemonidae			3		3	2	2	3	7		8		8	1	1		2	1		4	5
	Philopotamidae						6	2		8	1			1					1			1
Hemiptera	Pleidae																					
Odonata	Protoneuridae		1			1																
	Staphylinidae				17	17			2	2			2	2			1	1		1	1	2
	Veliidae		1		3	4		1		1	1			1		1		1		1	1	2
Acariformes	Oribatida																					
	Prostigmata		10	9	6	25	12	5	10	27	6	0	3	9	1	4	5	10	4	3	5	12

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