AMCI

AQUATIC ECOLOGY ASSESSMENT FOR THE SOUTH GALILEE COAL PROJECT EIS

'ALS TECHNICAL REPORT'

December 2011

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1 Introduction

1.1 Project Background

AMCI (Alpha) Pty Ltd and Alpha Coal Pty Ltd (a subsidiary of Bandanna Energy Limited) propose to develop a new mine near Alpha in the Galilee Basin, Central Queensland. The South Galilee Coal Project (SGCP) will produce up to 17 million tons per annum (Mtpa) of high volatile, low sulphur thermal coal for export to international markets.

1.2 Study Area, Project Footprint and Proposed Infrastructure

The SGCP is located immediately south-west of the township of Alpha, which is approximately 170km west of Emerald and 450km west of Rockhampton in the upper Belyando River sub-catchment of the Burdekin River Basin. The SGCP will target thermal coal at depths suitable for both open cut and underground mining. The current proposed mine life is 35 years. The proponent will continue to explore the areas of its mining tenements to further quantify the coal resource and its quality to assist in mine planning.

The key elements of the SGCP would include:

- Coal mining operations, including:
  - open cut and underground mining within Mining Lease Application (MLA) area 70453, producing up to 19 Million tonnes per annum (Mtpa) of run of mine coal and 17 Mtpa of product coal for the export market;
  - placement of waste rock and rejects in out-of-pit waste rock emplacements;
  - progressive backfilling of the open pits with waste rock and rejects as mining develops;
  - development of a mine water management system including clean water drainage channels, mine affected runoff collection, sediment dams, pit water management process, on-site water reuse procedures and a permanent diversion of Sapling Creek; and
  - underground services area;
- Mine Industrial Area (containing administration, bath house, storage, vehicle parking, workshops, washdown, refuelling, controls and communication infrastructure);
- Coal Handling and Preparation Plant (CHHP);
- Coal handling infrastructure (including conveyor systems, raw coal and product coal stockpiles);
- Development of a Mine Access Road and on-site haul roads and light vehicle roads;
- Construction of an on-site rail component (including loading loop, breakdown and fuel sidings);
- Construction of a SGCP rail spur component to connect to the common user rail component;
- On-site accommodation village;

- Fuel, oil and explosives storage facilities;
- Soil stockpiles, laydown areas and a gravel borrow pit;
- Raw water supply infrastructure (e.g. pipeline, groundwater bores and Raw Water Dam);
- Sewage and waste water treatment infrastructure;
- On-site landfill facility;
- Electrical and telecommunications infrastructure;
- Ongoing monitoring and rehabilitation;
- Ongoing exploration activities within existing exploration tenements; and
- Other associated minor infrastructure, plant, equipment and activities.

The study area for this assessment comprises MLA 70453 and the infrastructure corridor.

1.3 Assessment Context and Scope

The SGCP was referred to the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) on 17 May 2010 under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). On 16 June 2010 DEWHA determined the SGCP to be a controlled action due to potential impacts on the following matters of national environmental significance under the EPBC Act:

- Listed threatened species and ecological communities (Section 18 and 18A); and
- Listed migratory species (Section 20 and 20A).

DEWHA is now referred to as the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). As a controlled action, the SGCP will be assessed under the bilateral agreement between the Commonwealth and the State, whereby SEWPaC has accredited the Queensland Environmental Impact Assessment process.

On 11 March 2010, AMCI lodged an Initial Advice Statement and applied for significant project status from the QLD Coordinator General, Department of Infrastructure and Planning (DIP) under the *State Development and Public Works Organisation Act 1971*.

On 26 May 2010, the QLD Coordinator-General declared the SGCP to be a significant project for which an EIS is required. This declaration means the project is required to undergo a rigorous EIS process.

METServe has been contracted by AMCI to prepare the SGCP EIS. In July 2011, METServe and AMCI commissioned ALS Water Sciences (ALS) to undertake the surface water aquatic ecology, stygofauna (groundwater dependent invertebrates) and troglofauna (subterranean terrestrial invertebrates) assessment for the proposed SGCP EIS.

This report summarises the findings of ecological assessments made in relation to surface water aquatic ecosystems and stygofauna and troglofauna communities and is based on a combination of a desktop literature review and field investigations. It covers the assessment of potential impacts associated with activities and infrastructure development within MLA 70453 as well as those associated with the development and operation of the Infrastructure Corridor.

This report will serve as a technical appendix to the EIS.

1.3.1 Surface Water Aquatic Ecology

For the purpose of this study, surface water aquatic ecosystems consist of:

- Rivers and streams of various stream orders (excluding drains and gullies) that lie within non-tidal, freshwater reaches;
- Backwaters;
- Wetlands, billabongs and gilgais; and
- Any dams in the potential impacted areas that might support aquatic communities.

1.3.2 Stygofauna, Hyporheic Fauna and Troglofauna Communities

Stygofauna are referred to in this report as subterranean 'aquatic animals' that live in, and are totally dependent on groundwater. Communities are often dominated by crustacean invertebrates, but also contain oligochaetes, insects, other invertebrate groups, and occasionally fish. Species occur in limestone, calcrete, and fractured rock aquifers, but seem most abundant in alluvial aquifers (Hancock and Boulton 2008) where they are likely to contribute to water quality through processes such as biochemical filtration (Hancock et al 2005). Scientifically, stygofauna are extremely valuable as they have linkages to species with no or very few surface-dwelling representatives. Examples include Bathynellacea, Thermosbanacea, and Remipeda (Humphreys 2008). Many stygofauna evolved from surface-dwelling ancestors, so are critical to improving our understanding of evolution and can be used to help understand the aridification of Australia (Humphreys 2008).

The hyporheic zone is a region beneath and alongside a stream bed where there is mixing of shallow groundwater and surface water. The flow dynamics and behaviour in this zone (termed hyporheic flow or underflow) is recognised to be important for surface water/groundwater interactions, as well as fish spawning, among other processes. The assemblage of organisms which inhabits this zone is called 'hyporheos' or 'hyporheic fauna'. For the purpose of this study, the latter term is used henceforth in this report. Hyporheic fauna were considered as part of the stygofauna assessment program for the SGCP EIS.

The term 'troglofauna' in this report refers to subterranean 'terrestrial animals' that live in underground air-filled cavities, such as caves, rock fractures, calcrete cavities, or solute cavities. Most troglofauna taxa are invertebrates, and include millipedes, spiders, pseudoscorpions, isopods, and insects. Within the troglofauna, there are three general levels of specialisation that indicate the degree of dependence on subterranean conditions. Animals that use subterranean and external environments are called trogloxenes; animals that live primarily in subterranean environments but show few morphological adaptations are called troglophiles, and animals that live exclusively underground and have specialised adaptations for the dark, confined, and resource-poor conditions are known as troglobites. Troglobites are usually blind, white or translucent, have elongate antennae and legs, and have specialised metabolic and reproductive strategies (Eberhard and Humphreys 2003). This group is the focus of this assessment, because, at the depths sampled there are no known access pathways to the land surface apart from the artificial entrances caused by boreholes.

1.3.3 Description of Existing Environment

The scope of assessment for this study was provided in the AMCI Scope of Works – EIS Aquatic Ecology for South Galilee Coal Project: June 2011 and was also provided in the SGCP Terms of Reference (TOR) released on 29 November 2010. For the purpose of this report, this scope is reiterated below.

1.3.3.1 Surface Water Aquatic Ecology

The aquatic flora and fauna occurring in the areas affected by the proposal should be described, noting the patterns and distribution in the waterways (e.g. rivers, streams, creeks and other bodies of water) and any associated wetlands. The description of the flora and fauna present or likely to be present in the area should include:

- Fish species, mammals, reptiles, amphibians, crustaceans and aquatic invertebrates; occurring in the waterways within the affected area and any associated wetlands;
- Any near threatened or threatened aquatic species;
- A description of the habitat requirements, including movement requirements, and the sensitivity of aquatic species to changes in flow regime, water levels and water quality in the project areas;
- Aquatic plants including native and exotic/weed species. Reference should be made to Biosecurity Queensland's Annual Pest Distribution Survey 2008 data and predictive maps available on DEEDI's website (www.deedi.qld.gov.au) and used in conjunction with Queensland Herbarium naturalised flora data to source the occurrence of aquatic pest plants in the project area. Local Government Area Pest Management Plans should also be utilised to source the occurrence of priority aquatic pest plants in the project area;
- Aquatic and benthic substrate;
- Habitat upstream and downstream of the project or potentially impacted due to currents in associated lacustrine and aquatic environments; and
- Wetlands listed by DERM as areas of national, state or regional significance should be described and their values and importance for aquatic flora and fauna species.

1.3.3.2 Stygofauna and Troglofauna

Section 3.3.4 of the SGCP TOR identified the following requirements for an assessment of groundwater dependent ecosystems (GDE):

- The identification of all types of GDE's occurring within and outside the project area and potentially impacted by project activities. As the term 'groundwater dependent ecosystems' is a very broad term, ALS sought clarification from METServe on a definition of GDE's for the SGCP EIS. ALS was advised by METServe (29 October 2010) that the term GDE was to include stygofauna and troglofauna only. ALS extended the definition of stygofauna to include hyporheic fauna;
- An assessment should be made of the environmental water requirements for the protection of the identified GDE's; and
- Measures should be identified to avoid or mitigate potential impacts on GDE's. Describe the proposed monitoring for each identified GDE's;

Based on the above, the aim of this report is to assess the potential impacts of the proposed SGCP on subterranean fauna dwelling above the water table (troglofauna) and within the water table (stygofauna). The stygofauna and troglofauna assessment for this study involved the following:

- Review the literature and previous assessments undertaken for troglofauna in Queensland and include any relevant information in the assessment;
- Review relevant data and information to assist in the interpretation of results (this will include geology reports, maps and information specific to the ALS field sampling program);
- Carry out field sampling to collect SGCP-area scale information on the abundance, diversity and composition of stygofauna and troglofauna within the SGCP MLA;
- Review predicted impacts and assess the potential impacts to locations that may contain stygofauna and/or troglofauna;
- Assess the potential regional, state and national significance of impacts to stygofauna and troglofauna; and
- Provide a detailed technical report describing the results of the above assessments.

1.3.4 Identification of Potential Impacts and Mitigation Options

The scope for this section was to provide a discussion of the potential temporary and permanent impacts of the project on the aquatic ecosystems and a description of proposed measures to avoid, minimise or mitigate actions, including:

- Details of proposed stream diversions, causeway construction and crossing facilities, stockpiled material and other impediments that would restrict free movement of aquatic fauna;

- Measures to avoid fish spawning periods, such as seasonal construction of waterway crossings or other waterway barriers and measures to facilitate fish movements through water crossings;
- Details of alternatives to waterway crossings or other waterway barriers where possible;
- Offsets proposed for unavoidable, permanent loss of fisheries habitat;
- A description of methods to minimise the potential for the introduction and/or spread of weed species or plant disease;
- Measures to avoid or mitigate potential impacts on GDE's; and
- Describe the proposed monitoring for each identified GDE's and the monitoring of aquatic ecology health, productivity and biodiversity in areas upstream and downstream of the SGCP area.

Impacts assessed need to include those during the construction and operation phases, where applicable, and direct, indirect and cumulative impacts. This study should describe any impacts caused by the SGCP on the existing aquatic ecology environment either in isolation or in conjunction with other known existing or planned developments, particularly other mines and industries in the region. In particular the proposed Galilee Coal Project, Alpha Coal Project and Kevin's Corner Coal Project should all be reviewed for any potential cumulative impacts on aquatic ecology.

1.3.5 Relevant Legislation

Both State and Commonwealth legislation and regulatory guidelines directly relevant to the area of study and the SGCP should be briefly described, as well as its requirements relating to the SGCP. In particular, the assessment should also address any actions of the SGCP or likely impacts that would require an authority under the relevant legislation including the *Nature Conservation Act 1992* and/or the *Fisheries Act 1994.*

2 Assessment Approach

2.1 Summary

The aims of the aquatic flora and fauna assessment were to:

- Provide sufficient information to describe the ecological values and sensitive receivers associated with surface water and groundwater dependent ecosystems in the study area and to identify and quantify potential impacts on these in relation to the SGCP; and
- Address the SGCP TOR items in relation to the aquatic environment.

This was achieved through a combination of a desktop literature review study and field surveys. The literature review process was carried out to identify data gaps and provide a broad-level assessment of the aquatic ecosystems and associated ecological values present or likely to be present in the study area. The field assessment provided detailed, site-specific data that could be used to assess what ecological values might be affected by the SGCP through particular activities and to assess whether or not viable examples of those ecological values occur in areas that will not be affected by the SGCP.

2.2 Literature Review

The literature review incorporated a review of relevant scientific and grey literature (non-peered reviewed published and non-published technical reports and information sourced from the internet), a review of relevant databases and relevant EIS reports. It also included a review of studies previously carried out in the study area and a review of aerial photographs and mine plans in order to identify spatial data gaps and sites that could potentially be accessed to fill those gaps. For the surface water aquatic ecology component of this study, the EIS technical studies by AARC (2010) and GHD (2010) for the Alpha Coal Project were considered both spatially and contextually highly relevant, given that that Project was broadly similar in nature to the SGCP and was located only 60km north of Alpha. Much of the relevant legislation, data base searches and scientific literature were already summarised in those reports. Further, those reports contained details on the presence or likely presence of aquatic reptiles and mammals in the Galilee and broader Burdekin Basin and this study did not involve detailed aquatic reptile and mall surveys. Therefore, the AARC (2010) and GHD (2010) reports are cited heavily for the surface water aquatic ecology study component of this report.

2.3 Field Study

2.3.1 Surface Water Aquatic Ecology

For the surface water aquatic ecology component of this study, sampling was carried out twice during post-wet season conditions, once by Aquateco in April 2010 (herein referred to as the ‘April 2010 survey’) and once by ALS in July 2011. The findings of both field studies are outlined within this report. On both occasions, sampling covered macroinvertebrate, macrocrustacean, fish and aquatic macrophyte communities, aquatic habitat assessment and *in situ* water quality monitoring. Both field surveys employed standard methodologies to survey these flora and fauna, where applicable, though there were some differences in fish survey techniques used between the studies. Those differences still allowed between-study comparison and did not compromise the objectives of this study in terms of satisfying the study aims.

Aquatic reptiles were not part of targeted surveys in 2011, but were recorded as incidental sightings where observed. Limited turtle trapping were carried out as part of the April 2010 survey, but no specimens were captured. Information on aquatic mammals and reptiles likely to occur in the SGCP area was, therefore, gleaned entirely from relevant literature sources.

Based on the literature review and knowledge of ephemeral streams in Central Queensland, no targeted surveys for rare and threatened aquatic taxa were deemed to be required.

2.3.2 Stygofauna and Troglofauna

Sampling for stygofauna was undertaken between 16th and 21st June 2011 where a total of 22 groundwater bores were sampled. In addition, specialised troglofauna traps were placed in 28 groundwater bores and three sites were sampled for hyporheic fauna. The troglofauna traps were left in place for a period of six weeks. The traps were removed between the 3rd and 5th August 2011.

Sampling for stygofauna and troglofauna was undertaken in accordance with WA guidelines 2003 and 2007 referred to in section 2.4.5. The full set of results are provided and discussed in this report.

2.4 Relevant Legislation

A summary of the legislation relevant to the aquatic environment in the SGCP area is provided below.

2.4.1 Environment Protection and Biodiversity Conservation Act 1999

The *EPBC Act* is the Australian Government's central piece of environmental legislation and is managed by the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). This Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the Act as matters of national environmental significance.

The seven matters of national environmental significance to which the *EPBC Act* applies are:

- World heritage sites;
- National heritage places;
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed);

- Nationally threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas; and
- Nuclear actions.

In addition, the *EPBC Act* confers jurisdiction over actions that have a significant environmental impact on Commonwealth land, or that are carried out by a Commonwealth agency (even if that significant impact is not on one of the seven matters of 'national environmental significance').

2.4.2 Environmental Protection Act 1994

The *Environmental Protection 1994 Act (EP Act*) is designed to protect Queensland's environment while allowing for development that aims to improve quality of life, now and in the future, in a way that maintains ecological processes on which life depends. This approach is termed 'ecologically sustainable development' and is achieved through a cyclical integrated management program that includes:

- Researching the state of the environment, including essential ecological processes, and determining those environmental values to be protected or achieved by consulting industry, government and the community;
- Developing environmental protection policies that include indicators, standards, waste minimisation and management advice, and promoting community involvement and responsibility;
- Implementing and integrating environmental strategies into matters such as land-use planning and managing natural resources, ensuring actions to protect environmental values from environmental harm, monitoring contaminants in the environment, and requiring those causing environmental harm to pay costs and penalties; and
- Requiring accountability, including reviewing impacts of human activities, evaluating efficiencies and effectiveness of environmental strategies, and reporting on the state of the environment.

The *EP Act* regulates 'environmentally relevant activities', including mining or petroleum activity or as prescribed by the *Environmental Protection Regulation 2008*. The *EP Act* binds all parties, including the Queensland Government and its agencies and, as far as legislative power permits, the Commonwealth Government and other state Governments.

The *Environmental Protection Regulation 2008* supports the EIS process and specifies environmentally relevant activities prescribed under the Act. It outlines matters to administering authority must consider when making environmental management decisions and also details prescribed water contaminants.

2.4.3 Nature Conservation Act 1992

The *Nature Conservation 1992 Act (NCA)* is administered by the Queensland Department of Environment and Resource Management (DERM) and is aimed at the conservation of biological diversity, ecologically sustainable use of wildlife, ecologically sustainable development and international criteria developed by the World Conservation Union (International Union for the Conservation of Nature and Natural Resources) for establishing and managing protected areas.

The object of the NCA is the conservation of nature, achieved by an integrated conservation strategy for Queensland involving matters including:

- Gathering, researching and disseminating information on nature, identifying critical habitats and areas of major interest, and encouraging the conservation of nature by education and co-operative involvement of the community;
- Dedication and declaration of areas representative of the biological diversity, natural features and wilderness of Queensland as protected areas;
- Managing protected areas;
- Protecting native wildlife and its habitat;
- Ecologically sustainable use of protected wildlife and areas;
- Recognition of the interest in nature of Aborigines and Torres Strait Islanders and their co-operative involvement in nature conservation; and
- Co-operative involvement of landholders.

The *Nature Conservation (Wildlife) Regulation 2006* classifies and details the management intent for plants and animals that are presumed extinct, or considered endangered, vulnerable, rare, near threatened or of least concern. Taking or interfering with protected flora and fauna listed under the Act requires a permit. This includes moving or relocating a protected species.

2.4.4 Fisheries Act 1994

The *Fisheries 1994 Act (Fisheries Act)* provides for the management, use and protection of fisheries resources in Queensland.

The main purpose of the Fisheries Act is to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to apply and balance the principles of ecologically sustainable development and promote ecologically sustainable development.

The Fisheries Act’s objectives include:

- Ensuring fisheries resources are used in an ecologically sustainable way;
- Achieving the optimum community, economic and other benefits obtainable from fisheries resources;
- Ensuring access to fisheries resources is fair, and
- Ensuring resources are used in an ecologically sustainable manner is the most pertinent objective to this plan.

In the Fisheries Act, ecologically sustainable development means using, conserving and enhancing the community’s fisheries resources and fish habitats so that the ecological processes on which life depends are maintained; and total quality of life can be improved.

Construction of waterway barrier works, such as road crossings, pipeline crossings and culverts that limit fish stock access and movement require a developmental approval under the *Sustainable Planning 2009 Act* assessed against the relevant provisions of the *Fisheries Act*.

2.4.5 WA Guidelines for Subterranean Fauna

DERM requires sampling in areas where stygofauna and troglofauna are 'likely' to occur, and for the SGCP, there is a stated requirement that sampling should meet the requirements for surveys undertaken for Environmental Impact Assessments in Western Australia, as detailed in the following documents:

- WA EPA Guidance Statement No. 54, Guidance for the Assessment of Environmental Factors : Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia (EPA, 2003);
- WA EPA Guidance Statement No. 54a, Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA, 2007).

DERM do not have any established (published) protocols for sampling stygofauna and troglofauna in Queensland and adopt the WA guidelines by default. The WA Guidance Statements (EPA 2003, 2007) provide information which the WA EPA considers important when assessing proposals where subterranean fauna is a relevant environmental factor. This project has adopted the WA protocols for sampling stygofauna and troglofauna so that study results fully satisfy DERM requirements.

For stygofauna and troglofauna, WA Guidance Statement 54 (2003) specifies that sampling should occur in at least two seasons and bores should encompass the full range of aquifer types present, with the more prospective habitats assigned significant sampling effort. The guidance statement recommends that the most efficient sampling design for stygofauna will include the sampling of 20 impact bores (i.e. those within the zone of mining impact) in two seasons spaced at least three months apart. This equates to a total of 40 impact bores across two sampling events within the mine footprint. An equal sampling effort using comparable methods should be expended on control bores located outside the zone of influence of the mine. As it can be difficult for mining companies to find a sufficient number of bores outside the impact area, a focus on finding sufficient bores inside the expected zone of impact is recommended. For troglofauna the WA guidelines recommend 60 samples be collected from the impact area across two seasons spaced at least three months apart in order to account for any temporal variation in community composition. If stygofauna or troglofauna species that are not known from elsewhere (e.g. previous surveys, published literature and reports) are collected from the study area, then further survey effort is needed to find these species from areas not affected by mining.

The WA guidelines do allow for the conduct of Pilot Studies where it is considered that the likelihood of finding stygofauna or troglofauna is very low (e.g. poor groundwater quality, unsuitable geology, historic sampling of the local area has not recovered stygofauna or troglofauna, lack of groundwater etc.). In the event that a Pilot Study does find stygofauna or troglofauna, additional survey effort is required to satisfy the full WA Guideline requirements.

2.5 Surface Water Aquatic Ecosystems

2.5.1 Site Selection and Location

Based on the results of the literature review, 11 sampling sites were identified for the July 2011 SGCP surface water aquatic ecology study. These include 10 sites within or adjacent to MLA 70453 and one site adjacent to the Infrastructure Corridor. With respect to the former, this included a mixture of sites within the proposed open pit and underground mining areas, sites that could potentially receive downstream mine wastewater runoff, sites upstream of the mine that may be cut off from downstream reaches and sites that will not be directly affected by the SGCP (Table 2-1). Two of these 11 sites had been sampled previously during the April 2010 survey. Low flow conditions encountered at that time limited the number of sites containing water that could be sampled compared to what had been nominated prior to their fieldwork (Aquateco, 2010). Also, a detailed mine plan was not available at that time upon which to base a more extended survey (Aquateco, 2010).

As part of the combination of the two studies, sampling focussed on Tallarenha, an unnamed tributary of this system, Sapling Creek, Alpha Creek, Dead Horse Creek and Saltbush Creek.

The sites that were actually surveyed during the July 2011 study varied slightly from the list given in Table 2-1 in that:

- TC-2 could not be accessed;
- UT-1 was dry at the time of sampling. Another unnamed tributary site (UT-2), which also lies within the proposed mine pit area, was considered as a replacement, but was also dry at the time. UT-2 was considered representative of both sites so was surveyed in terms of habitat assessment;
- A large dam was present on the unnamed tributary, which featured a range of submerged and emergent macrophytes not present at other sites, so this site (UT-Dam) was sampled;
- A natural wetland (AC –Lagoon) adjacent the Alpha Creek upstream site AC-1 was located and sampled; and
- Another large dam on Sapling Creek (SC-Dam) was located and assessed for habitat characteristics and *in situ* water quality.

A map showing the locations of sites sampled in July 2011 is shown in Figure 2-1.

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Table 2-1: Site codes and justification for selection

Monitoring Site	Site Description	Justification
Tallarenha Creek		
TC-1	Upstream (Control)	Upstream reference site – no impact proposed due to mining or mine runoff. Shows what aquatic ecosystems values will be retained in this creek if project goes ahead.
TC-2	On-site (Impact)	Area of stream potentially impacted by subsidence impacts from underground mining.
TC-3	Downstream (Impact)	Characterises receiving environment downstream of underground mining area.
Unnamed Tributary		
UT-1	On-site (Impact)	Impact site located within open pit mining area.
Sapling Creek		
SC-1	Upstream (Control)	Upstream reference site – no direct impacts proposed due to mining or mine runoff. Shows what aquatic ecosystem values will be retained in this creek if project goes ahead.
SC-2	On-site (Impact)	Area of stream impacted by open pit mining and located downstream of underground mining area. Opportunity to carry out repeated sampling at an Aquateco monitoring site to assess temporal variability.
SC-3	Downstream (Impact)	Characterises the receiving environment downstream of the mining area.
Dead Horse Creek		
DC-2	Reference (Control)	Nearby reference site.
Alpha Creek		
AC-1	Upstream (Control)	Site upstream of any mine impacts.
AC-2	Downstream (Impact)	Site potentially impacted by uncontrolled releases from the southern sediment dam. Impact site with respect to mine runoff impacts, but also affected by runoff from non-mine runoff upstream. Opportunity to carry out repeated sampling at an Aquateco monitoring site to assess temporal variability.
Saltbush Creek tributary		
Site 04	Representative Infrastructure Corridor Waterway	Site adjacent the northern section of the Infrastructure Corridor that had retained sufficient water for sampling in July 2011 and could be considered as representative of stream habitat intersected by the Infrastructure Corridor.

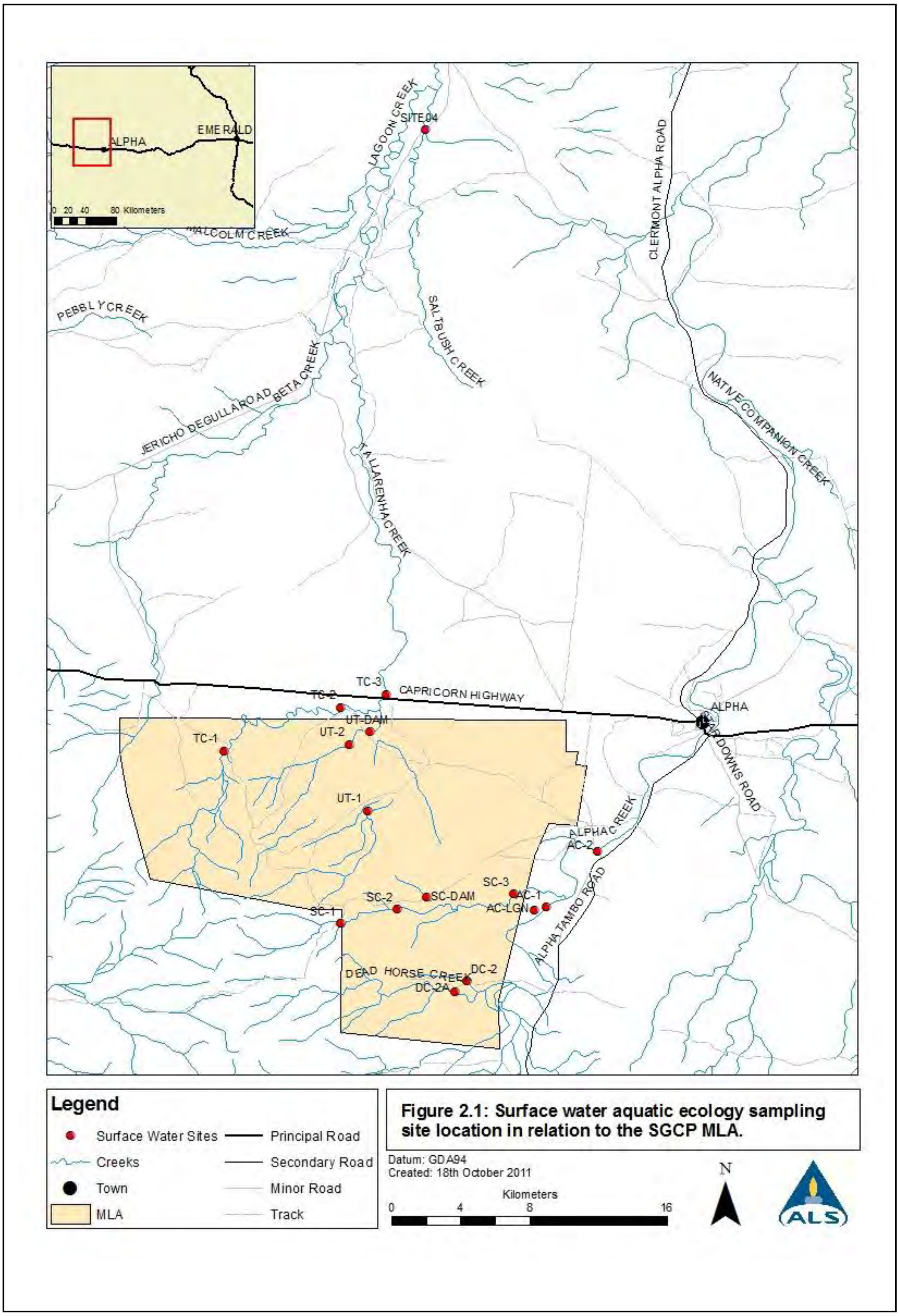

Figure 2-1: Locations of surface water aquatic ecology sites sampled in July 2011

2.5.2 Macroinvertebrates

Sampling of macroinvertebrates was undertaken in accordance with the *Monitoring and Sampling Manual, Environmental Water Protection (DERM, 2009a)*. Pool bed and edge habitats were sampled as part of the April 2010 survey. Based on the fact that Aquateco (2010) found that edge habitat tended to host the greater diversity and few, if any, taxa were unique to pool bed samples, AUSRIVAS-style macroinvertebrate sampling for the July 2011 sampling round was restricted to edge habitat. However, the ALS July 2011 study also involved the collection of composite habitat samples where there was atypical habitat, such as shallow flowing water over sand bars. Such habitats often support different macroinvertebrate assemblages, so it was essential that sampling captured such habitats in order to provide a truly representative picture of diversity and taxonomic composition within the study area.

Samples were collected using a standard ISO 7828 (1983) design sweep-net with 250-micron mesh. AUSRIVAS edge habitat samples were collected from a 10m section of edge habitat as defined in DERM (2009a). Composite habitat sampling involved the sampling of each identifiable atypical non-edge microhabitat at a given site (up to 5m sections of each) and pooling those into one combined sample representative of that site. Composite habitat sampling was only carried out at one site (AC-2) as this was the only site that featured shallow flowing water over sand bars or any other habitat other than pool and bed habitat at the time of sampling.

For all types of samples, the collected material was placed into a sorting tray and macroinvertebrates live picked for a minimum of 30 minutes by an AUSRIVAS accredited staff member using forceps and pipettes. If 200 animals were not collected at the end of 30 minutes, sorting continued for a further 10 minutes. If new taxa were found in this 10 minute period, sorting time was extended a further 10 minutes. This sample processing cycle continued for a maximum of one hour (DERM, 2009a). The objective of the above sorting protocol was to obtain a sample containing as diverse a fauna as possible (and hence provide a useful measure of taxa richness). As such, attempts were made to avoid bias towards abundant taxa and to collect all taxa present in the sample, including rare or cryptic animals.

Picked samples were placed in 200mL plastic jars and preserved in 70% ethanol. Each sample jar was clearly labelled with information including site, habitat, sampling method, date and the name of the person who collected the sample.

AUSRIVAS-style samples were generally identified to at least family level, except for certain taxa (e.g. sub-family for members of Chironomidae and order level for Acarina, Microcrustacea, Nematoda and Hirudinea), as per the DERM (2009a) guidelines. Where possible, July 2011 specimens were identified to genus/species (where possible). Aquateco (2010) identified microcrustacea to family level, which is not required under AUSRIVAS protocols, but does shed light on the types of microcrustacea present within the study area. Some pooling of Aquateco (2010) macroinvertebrate data into appropriate taxonomic groupings was required prior to performing some of the data analyses detailed below.

Macroinvertebrate data were analysed using a combination of univariate and multivariate data analysis techniques. A suite of standard univariate indices was used to assess the diversity and status of macroinvertebrate assemblages at the different sites. These included:

- Taxa richness –measure of diversity (according to the level of taxonomic resolution applied);
- PET Richness – the number of macroinvertebrate taxa belonging to the commonly pollution-sensitive Plecoptera, Ephemeroptera and Trichoptera groups in a given sample; and
- SIGNAL 2 (Stream Invertebrate Grade Number – Average Level) is a biotic index that provides a measure of the relative number of pollution-tolerant and pollution-sensitive taxa within a given assemblage, based on sensitivity gradings for different taxa provided by Chessman (2003). Higher SIGNAL 2 scores indicate that an assemblage features a greater array of pollution-sensitive taxa compared to pollution-tolerant taxa. In addition to deriving SIGNAL 2 scores for each site, the sensitivity ratings information underpinning this index was used to assess which, if any, pollution-sensitive taxa occur in areas potentially affected by the SGCP.

Taxa richness, PET Richness and SIGNAL 2 scores were compared between sites and also to recommended ranges for Central Queensland waterways as stated in the Queensland Water Quality Guidelines (2009b). The latter provided a measure of 'health' for the macroinvertebrate assemblages at each site.

Another means of assessing macroinvertebrate community health that was used as part of this study was the QLD AUSRIVAS model. This model uses site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress based on site location and a set of predictor variables (physical and chemical characteristics which cannot be influenced due to human activities, e.g. altitude), was used to assess whether the assemblages sampled at each site were representative of what would be expected based on those location and habitat conditions. The QLD AUSRIVAS produces two main outputs:

- The OE/50 score, which is a ratio of the observed (O) fauna to the expected (E) fauna and can range from zero, when none of the expected taxa are found at a site, to one, when all the expected taxa are found. Values can be greater than one if more families are found at the site than predicted by the model; and
- 'Health' rating bands based on the OE/50 scores derived from the model, as per Table 2-2 below. These bandings provide evidence of whether or not the diversity and makeup of the macroinvertebrate assemblages has diminished, potentially due to anthropogenic influences.

The specific AUSRIVAS model used for this study was the Queensland Coastal autumn edge habitat model. This was based on the location of the study being east of the Great Dividing Range and the samples having commonly been collected from edge habitat as part of the two sampling rounds in autumn (or in the case of 2011, closest to autumn). Strictly speaking, the QLD AUSRIVAS model does not cover winter sampling, however, in 2011 the extended presence of water and / or flows in streams due to the heavy 2010/11 wet season meant that, temperature and ambient light levels aside, habitat conditions were quite typical of what would normally be expected in autumn. Hence, a decision was made to run the July 2011 samples through that model. In any case, the use of QLD AUSRIVAS for assessments in ephemeral stream habitat must always be interpreted with caution as the model was developed based on perennial streams.

Table 2-2 Queensland AUSRIVAS assessment bandwidths

Band Label	Band Name	Band Description
Band X	More biologically diverse than reference sites.	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
Band A	Reference condition.	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
Band B	Significantly impaired.	Fewer families than expected. Potential impact either on water quality or habitat quality or both, resulting in loss of taxa.
Band C	Severely impaired.	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
Band D	Extremely impaired.	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

In addition to the above, a range of multivariate analyses were carried out on macroinvertebrate composition data to determine the spatial patterns in macroinvertebrate community composition within the study area. A particular focus of the multivariate analysis was to determine whether there are any taxa or assemblages represented in areas affected by the SGCP that are not also represented in areas that will not be affected by the SGCP. These analyses were also used to assess if there were any habitat associations for particular habitat based on catchment or habitat type, which was considered important as some waterways and habitats may be more vulnerable to the impacts of the SGCP than others.

2.5.3 Fish

Fish surveys were carried out using a variety of gear types, including:

- Backpack electrofishing;
- Fyke nets;
- Seine nets, and
- Collapsible Bait traps.

Of these, only electrofishing and bait trapping were used during the 2010 and 2011 surveys. Backpack electrofishing was carried out using different gear on each of the sampling occasions (Smith-Root electrofisher in 2010 and a NIWA EF300 electrofisher in 2011). The sampling procedures were also different, with Aquateco (2010) applying continuous effort until the available habitat was sampled, while in July 2011, ALS carried out five replicate 2.5 minute 'shots' where there was sufficient habitat, in order to provide both a measure of within-site catch per unit effort variation and a representative idea of what species occurred at each site. For each shot, the amount of on time was recorded and catches were kept separate. There were some sites for which the amount of available habitat in July 2011was restricted. For those sites, a similar approach to that used by Aquateco (2010) was adopted.

Aquateco (2010) used seven opera house style bait traps per site, while ALS used 10 concertina-style bait traps per site, where sufficient water depth allowed. In both cases, bait traps were deployed for a minimum of two hours per site and were set near available structural habitat (e.g. structural woody habitat, draping aquatic vegetation, in-stream aquatic macrophytes, undercut banks).

Aquateco (2010) set fyke nets and turtle traps at both sites in April 2010. The cod end of each net was buoyed to ensure any turtles or platypus caught would be able to breathe. Fyke netting was not carried out as part of the July 2011 survey as fyke netting works best in flowing stream habitat, whereas most sites encountered during the July 2011 survey were either isolated pool habitat or wetland habitat. The two sites in Alpha Creek featured flowing water, but AC-1 was too deep to set fyke nets and fyke netting in AC-2 was unlikely to have resulted in any significant gains with respect to increasing the diversity of the catch over and above what was possible using bait trapping and electrofishing.

Two seine netting shots were attempted at SC-2 in July 2011. This was the only site that featured a section of shallow gradient bank largely free of submerged snags, rocks and submerged vegetation. This technique was not particularly effective at that site, as the boggy substrate made the smooth deployment of the net difficult.

The shallow, confined pool habitat present at most sites in July 2011meant that the combination of backpack electrofishing and bait trapping were effective means of collecting representative fish catch samples.

For all gear types, all fish caught were identified and counted. Field identifications of species were made using relevant keys (e.g. Allen et al. 2003). In July 2011, a proportion of individuals (up to 20 per species per site) were measured (total length to the nearest millimetre) and any wounds, lesions and deformities were recorded, if present. On both occasions, native fish were released alive wherever possible. Introduced fish were euthanased and disposed of appropriately and humanely.

Given the differences in collection methods and the fact that Aquateco (2010) did not present catch data based on the method of capture, fish community data were explored largely in terms of the diversity, distribution and relative abundance of the species captured over the two rounds of sampling.

2.5.4 Aquatic Habitats

As per the QLD AUSRIVAS *Monitoring and Sampling Manual, Environmental Water Protection (DERM, 2009a)*, information about site habitat conditions was recorded in a systematic and comparable way between sites, by completing QLD AUSRIVAS habitat assessment field sheets.

The habitat inventory at each site included the whole reach (100m section of the river), the habitats sampled, and the surrounding riparian and terrestrial environment. The information recorded was largely used to describe the nature of aquatic habitats present within the study area and any existing impacts potentially affecting them, but was also used to help interpret trends in the biological data.

As part of habitat assessment recording, the location of each site was recorded, so its location in relation to the SGCP could be determined and the site could be revisited for sampling if required. Photographs of each site were taken as a further record of habitat conditions observed at the time.

2.5.5 *In situ* Water Quality

In situ physical and chemical parameters were measured at each site using a TPS 90FL series multiprobe in April 2010 (AQUATECO, 2010) and a YSI650 MDS multi-parameter water quality meter in 2011 (ALS current study). The YSI water quality meter was calibrated in accordance with the manufacturer's specifications prior to sampling. Both instruments were used to measure: pH; EC (µS/cm); Salinity (g/L) and Water Temperature (˚C); and Dissolved Oxygen level (% saturation and mg/L) in situ. Turbidity (NTU) was measured using the TPS multiprobe in April 2010, while a Hach 2100P turbidity meter was used to measure turbidity in July 2011. Alkalinity, a key factor influencing the makeup of macroinvertebrate communities, was measured in July 2011using alkalinity field titration kits.

In line with the DERM (2009a) guidelines, water quality measurements were taken before any other sampling to ensure that the results are not compromised by disturbance of bottom sediments caused by sampling activity. In turn, care was taken not to disturb any of the biological habitats that were to be sampled when measuring water quality. Flow conditions and water levels, along with water depth, were assessed qualitatively at the time of sampling. This information was recorded to aid the interpretation of the water quality data.

In-situ water quality data were tabulated and assessed against relevant guidelines, which include the following:

- ANZECC & ARMCANZ (2000) Water Quality Guidelines (freshwater ecosystems with a species protection level of 95%); and
- Queensland Water Quality Guidelines 2009 (central coast Queensland region, lowland streams).

2.6 Stygofauna Community

2.6.1 Selection of Groundwater Bores for Stygofauna Sampling

The selection of groundwater bores for stygofauna sampling for this project was undertaken to fulfil the following criteria (where possible):

1. Aperture of 50mm diameter or greater;

2. Intersect the water table;

3. Preferably lined and slotted through the water column;

4. Vertical (not angled);

5. Geographically spread across the proposed mine lease and include reference bores outside the potential zone of impact (i.e. water drawdown zone);

6. Cover all hydrogeological units present, including a focus on shallower alluvial aquifers if present;

7. Of varying age, in excess of six months, and preferably undisturbed (i.e. not regularly pumped or purged); and

8. Have a salinity less than 5,000 µS/cm EC (and preferable less than 1,500 µS/cm EC) and a DO in the range of 2 to 4mg/L.

A total of 22 groundwater bores were identified by METServe for stygofauna sampling. Six of these bores were also used for troglofauna sampling. Where this occurred, stygofauna sampling preceded troglofauna sampling. Table 2 3 provides a list of the monitoring bores used for stygofauna sampling in this study. A locality map showing the spatial arrangement of stygofauna sampling sites in relation to the MLA is given in Figure 2-2.

2.6.2 Sampling Methodology

All bores were 50mm diameter, so 40mm diameter nets were used for sampling (ALS nets conform to WA guideline [2003 & 2007] requirements). Nets were made of 50µm mesh material and weighted at the bottom with a brass fixture and attached plastic collecting jar. The net was lowered to the bottom of the bore, bounced three to five times to dislodge resting animals, and slowly retrieved. At the top of each haul, the collecting jar was rinsed into a 50µm mesh brass sieve and the net lowered again. Once six hauls were completed, the entire sieve contents were transferred to a labelled sample jar and preserved in 100% AR Grade ethanol. A small amount of Rose Bengal, which stains animal tissue pink, was added to each sample to aid sample processing.

2.6.3 Laboratory processing

Sample jars were drained of ethanol and washed gently into channelled sorting trays to create a thin layer of sediment spread across the bottom of the tray. Samples were then sorted under a Leica MZ9 stereomicroscope with planachromatic 10x objective lenses and a zoom capability of between 6.3x and 60x.

2.6.4 Groundwater Quality Sampling

Groundwater samples were collected using a bailer lowered to approximately 3m below the water surface. Water was measured for temperature (°C), pH, electrical conductivity (µs/cm), and dissolved oxygen (mg/L and % saturation) using a YSI 556 multiparameter water quality meter.

Groundwater sampling preceded biological sampling to ensure the groundwater contained within the bore was undisturbed. The YSI field meter was calibrated prior to its use in the field, with calibrations cross-checked in the field. The meter was used in accordance with the manufacturer's specifications.

In addition to *in-situ* water quality, measurements were also collected from each groundwater bore on depth to water table (using an electronic dip probe), depth to end of hole, bore diameter and construction, purpose of bore, GPS location and bore ID, presence of tree roots, surrounding landuse, sampling date and time and sampling team. A photographic record of each bore and surrounding landuse was also collected. All field data were recorded on specialised ALS recording sheets.

Table 2-3: Location and characteristics of groundwater bores used for stygofauna sampling (e = estimated depth). Shaded rows show bores also used for troglofauna sampling.

Bore ID	Easting	Northing	Depth to Water (m)	Depth to End of Hole (m)	Bore Diameter (mm)	Bore Covered	Tree Roots Present
BH90C	449168	7373639	46.71	72	150	Yes	No
BH83C	445625	7379288	58.98	121	50	Yes	No
CK169C	448028	7375639	61.57	75	50	No	No
BH35	446482	7382516	42.80	90e	50	Yes	No
BH116	446704	7380453	49.88	53	150	Yes	No
BH108	446584	7380455	50.33	85	50	Yes	No
BH35C	446483	7382519	42.87	62e	50	Yes	No
BH107	446294	7382499	43.50	56	150	Yes	No
BH118	446388	7382497	42.92	79e	50	Yes	No
CK157C	446349	7383348	39.13	70e	50	Yes	No
Near VW02	441609	7383187	65.07	85e	150	Yes	No
BH29C	446886	7380537	49.39	69	50	Yes	No
CK108C	446516	7380738	49.85	80e	125	Yes	No
Windmill 1	448783	7382079	28.86	60e	150	No	No
CK106	446558	7381079	49.21	87	150	No	No
CK159	446780	7381142	48.09	71e	150	No	No
BH28C	444944	7380215	59.43	139	50	Yes	No
MB03	445648	7379294	59.22	80	50	Yes	No
BH115	446652	7378676	60.32	85	50	Yes	No
CK163	446826	7378680	59.72	76	50	No	No
Windmill 2	453138	7381101	25.31	40e	150	No	No
BH112	447923	7375649	63.18	78	50	No	No

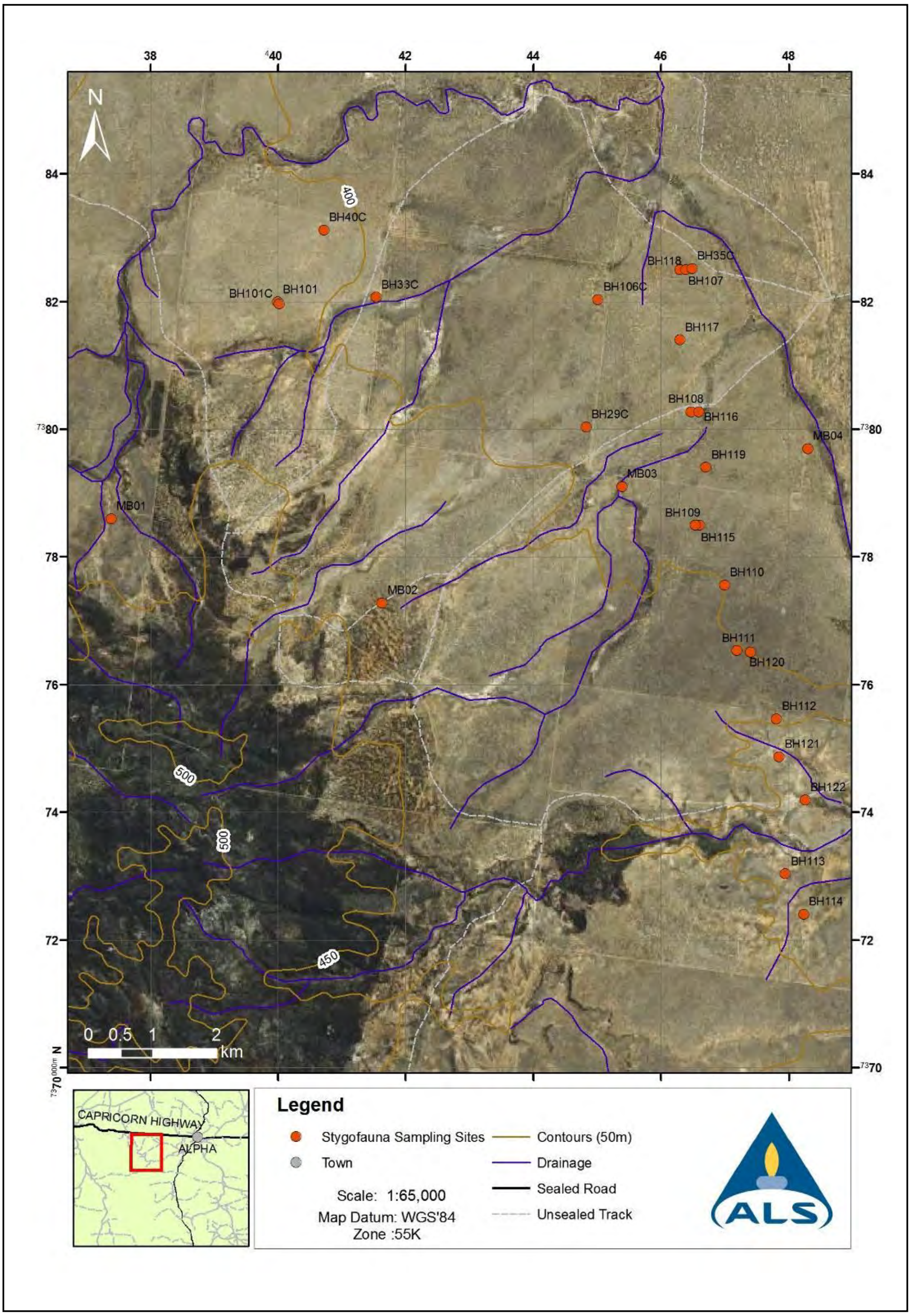

Figure 2-2: Location of groundwater bores surveyed for stygofauna in relation to MLA 70453

2.7 Hyporheic Fauna

Attempts were made to collect stygofauna from the hyporheic zone of Sapling Creek using Karaman-Chappuis pits (Malard *et al* 2001). The hyporheic site was located approximately 100m north of BH90C (55K 449168 mE, 7373639 mS). Three pits were excavated into the dry sand bed of the creek using a spade at points considered likely to be near water (i.e. outside of bends, areas of damp sand, depressions in sand bed). A confining layer of clay was encountered at depths of between 10 and 20cm (Figure 2-3). In two pits there was no standing water, indicating that the local water table had receded beneath the clay layer and the hyporheic zone was absent. In the third pit, a thin film of approximately 1cm was present over the clay layer, however this pit was in an area heavily visited by cattle and the origin of the water was unlikely to have been through connections to the aquifer. As a result, no hyporheic faunal samples were collected and it is concluded that no true hyporheic zone exists within Sapling Creek at this locality. Further hyporheic sampling is not recommended.

Figure 2-3: Attempted Karaman-Chappuis Pit in the bed of Sapling Cree

2.8 Troglofauna Community

Previous troglofauna assessments of Queensland have focussed on cave habitats. Troglofauna communities are known from the Chillagoe, Undarra, and Rope Ladder Caves in north Queensland. The fauna of these caves includes plant hoppers, cockroaches, centipedes, spiders and isopods (Howarth and Stone 1990, Weinstein and Slaney 1995, Eberhard and Humphreys 2003). The troglofauna sampling at South Galilee is the first non-cavernous survey in central Queensland.

2.8.1 Selection of Groundwater Bores for Troglofauna sampling

The selection of groundwater bores for troglofauna sampling for this project was undertaken to fulfil the following criteria (where possible):

1. 50mm diameter or greater (in order to allow access for troglofauna traps);
2. Preferably intersect the water table in order to provide a humid atmosphere within the bore, although this is not a specific requirement;
3. Unlined, or if lined, not block access to prospective geological formations that may contain troglofauna;
4. Vertical (not angled);
5. Capped at the surface to limit the ingress of terrestrial fauna;
6. Geographically spread across the proposed mine lease and include reference bores outside the potential zone of impact;
7. Cover all prospective geological units present; and
8. Of varying age, in excess of six months, and preferably undisturbed.

Traps were placed in 28 bores at SGCP from 16 to 21 June 2011. Troglofauna traps traps were recovered from 22 bores (Table 2-4) between 3 and 5 August 2011. Six of the 22 groundwater bores used for troglofauna sampling were also used for stygofauna sampling. Where this occurred, stygofauna sampling preceded troglofauna sampling. The six stygofauna net hauls collected from the six dual purpose bores also provided an important scrape of the exposed rock surface between the end of the PVC lining and the beginning of the water scraping process has been shown to be a useful method for troglofauna. In this case, each stygofauna sample (during processing) carefully assessed for the presence of troglofauna. A map showing of troglofauna sampling bores in relation to the MLA is given in

Figure 2-4.

Table 2-4: Properties of bores sampled for troglofauna at South Galilee. All variables are in metres (shaded rows show bores also used for stygofauna sampling).

Bore ID	Easting	Northing	Depth of casing	Depth to end of hole or to water	Length of rock exposed	Depth of trap placement
BH15C	447100	7375762	54	67.26	13.26	60
BH28C	444944	7380215	54	59.43	5.4	56
BH83C	445625	7379288	55	58.98	4	56
BH109	446600	7378494	55	60	5	56
BH112	447923	7375649	50	63.18	13.2	53
CK163	446826	7378680	54	59.72	5.3	56
CK169C	448028	7375639	47	61.57	14.57	50
BH07C	446223	7374293	60	69.1	9.1	65
BH88	447122	7374266	56	62	6	60
BH90C	449168	7373639	40	46.71	6.7	43
BH100	447188	7376736	57	63.7	6.7	61
BH100C	447194	7376719	57	64	7	60
BH111	447190	7376532	54	63.4	9.4	60
BH114	448233	7372403	39	52.5	13.5	47
BH120	447403	7376513	53.5	63.5	10	57
BH121	447848	7374868	40	54.6	14.6	50
BH123	448441	7372589	42	53.6	11.6	47
CK167	447547	7376415	57	63.1	6.1	60
CK172	447597	7376629	52	62.94	10.94	56
SP137	448005	7375052	40	54.4	14.4	50
SP141	446517	7374271	43	69.3	26.3	65
SP137C	447886	7374873	39	54.51	15.51	43

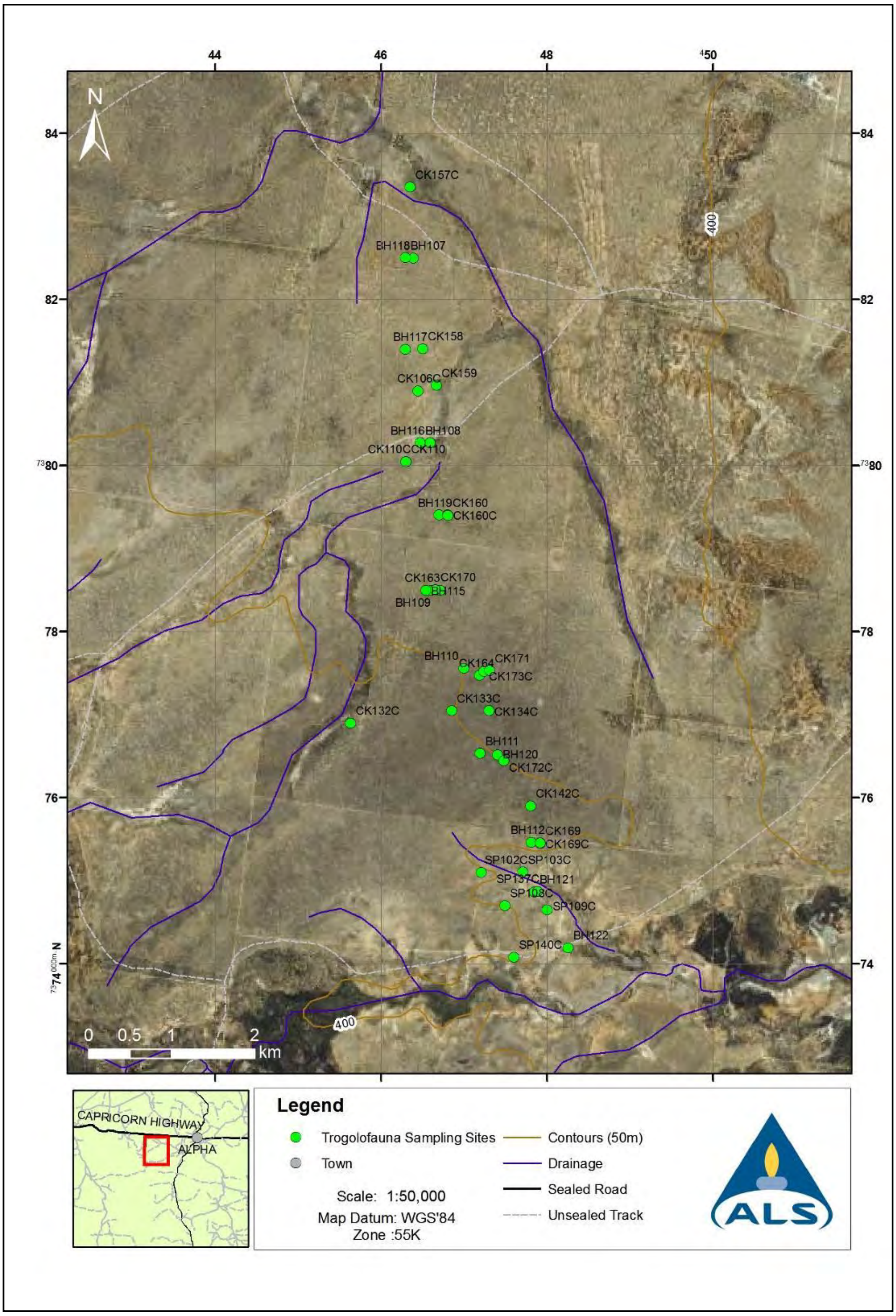

Figure 2-4: Location of troglofauna bores surveyed in relation to MLA 70453

2.8.2 Sampling Methodology

Troglofauna were sampled using traps baited with leaf litter and dried dog food. Poplar leaf litter was air dried for four weeks, washed under a running tap then soaked in water to re-saturate, microwaved (to kill any vagrant terrestrial fauna), then stored moist in sealed plastic bags until installed in the troglofauna traps. A sub-sample (5%) of the leaf litter was examined under a dissecting microscope to ensure no animals remained. Troglofauna traps were made of 1L white plastic bottles drilled with holes along the side (Figure 2-5). Approximately 100g of moist leaf litter and four pieces of dried dog food were installed in each trap and lowered into each bore until they were suspended against bare rock following scrutiny of bore casing and hydrogeological data.

Figure 2-5: ALS troglofauna traps, leafpacks and dry dog food bait.

Traps were placed in 28 bores at SGCP from 16 to 21 June 2011. Traps were retrieved on 3, 4 and 5 August 2011. Six troglofauna traps (SP109C; BH122; CK144; BH115; BH35C; CK143) were unrecovered because of stock damage to the surface component of the traps (i.e. tie off/anchor point), or because the drill pads had been rehabilitated by AMCI and the entire bore had been lost at the surface.

Upon retrieval, trap contents were emptied into zip-seal bags containing 100% AR Grade ethanol, then stored in insulated plastic boxes for transport to the ALS Brisbane laboratory.

2.8.3 Sample Processing

Processing and identification of troglofauna samples was conducted by experienced ecologists at the ALS Water Sciences Laboratory in Brisbane. For each sample, leaves were rinsed under running water into a 63µm sieve. Each leaf was washed into the sieve and inspected individually under a magnifying lens and lamp to ensure no fauna remained. Once all leaves were washed, they were discarded. Sieve contents were then rinsed into a channelled sorting tray and scanned under a Leica MZ9 stereomicroscope with planachromatic 10x objective lenses and a zoom capability of between 6.3x and 60x. All animals were removed for identification.

2.8.4 Temperature and Humidity Measurement

At the time of placement of each troglofauna trap, ambient air temperature and relative humidity was measured outside the bore as well as within the groundwater bore at 30m depth. Air movement within the bore was assessed and depth to water table was measured. These measurements were considered important for assessing the prospective value of each bore to contain troglofauna. Humidity and air temperature were measured using a La Crosse Meter (Model WS9123UIT) operating at a frequency of 915MHz.

2.9 Impact Assessment

The impact assessment approach used for this study was based on a narrative approach whereby:

1. The conservation value of aquatic and GDE habitats and associated fauna were assessed to determine what key values could potentially be lost or harmed by the SGCP;
2. The sensitivity of various aquatic and GDE taxa to different types of impacts linked to activities associated with the SGCP was described to highlight what aspects of the aquatic and GDE communities are most at risk and how those communities might change as a result of the SGCP;
3. Activities potentially affecting waterways and GDEs in the SGCP area were summarised, including their location in relation to specific waterways so that a spatial context could be provided when describing their potential impacts;
4. Impact assessment covered the construction and operation phase activities;
5. Separate impact assessments were given for surface water and GDE habitats and associated biota; and
6. Mitigation options aimed at reducing or eliminating the potential impacts identified were put forward. To our knowledge, these were based on best practice environmental management practices.

The first two task outputs are summarised in the existing environment section of this report as a lead in to the impact assessment section.

3 Existing Environment Description

3.1 Stream Conditions and Landuse

Streams within the SGCP area flow into the Belyando River, which is part of the Burdekin River catchment. The Belyando River catchment is the largest sub-catchment within the Burdekin River Basin, covering 73,335 square kilometres (Australian Natural Resources Atlas, 2007). Streams in the upper Belyando sub-catchment are ephemeral in nature and, for the majority of the year do not contain any water. Water quality and quantity in these streams is therefore highly variable and largely dependent on the time of year in relation to seasonal rainfall. This also has a profound effect on the ecology of these systems.

Low intensity cattle grazing and mineral exploration are the predominant land use activities on the SGCP site. Grazing accounts for approximately 94% of landuse in the Belyando Catchment, with small areas under conservation management, or used for forestry and dryland agriculture. The majority of land within the Belyando sub-catchment is considered to be in fair condition, though parts of it are either highly vulnerable or in marginal condition (Dight, 2009). Floodplain clearing has led to a significant loss of riparian vegetation, thus waterways in the Belyando sub-catchment often have elevated suspended sediment concentrations (Dight, 2009). There are, however, several national parks and scientific areas within this sub-catchment of high conservation value.

3.2 Climate

The SGCP area has a warm climate with mean maximum temperatures ranging from 34.4˚C in December and January to 23.3˚C in July. Mean minimum temperatures range from 22.3˚C in January to 8.9˚C in July. Hot conditions (>30˚C) can be expected from October to April. The average annual rainfall ranges between 540.8mm to 556.8mm depending on which gauging station data is obtained from (Emerald - site number 035264, Barcaldine - site number 036007, or Alpha Post Office –site number 035000). The majority of rainfall occurs in the warmer months of the year (October to March). Historically, the highest monthly rainfalls occur in January, and 75% of the annual rainfall occurs between October and March.

In the few months preceding the 2010 field survey there was substantial rainfall in the study area, particularly in January and February (Figure 3-1), which generated several flow events in both Sapling and Alpha Creeks. However, Alpha Creek had almost ceased flowing and Sapling Creek was reduced to a few remnant pools (Aquateco, 2010). The July 2011 sampling event followed a particularly heavy wet season, which began with well above normal rainfall in September 2010 and was followed by similarly uncharacteristically high rainfall for the months of November and December 2010 and March and April 2011 (Figure 3-1). Consequently, ponded water was still present at this time and there was still flow in Alpha Creek. This scenario would normally not extend beyond April each year according to local anecdotal advice provided to Aquateco (Aquateco, 2010). As such, the 2011 sampling data represent somewhat unusual conditions and this should be considered when interpreting the 2011 data.

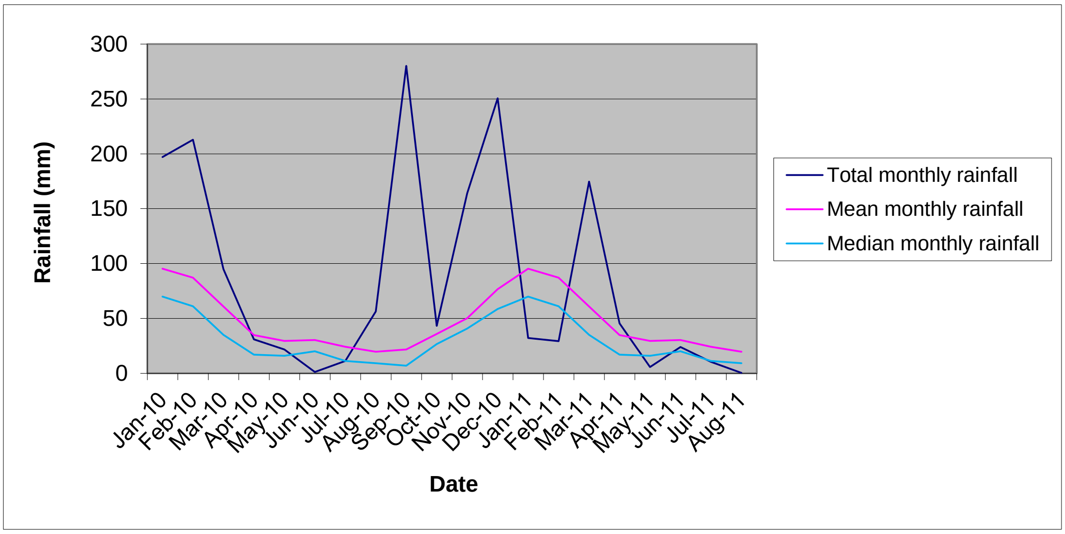

Figure 3-1: Total recorded monthly rainfall versus long term mean and monthly rainfall for the study area based on data from the Alpha Post Office gauging station (Station 035000)

3.3 Surface Water Aquatic Habitat Description

A range of waterway habitats including creeks of various stream order and palustrine and lacustrine waterbodies were assessed during the course of the study. Lacustrine systems are large, open, waterbodies such as reservoirs and dams. Palustrine systems include gilgais, billabongs, swamps and wetlands (DERM, 2009b *In* GHD, 2010). Gilgais are wetlands that form on cracking clays in Brigalow forests and are essentially depressions that fill with rain during the wet season. Small-bodied fish and crustaceans are the main aquatic fauna likely to use gilgai habitat (GHD, 2010). Palustrine habitats can sometimes host a high diversity of aquatic plants and act as a nursery for certain fish species (GHD, 2010), but this appears unlikely for the type surveyed in the study area.

All sites, with the possible exception of SC-2, DC-2A, TC-3 and AC-1 were relatively intact and representative of natural conditions. Those other sites were affected by one or a combination of disturbance factors outlined in the section below.

3.3.1 Stream Habitats

The stream habitats surveyed in the study area ranged from:

- Narrow, low order streams that only retain surface water for a very limited time following rainfall, and which featured no flow and only small isolated pools (where present) at the time of sampling; to
- Higher order streams with prolonged surface flow connectivity that were flowing at the time of sampling.

Examples of each are given below:

3.3.1.1 Very low (1st or 2nd) order streams

Examples of very low order stream habitat within the study area are provided in sites UT-1 and UT-2 that lie in an unnamed tributary of Tallarenha, TC-1 in the upper reaches of Tallarenha, SC-1 in the upper reaches of Sapling Creek and DC-2A in Dead Horse Creek.

UT1 and UT2 were narrow, shallow, sand/gravel dominated streams that were completely dry at the time of sampling in July 2011 (see Figure 3-2). TC-1 and DC-1 were similar in size, but the channel at these sites was deeper and contained small depressions, such that small, isolated pools of <10m in length were present where bottom sediment contained a greater clay content (see Figure 3-3). For DC-2A, this only occurred at an off-shoot of the main channel, which may have been created as a drinking water reservoir for cattle (Figure 3-4). SC-1 was different to other sites of a similar stream order in that it had a bed that was a mixture of underlying bedrock, cobbles and boulders and sand/gravel (Figure 3-5). This allowed small pools <20m in length to remain at the time of sampling in July 2011. Further downstream on the main Sapling Creek channel (but still upstream of the SGCP MLA), the channel was much more akin to that observed at UT-1 and UT-2 and there was no surface water present.

Given their position in the catchment, combined with a predominantly sand/gravel sediment type and at times shallow uniform channel, these habitats, they would tend to dry out relatively quickly following rainfall and, as such, would offer limited habitat value to aquatic flora and fauna. Few refugial pools would be expected to occur in such reaches.

Figure 3-2: Creek bed at UT-2 in July 2011 (looking downstream)

Figure 3-3: Site TC-1 in July 2011 (looking downstream)

Figure 3-4: Backwater at DC-2A in July 2011

Figure 3-5: Site SC-1 in July 2011 (looking downstream)

3.3.1.2 Low to moderate (3rd) order streams

Examples of low to moderate stream habitat within the study area include the lower reaches of Tallarenha Creek (TC-3) and Sapling Creek (SC-2 and SC-3) and Site 04 on the tributary of Saltbush Creek. These reaches tended to feature wider and/or deeper channel than further upstream. The channel at TC-3 was quite incised and featured a 3-4m high rock deposit on one of its banks. The upper banks at this site were steep and high enough to warrant a moderate sized bridge crossing. A number of pools 50m or more occurred in this reach and the depth of the pool sampled exceeded 1m in places.

The substratum in the lower reaches of Sapling Creek and at Site 04 was mud/clay dominated. While stream banks in these reaches were not steep like TC-3, the mud/clay sediment in these reaches was sufficient to retain relatively large, isolated pools. In the case of Site 04, the pool sampled was several hundred metres in length (see Figure 3-7 and Figure 3-8). These pools are likely to persist for a relatively prolonged period and, as such, offer potential refugial habitat value to aquatic fauna.

Figure 3-6: Steep bank at site TC-3

Figure 3-7: Site SC-2 in July 2011 (looking downstream)

Figure 3-8: Site 04 in July 2011 (looking downstream)

3.3.1.3 Moderate to high (4th or greater) order streams

Moderate to high order stream habitat within the study area is solely represented by Alpha Creek. While still ephemeral in nature, water flows in Alpha Creek persist for longer than any other stream habitat within the study area. The channel of Alpha Creek is heavily incised and the upper bank is steep. The lower bank is often steep and mud/clay lined, such that even though the stream bed is predominantly sand/gravel, surface water in this system is retained for long periods. Alpha Creek instream habitat upstream of the confluence with Sapling

Creek was of a uniform depth of around 1.5m, but that was due partly to the ponding effects of the road crossing construction that provides access to the Sapling Creek property. That crossing structure also created artificial cascade habitat at AC-1. Downstream at AC-2, instream habitat was more diverse, with deep pool habitat interspersed with shallow run and almost riffle like habitat (shallow flowing water over sand bars - only just visible in the centre of Figure 3-10). This was supplemented by large woody debris (snags and branches) and tree root habitat (Figure 3-10). Conditions at site AC-2 were probably more representative of Alpha Creek as they were not impacted by the ponding effects associated with the causeway crossing at AC-1. Given its prolonged flow period and diverse stream habitat, Alpha Creek is the highest value stream habitat within the study area.

Figure 3-9: AC-1 in July 2011 (looking upstream)

Figure 3-10: Shallow riffle-like habitat and woody debris habitat at AC-2 in July 2011

3.3.2 Lacustrine Habitats

Lacustrine habitats within the study area are represented by the two dams: UT-Dam and SC-Dam (see Figure 3-11 and Figure 3-12). UT-Dam was much smaller in area in 2004 than it was in 2011 based on Google Earth ™imagery. While this is no doubt a function of the large wet season in 2010/11, the dense covering of submerged and emergent macrophytes in the margins of this dam in 2011 (Figure 3-13) suggested that water levels in this dam had been present for some time. Both dams were at least 500m x 500m in area in July 2011. Shallow water of <1m dominated these water bodies as water from the deeper main dam had spilled over onto adjacent land. This was particularly evident at SC-Dam, where the margins were dominated by flooded pasture grass as well as smart weed (*Persicaria* sp.). The main dams associated with these waterbodies could be several metres deep, though this was not determined at the time. Based on their size, both dams are expected to retain water for extended periods. Site SC-2 has reportedly not been completely dry since 1926 according to the property owner (Warren Gleeson, owner of the Sapling Creek property, pers. comm.) On this basis alone, they are likely to be important aquatic habitat features within the study area. The fact that the dam associated with site UT-Dam was the only site that had submerged macrophyte habitat present, this dam is also unique with respect to waterways present in the study area. While this is based on limited sampling in dam habitat in the Galilee Basin, this places further importance on the lacustrine habitat associated with that dam. Both dams featured large woody debris, both submerged and standing timber (see Figure 3-11 and Figure 3-12), which would offer suitable habitat for aquatic fauna to shelter in.

Figure 3-11: UT-Dam in July 2011

Figure 3-12: SC-Dam in July 2011

Figure 3-13: Submerged macrophyte habitat at UT-Dam in July 2011

3.3.2.1 Palustrine Habitat

Palustrine habitat in the study area is represented by the lagoon associated with the AC-Lagoon site, adjacent Alpha Creek. This wetland was around 200m x 200m in area at the time, with evidence that the water level had receded by around 1m in the weeks leading up to sampling. It was shallow (depths generally <1m) and featured mud-clay bed and banks and banks were of a shallow gradient. The major instream habitats were large woody debris in the form of submerged logs and branches as well as standing timber. Detritus was abundant at this site.

AC-lagoon, while cut off from the main Alpha Creek channel most of the time, could be hydrologically connected to Alpha Creek during floods. As such, it may act as a receiving water body with respect to discharges and runoff from the SGCP at such times. It is perhaps more vulnerable than Alpha Creek as a receiving waterbody, in that once water levels recede, contaminants could largely remain within this lagoon. The low dissolved oxygen levels recorded in this lagoon (and which are probably characteristic of it) would readily facilitate the release of any metals and nutrients associated with mine runoff from sediments into the water column as bioavailable forms.

3.3.3 Existing Impacts

As discussed above, the landuse over much of the study area is grazing. The key existing impacts associated with this landuse evidenced during this study included:

- Unfettered cattle access to waterways;
- Vegetation clearing;
- Dam construction; and
- Road and creek crossing construction

3.3.3.1 Cattle Access to Waterways

Cattle access to creeks was observed at all sites to a greater or lesser extent. Sites AC-2 and DC-2 were the most affected sites with respect to this type of impact (Figure 3-14). Cattle access to creeks results in bank erosion, bed habitat compaction and pugging due to trampling (Figure 3-15), direct nutrient input through defecation and riparian vegetation damage and destruction. These impacts affect aquatic fauna through degraded water quality and habitat quality.

3.3.3.2 Vegetation Clearing

All sites featured a narrow band (generally <5m) of riparian vegetation. While not confirmed, observations from remote sites free of any obvious anthropogenic disturbance suggest that this is a natural feature. Riparian clearing for agricultural purposes was not obvious at the sites surveyed. Much of the riparian vegetation clearing evidenced was associated with creek crossing construction, which only involved clearing in a narrow corridor. Hence, impacts on stream shading, bank stability and woody debris supply associated with vegetation clearing in the study area are currently minor.

3.3.3.3 Dam Construction

Dams have been constructed in the Tallarenha Creek and Sapling Creek catchments. These have resulted in a permanent change from stream habitat to lacustrine habitat, which represent entirely different ecosystems and ecosystem values from the natural stream habitat. Nonetheless, as above, dams can have features not offered elsewhere which are beneficial to aquatic flora and fauna. For instance, the two dams surveyed are likely to retain water for long periods, so could serve as refugial habitat for fish and invertebrates as well as migratory birds. Water levels in these dams are stable enough to support abundant macrophyte growth, some of which was not found elsewhere in the study area. Hence, dam construction may have altered the environment from natural, but has had some ecological as well as social benefits.

Figure 3-14: Cattle accessing Sapling creek at SC-2 in July 2011

Figure 3-15: Pugging associated with cattle footprints at SC-2

3.3.3.4 Road and Creek Crossing Construction

Creek crossing construction has resulted in a loss of riparian vegetation from a narrow corridor. This is unlikely to have resulted in any major impact to waterways, even when viewed collectively at the study area level. Other impacts associated with creek crossing construction include bank erosion, bed alteration or compaction and increased turbidity through vehicle wash, but these impacts are usually spatially confined. Most creek crossings observed in this study were simple fords, where a path had simply been graded across the channel (see Figure 3-16). These crossings would have the least associated ecological impacts as they are drowned out much of the time (so pose no barrier to fish movement) and the bed in the crossing section was of natural form. The recently completed creek crossing at AC-1 differs markedly from this in that it is made of angular cobble material (very different to the sand/gravel present) and sits at a level that creates ponding upstream and a cascade downstream, with a drop of up to 1m to the downstream section from the road height at the crossing (Figure 3-17). Further, ponding created by a difference in the height of the road and the upstream reach water level has reduced habitat diversity upstream of the crossing. The drop off on the downstream side of the crossing most likely cuts off the downstream section from the upstream sections except during moderate to high flow events. This may reduce fish diversity and abundance in the upstream reach. Note that, based on the makeup of the fish community in the study area, obligate migratory fish species are unlikely to have been affected by this (see Section 3.5.4).

Apart from creek crossings, numerous farm tracks have been created within the SGCP area. Those in the Sapling Creek catchment are built on dispersive soils that readily wash out, creating rut holes when it rains. In upper Sapling Creek, some tracks have suffered severe gully head erosion (e.g. see Figure 3-18) and some of the sediment may have mobilised to the creek itself. The issue of dispersive soils in Sapling Creek catchment is of relevance to the SGCP EIS as similar issues may arise through road access and other mine infrastructure construction in that catchment, should the SGCP go ahead.

While not shown in this report, recent earth works had been undertaken adjacent the highway bridge at TC-3 in July 2011. These earth works involved grading right to the edge of the bank. Bare earth and earthen mounds were left exposed at the completion of those works, which would have been vulnerable to erosion and sediment runoff. Such potential impacts could potentially be replicated at other waterway crossings in the study area and, if not controlled, could be replicated as part of the SGCP.

Figure 3-16: Simple ford crossing at AC-2

Figure 3-17: Constructed causeway at AC-1

Figure 3-18: Severe gully head erosion associated with a washed out farm track in upper Sapling Creek

3.4 Subterranean Ecosystem Habitat Description

3.4.1 Regional Geology Overview (METServe, Nov 2011)

The SGCP is located within the Late Carboniferous-Middle Triassic Galilee Basin. The Galilee Basin has an area of approximately 247,000km^2 and is a large scale intracratonic basin with predominantly fluvial sediment infill. It can be divided into northern and southern regions with a boundary in the vicinity of the Barcaldine Ridge extension of the Maneroo Platform.

The northern Galillee Basin is divided into two depositional environments. The Koburra Trough is located on the eastern side of the northern region of the Galilee Basin, and overlies the Drummond Basin. The Koburra Basin is also the Galillee Basin's thickest recorded sequence, with up to 2,818m of strata recorded. On the western side of the northern Galillee Basin is the Lovelle Depression.

The southern Galilee Basin is divided by the Pleasant Creek Arch into two depositional centres; the Powell Depression to the west and the Sprinsgure Shelf to the east. The SGCP is located in the southern region of the Galilee Basin.

The rocks of the Galilee Basin are of similar age to those of the Bowen Basin (Late Permian) which are exposed to the east of the Drummond Basin. The Bowen and Galilee Basins are separated along a north-trending structural ridge between Anakie and Springsure, referred to as the Springsure Shelf. Much of the western portion of the Galilee Basin is interpreted as occurring beneath Mesozoic sediments of the Eromanga Basin. The Anakie Inlier comprises older Palaeozoic rocks.

Late Permian, coal-bearing strata of the Galilee Basin sub-crop are found in a linear, north-trending Belt in the central portion of the exposed section of the Basin and are essentially flat lying (dip generally <1° to the west). No major, regional scale fold and fault structures have been identified in regional mapping of the SGCP area.

Quaternary deposits in the SGCP are mostly alluvial and consist of gravel, sand and poorly consolidated clayey sandstone. Thickness of the Quaternary sediments varies over the Project area, but generally thickens to the east. Thicker alluvium is associated with current surface water drainage systems and may contain localised occurrences of groundwater, especially following wet season rainfall, but the alluvium is not extensive or continuous, with limited effective storage. It is therefore not regarded as a significant groundwater resource.

Tertiary deposits overlie the Galilee Basin and comprise consolidated siltstone and sandstone typically 5-15m thick and are thickest in the northern and central region of the SGCP. These sediments are not regarded as comprising a significant groundwater resource as only limited and minor flows have been encountered.

The Cainozoic unconformably overlies the Rewan Formation and Permian Sequence and the Rewan Formation only occurs in the west of the project area. The Late Permian to Early Triassic Rewan Formation unconformably overlies the Bandanna Formation. The formation is composed of terrestrial alluvial sediments including meandering channel deposits and flood-basin siltstone and sandstone units.

Both the economic and sub-economic coal seams within the project area are contained within the Permian sedimentary deposits comprising the Bandanna Formation and the underlying Colinlea Sandstone. The coal seams are named alphabetically with the uneconomic A and economic B seams being seams being uppermost. The major coal seam that will be the target of mining within the deposit is the D seam.

The Late Permian Bandanna Formation ranges from a lacustrine/paludal to a fluvial deposit in the southern region of the Galilee Basin, conformably overlying the Colinlea Sandstone and interfingering with the Black Alley Shale. The unit is the target formation of the SGCP and is composed of:

- grey slightly micaceous and silty, carbonaceous sub-fissile shale;
- grey argillaceous and carbonaceous siltstone;
- grey fine to medium grained fused, micaceous quartz, feldspathic sandstone and;
- coal.

The Early to Middle Permian Colinlea Sandstone unconformably overlies the Jochmus formation in the eastern and southern central Galilee Basin. Deposition of the unit occurred in an alluvial environment dominated by peat swamps and easterly and southerly flowing rivers. Sediments were derived from volcanic and metamorphic provinces to the north of the Basin's margins. Strata range from light-medium grey carbonaceous, highly argillaceous siltstone to shale interbedded with minor white to light grey, very fine to fine grained, angular to sub-rounded micaceous quartzose sandstone and coal.

From a groundwater perspective, major hydrostratigraphic boundaries occur within the SGCP at the base of weathering, beyond which groundwater is often encountered under confined conditions in the D-D1 seams and also in some sandstone units.

3.4.1.1 Relationship to the GAB

The Great Artesian Basin (GAB) is a large hydrogeological basin consisting of the Eromanga, Surat and Carpentaria Basins as well as parts of the Bowen, Surat and Galilee Basins. The GAB consists of confined artesian and sub-artesian groundwater and the confined aquifers of the Basin are bounded by the Rewan Group sediments, which form the basement of the aquifers, with the Winton Formation acting as the upper confining layer.

The lower boundary of the GAB (outcrop of Rewan Formation) occurs approximately 15-20km west of the western limit of mining and the economic coal seams occur below and to the east of the Rewan Formation confining layer. The Rewan Formation aquitard, which is taken to be approximately 175m thick in the area to the west of the SGCP has a vertical hydraulic conductivity in the order of 1.2 x 10-8 to 1.2 x 10-9 m/s (1 x 10^{-4} to 1 x 10^{-3}m/day), based on calibrated values for GAB confining units from an early phase of GAB groundwater modelling (Geoaxiom and Heritage Computing, 2011). It is therefore determined that there is little likelihood of the project impacting on groundwater of the GAB.

3.4.1.2 Existing Groundwater Environment

The majority of the alluvial bores occur around the township of Alpha and along Alpha Creek where shallow groundwater is being accessed for stock and domestic purposes. There are also a number of bores in Tertiary sediments around Alpha which contribute to the town water supply.

Groundwater sourced from the few Tertiary, Triassic and Permian aquifers within and adjacent to the SGCP is utilised primarily for stock watering.

3.5 Surface Water Aquatic Fauna

3.5.1 Macroinvertebrates

3.5.1.1 Dominant Taxa

The 10 most numerically common taxa recorded in April 2010 and July 2011 included microcrustacea (cladocerans, copepods and ostracods), members of order diptera (true flies), the midge family chironomidae (tanypodinae and chironominae), baetid ephemeroptera (mayflies) and dytiscid and hydraenid water beetles (coleoptera) (Table 3-1 and Table 3-2). The key differences between the April 2010 and July 2011 surveys in terms of numerically common taxa were that Hemipterans such as water boatmen (Corixidae) and water treaders (Mesoveliidae) were among the 10 most abundant in April 2010, but were not in July 2011. Also, caenid mayflies were among the 10 most numerically common taxa in July 2011 samples, but were not in April 2010. The study by AARC (2010) for the nearby Alpha Coal Project EIS also commonly encountered macroinvertebrates water boatmen (Hemiptera: Corixidae), midge larvae (Diptera: Chironomidae) and mayfly larvae (Ephemeroptera: Baetidae).

In April 2010, 19 out of the 25 (AURIVAS-level resolution) taxa recorded were insects (76%). In July 2011, 64 out of the 78 taxa (82%) recorded were insects. These results accord with the findings of Williams (2006), who reported that macroinvertebrate communities of ephemeral streams in Central Queensland are dominated by insects (particularly Ephemeroptera, Odonata, Diptera and Hemiptera).

Table 3-1: Numerically common taxa recorded in April 2010

Order	Family / sub-Family	Total Number Recorded
Crustacea	Cladocera	1,181
Crustacea	Copepoda	917
Crustacea	Ostracoda	81
Diptera	Tanypodinae	55
Ephemeroptera	Baetidae	30
Arachnida	Acarina	29
Coleoptera	Hydraenidae	24
Hemiptera	Mesoveliidae	20
Hemiptera	Corixidae	14
Coleoptera	Dytiscidae	13
Trichoptera	Leptoceridae	13

Table 3-2: Numerically common taxa recorded in July 2011

Order	Family / Sub-Family	Total Number Recorded
Crustacea	Copepoda	567
Diptera	Chironominae	320
Crustacea	Cladocera	153
Diptera	Tanypodinae	148
Coleoptera	Dytiscidae	121
Ephemeroptera	Caenidae	112
Crustacea	Ostracoda	94
Ephemeroptera	Baetidae	93
Coleoptera	Hydraenidae	84
Trichoptera	Leptoceridae	65

3.5.1.2 Diversity

As stated above, 25 taxa were recorded from four samples collected at two sites in April 2010, while 78 taxa were recorded from 12 samples collected across 11 sites in July. Note that this is based on AUSRIVAS-level taxonomic resolution groupings. AARC (2010) recorded 58 taxa (at the family/genus level) from 16 sites for the nearby Alpha Hancock Coal Project EIS. The actual species diversity in the study area is likely to have been much higher than what was recorded in this study. For instance, while cladocera, ostracoda and copepod form three taxonomic groups in the above diversity calculations, Aquateco (2010) recorded three ostracod families (Cyprididae, Ilyocypridinae, Notodromadidae), six cladoceran families (Macrothricidae, Chydoridae, Daphniidae, Sididae, Moinidae, Bosminidae) and two copepod sub-orders (Cyclopoida and Calanoida). At present, macroinvertebrates are rarely taken to genus or species level, but this study found that there were multiple genera belonging to the following families:

- Ancylidae (at least 2 genera);
- Dytiscidae (at least 6 genera);
- Hydraenidae (at least 2 genera);
- Ceratopogonidae (at least two genera);
- Simuliidae (at least two genera);
- Baetidae (at least three genera);
- Caenidae (at least two genera);
- Coroxidae (at least two genera);
- Notonectidae; (at least two genera);
- Pleidae (at least two genera);
- Comphidae (at least two genera);
- Corduliidae ((at least two genera);
- Hydrobiodidae (at least two genera);
- Hydropsychidae (at least two genera); and
- Leptoceridae (at least two genera);

In July 2011, taxa richness for edge habitat and composite habitat based on AUSRIVAS-resolution level data ranged between 21 taxa at DC-2A (the Dead Horse Creek 'reference' site) and 34 taxa at TC-1 (Tallarenha Creek 'reference' site). Ten of the 12 samples recorded a taxa richness of 25 or more in July 2011. Taxa richness for edge habitat in April 2011 did not exceed 15 (Figure 3-19). This difference between taxa richness between years was probably a function of timing of sampling in relation to when streams began to dry up and cease to flow and inundation duration prior to sampling. In July 2011, Alpha Creek was still flowing, while Sapling Creek at SC-2 would have had water present following initial filling for much longer in 2011 than in 2010.

Site 04 in near the Infrastructure Corridor had a comparable taxa richness to sites within and adjacent to the MLA. 'Reference' and 'impact' sites within Tallarenha Creek, Sapling Creek and Alpha Creek had similar taxa richness, though taxa richness was slightly lower at the 'reference' sites in Tallarenha Creek, Sapling Creek than that for 'impact' sites (Figure 3-19).

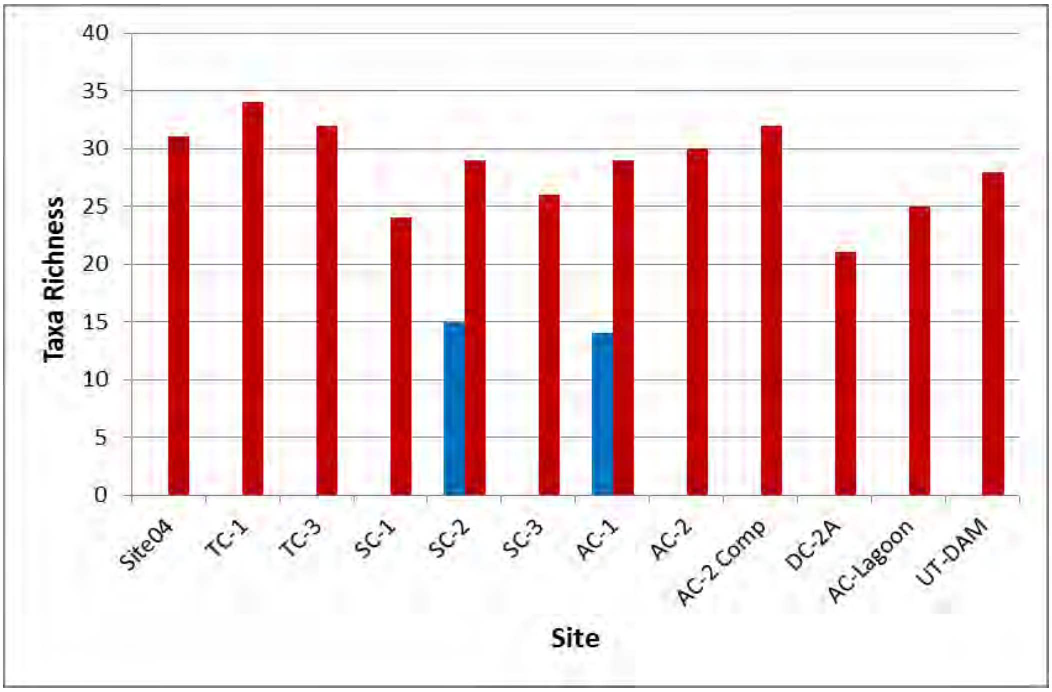

Figure 3-19: Variation in taxa richness between sites and years. Blue columns represent April 2010 data and red columns represent July 2011 data.

3.5.2 Pollution-Sensitive Taxa

PET taxa are generally considered to be among the more pollution-sensitive macroinvertebrate taxa, hence the common use of the PET richness to assess the status of macroinvertebrate communities. However, pollution sensitivity varies within individual PET taxa families. A total of nine PET taxa (based on AUSRIVAS-resolution level data) were recorded in July 2011. These included:

- Ephemeroptera (Baetidae-SIGNAL =5; Caenidae –SIGNAL =4, Leptophlebiidae –SIGNAL = 8, and an unidentified family –SIGNAL = 9); and
- Trichoptera (Leptoceridae –SIGNAL = 6; Ecnomidae –SIGNAL = 4; Hydropsychidae – SIGNAL = 6; Philopotamidae – SIGNAL =8; and Hydrobiosidae –SIGNAL = 8).

In April 2010, only caenidae, baetidae and leptoceridae were recorded.

No Plecoptera taxa were recorded in either study, but that was not unexpected as those taxa generally only occur in cold, mountain streams with flowing water over rocky substrate.

Based on the SIGNAL sensitivity ratings for these taxa, PET taxa include families that are mildly pollution-tolerant (SIGNAL =4) to highly pollution sensitive (SIGNAL = 8 or 9). The most sensitive Trichoptera taxa were only recorded at the Alpha Creek downstream 'impact' site (AC-2). This was probably due to the fact that those families generally occur in shallow flowing habitat, such as the type only found at AC-2 in July 2011. In terms of the most sensitive Ephemeroptera taxa, Leptophlebid mayflies were recorded at most sites, but were not present at

Site 04, either of the two wetland sites (UT-Dam and AC-Lagoon) or in Dead Horse Creek (DC-2A). The unidentified mayfly was only recorded from the two Alpha Creek sites (AC-1 and AC-2). The absence of sensitive Trichoptera taxa from DC-2A was not unexpected as essentially, this site was a shallow backwater used by cattle as a drinking water source and had very high turbidity (around 1000 NTU) and very low dissolved oxygen levels (around 10% saturation). The absence of this caddisfly family from the three other sites, however, may be due to habitat preference as Site 04 was essentially an isolated pool that probably functioned much like a wetland lagoon.

PET richness for edge and composite habitat in July 2011 ranged between three and eight, while in April 2010, PET richness for edge habitat never exceeded two (Figure 3-20). The reduced PET richness in April 2010 was probably due to similar reasons outlined above for reduced taxa richness. It should be noted that the PET richness recorded in both April 2010 and July 2011 exceed those recorded by AARC (2010) for the Alpha Coal Project EIS. In that study, many sites had no or only one PET taxa present. This was purportedly due to sampling being carried out shortly after a heavy rainfall event.

For creek systems potentially affected by the SGCP, PET richness was invariably higher at downstream 'impact' sites in July 2011 (Figure 3-20). Wetland sites and those stream sites that featured isolated pools in the late phase of drying out (i.e. SC-1 and DC-2A), tended to have a lower PET richness and, once again, Site-04 was similar to the wetland sites (Figure 3-20). Site AC-2 had unusually high PET richness within both the edge habitat and composite habitat samples. This was most likely due to the fact that this was the only site with flowing water over shallow sand bars, a habitat preferred by certain PET taxa.

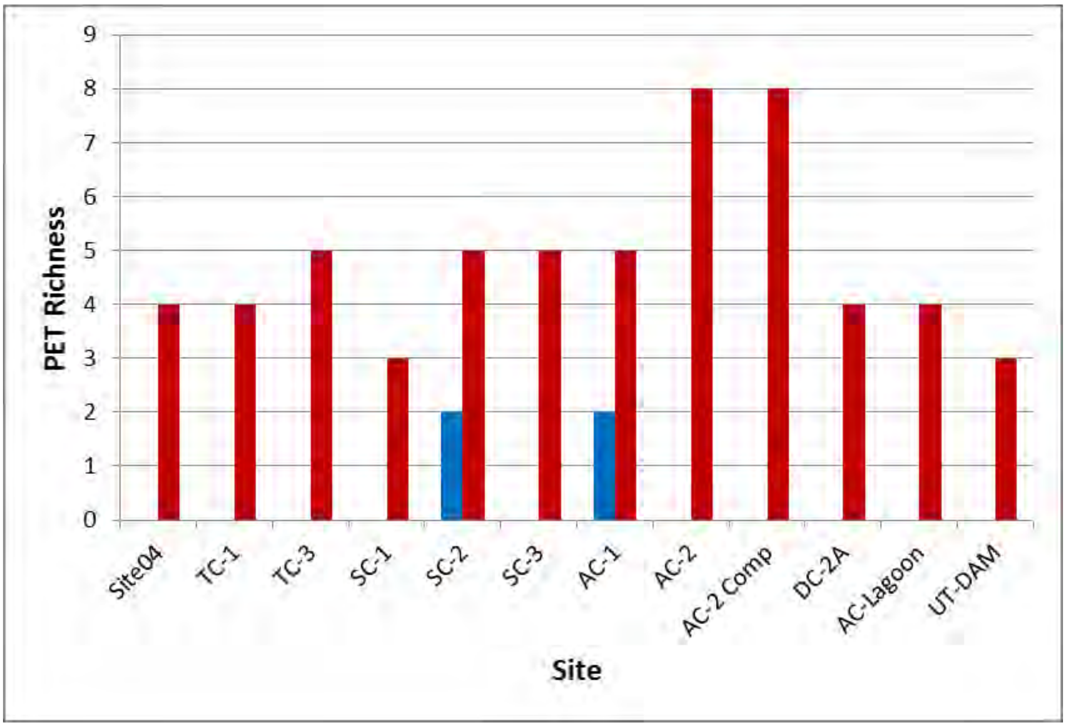

Figure 3-20: Variation in PET richness between sites and years. Blue columns represent April 2010 data and red columns represent July 2011 data.

SIGNAL 2 scores, which essentially represent a ratio between pollution-sensitive and pollution-tolerant taxa within a sample, varied moderately between sites in July 2011, but were highest at AC-2, once again, reflecting the number of PET taxa and other sensitive taxa present at that site.

The two wetland sites recorded low SIGNAL 2 scores, suggesting that this habitat type featured both a reduced PET richness and a reduced proportion of pollution-sensitive taxa relative to pollution-tolerant taxa. This might be because wetland habitats such as these often have lower dissolved oxygen levels through lack of flow, the breakdown of organics, increased respiration rates at night where macrophytes are present in abundance, or a combination of these factors. AC-Lagoon recorded dissolved oxygen levels of only 43.4% saturation. UT-Dam had thick growth of submerged macrophytes and recorded hyper-saturated oxygen levels during the day (117.6%), but this could quite possibly have changed at night to reduced oxygen conditions when those macrophytes ceased photosynthesis and began respiring. Note that the SIGNAL 2 scoring system was not developed with application in wetland habitat in mind, but this index was applied to wetlands in this study merely to highlight the level to which potentially pollution-sensitive macroinvertebrates occur in this type of habitat compared to adjacent stream habitat.

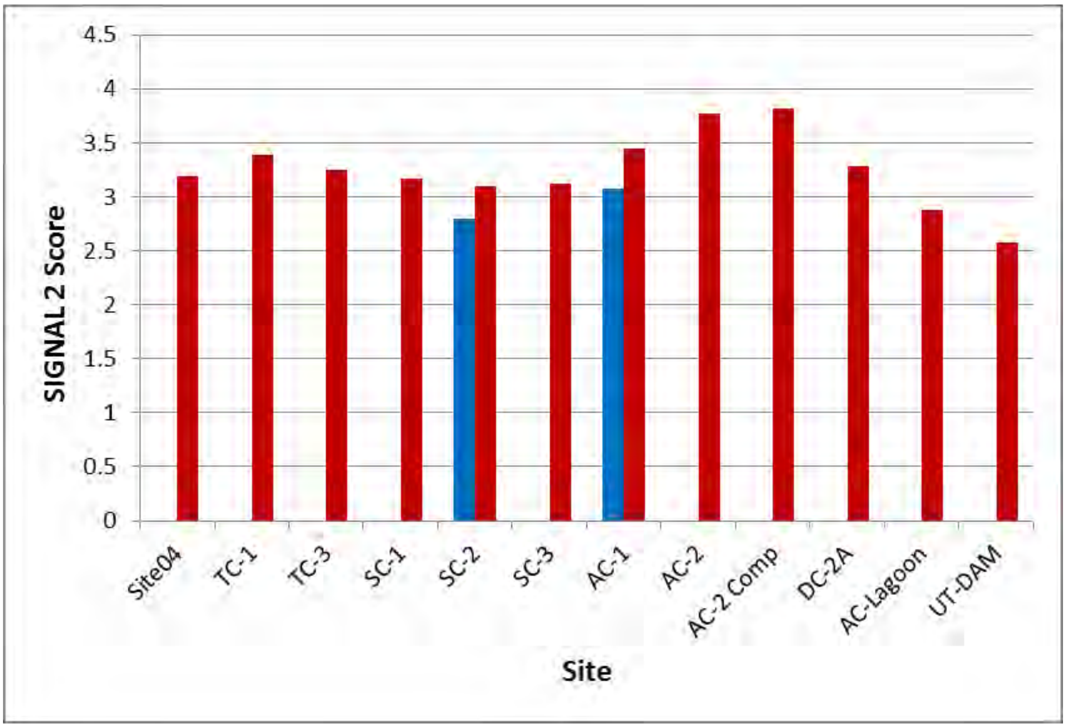

Figure 3-21: Variation in SIGNAL 2 Score between sites and years. Blue columns represent April 2010 data and red columns represent July 2011 data.

3.5.3 Community Condition ('Health' Status)

The 'health' status of macroinvertebrate communities was assessed based on comparisons with the above univariate indices with guideline ranges for Central Queensland and based on QLD AUSRIVAS model bandings for each site.

- Taxa richness was generally within the recommended range in 2011, except for DC-2A in 2011, whereas taxa richness was less than expected at both sites in 2010. This was most probably related to the fact those samples were collected later during the drying phase;
- Taxa richness and PET richness were much higher than expected for edge and composite habitat sample at AC-2, probably because of the shallow flowing habitat present and its ability to host taxa that might otherwise only occur in riffles (shallow flowing water over cobble and gravel beds). Edge habitat at this site was close to the shallow, flowing habitat, so there was probably some PET taxa shared between the two habitats; and

- Most sites had lower than expected SIGNAL 2 scores. The exceptions were sites in Tallarenha Creek and Alpha Creek in July 2011. The majority of taxa collected during this study can be described as generalists that are resilient to stressful conditions, a trait that makes them ideally suited for surviving in the variable and sometimes harsh conditions associated with ephemeral stream environments (Williams, 2006). This may well explain the relatively low SIGNAL 2 scores recorded at many of the sites. It should be pointed out that the ranges for taxa richness, PET richness and SIGNAL 2 presented in the Queensland Water Quality Guidelines (DERM, 2009b) are based on the averaging of data across a range of ephemeral and perennial stream types. Therefore, they may not truly represent what levels of taxa richness or SIGNAL 2 scores might be expected to occur within the study area. This is somewhat supported by the AUSRIVAS results below. Furthermore, a number of sites monitored by AARC (2010) also had SIGNAL 2 scores between two and three, so low SIGNAL 2 scores appear to be characteristic of the study region.

Site	Habitat	20th to 80th percentile (QWQG)	Site04	TC-1	TC-3	SC-1	SC-2 2010	SC-2 2011	SC-3	AC-1 2010	AC-1 2011	AC-2	DC-2	AC-Lagoon	UT-DAM
Taxa Richness	Edge	23-33	31	34	32	24	15	29	26	14	29	30	21	25	28
	Composite	12-21										32			
PET Richness	Edge	2-5	4	4	5	3	2	5	5	2	5	8	4	4	3
	Composite	2-5										8			
SIGNAL 2	Edge	3.31 - 4.20	3.19	3.38	3.25	3.17	2.80	3.10	3.12	3.07	3.45	3.77	3.29	2.88	2.57
	Composite	3.33-3.85										3.18			

Table 3-3: Comparison of univariate macroinvertebrate indices with recommended ranges for Central Queensland given in DERM (2009b). Values in red indicate values outside of the expected range.

QLD AUSRIVAS results show that in July 2011 the edge habitat communities at all sites were either Band A (similar to reference) or Band X (more biologically diverse than reference conditions). Sites AC-1 and SC-2 improved from a Band B (significantly impaired) rating between 2010 and 2011 (Table 3-4).

These results could suggest that, where catchment inputs maintain water levels and flow over an extended period, the condition of the macroinvertebrate community associated with edge habitat is maintained. Where catchment inputs are lower or samples are taken late in the drying phase, as they were in April 2010, the condition of the edge-associated macroinvertebrate community is poorer. However, as mentioned above, some of the sites sampled in July 2011 were in the late stages of drying and/or had poor water quality, yet still achieved a good rating. It is more likely, that either the 2010 samples were collected sooner after a hydrological disturbance than the July 2011 samples (based on the dominance of early colonising Microcrustacea and Hemiptera taxa present and the turbid water present at AC-2 at that time), or that the sample collection and processing methods for that study were compromised.

As pointed out in section 2, results based on QLD AUSRIVAS need to be interpreted with caution given that the AUSRIVAS model was not built with ephemeral stream sampling in mind, and given that samples collected in July 2011 were assessed using the autumn model. Nonetheless, diversity in winter is expected to be lower than in autumn or spring, so the fact that the July 2011 samples achieved such good ratings provides further evidence that the extended flow period in 2011 has sustained the macroinvertebrate community of the study area.

Table 3-4: QLD AUSRIVAS results for 2010 and 2011

Site	2010		2011	
	OE/50	Band	OE/50	Band
Site 04			1.34	X
TC-1			1.21	X
TC-3			1.28	X
SC-1			1	A
SC-2	0.64	B	1.07	A
SC-3			1.1	A
AC-1	0.57	B	1.35	X
AC-2			1.1	A
DC-2A			0.89	A
AC-Dam			1.06	A
UT-Dam			1.13	A

3.5.3.1 Habitat Association

Multivariate analysis of July 2011 sample data revealed that composite habitat taxonomic composition was quite distinct from that of edge habitat. Cluster analysis results shown in Figure 3-22 show that the AC-2 composite habitat sample splits from the grouping for edge habitat samples at the 20% similarity level. This means it only shared 20% of taxa with edge habitat samples. This suggests that shallow flowing habitat hosts a distinct fauna. Given such habitat are somewhat rare within the study area (albeit that this assumption is based on only two sets of data from a limited number of sites within Alpha Creek), a greater level of protection may need to be applied to such habitats than edge and regular pool bed habitats.

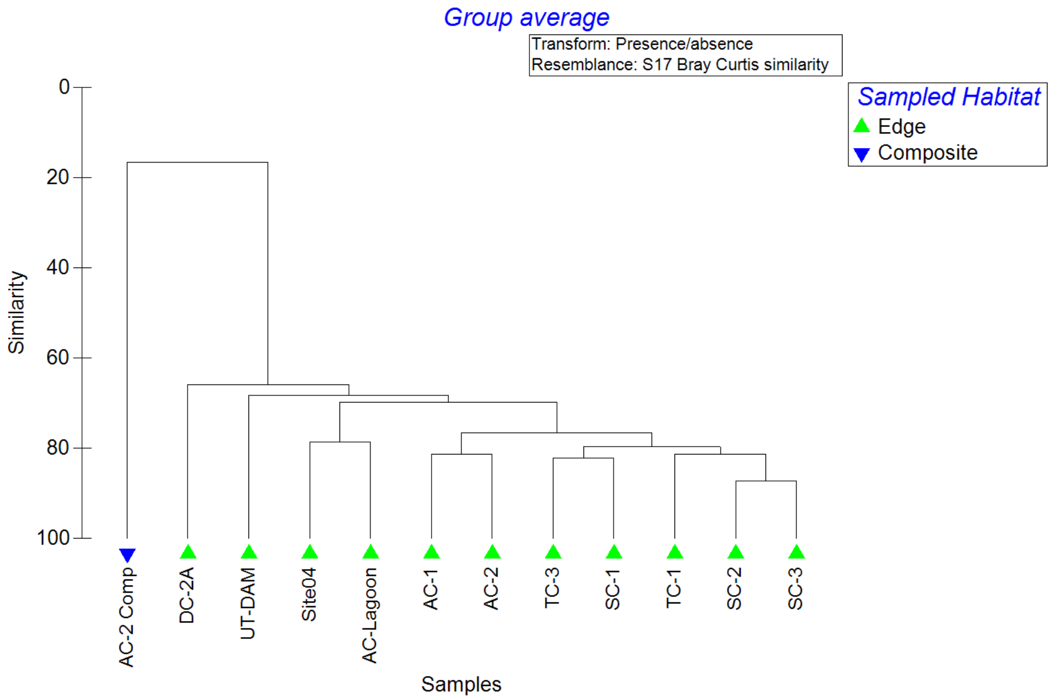

Figure 3-22: Cluster analysis results based on July 2011 macroinvertebrate data shown according to habitat type sampled

Separate multivariate analyses were performed only on edge habitat data from July 2011. Results presented in Non-metric Multidimensional Scaling (NMDS plots) in Figure 3-23 to Figure 3-25 show the relationship between samples collected from different sites according to:

- The catchment they came from;
- Whether they came from stream habitat or wetland lagoon type habitat; and
- Where they were collected in relation to the SGCP.

The closer two samples are within these plots the more similar in taxonomic composition they are. Similarity level bandings based on cluster analysis performed on these data are also shown.

All samples within these NMDS plots are grouped within a 60% similarity banding, which means they share roughly 60% of the same taxa. Stream habitat samples from Tallarenha Creek, Sapling Creek and Alpha Creek were clustered closer to each other in these plots, suggesting that they shared taxa in common at roughly an 80% similarity level. Samples from other sites were more spread out in these plots. There was some grouping of lagoon samples versus stream habitat (Figure 3-24), though Analysis of Similarities (ANOSIM) results showed that such differences were not significant (R =0.586, p =0.055). Site 04 was similar in taxonomic composition to that of AC-lagoon based on the proximity of sample scores for these two sites in the NMDS plots, further demonstrating that this site functioned as a lagoon at the time of sampling.

Dead Horse Creek edge habitat fauna was distinct from that of all other sites. This could suggest that Dead Horse Creek is not necessarily a good ‘reference’ site or analogue for streams within or adjacent to the SGCP MLA, or that this difference was simply a function of the poor habitat conditions at this site at the time of sampling. This finding requires further investigation if Dead Horse Creek is to be considered as a ‘reference’ site for any future monitoring associated with the SGCP.

While they were generally similar in taxonomic composition, there was a slight separation of ‘control’ and impact’ site samples from Tallarenha Creek, Sapling Creek and Alpha Creek in the NMDS plot in Figure 3-25. However, results of ANOSIM showed that, overall, ‘control’ sites were not significantly different in macroinvertebrate fauna composition compared to ‘impact’ sites (R = -0.09, p = 0.676). This is important, as it means that if ‘impact’ sites are affected in these catchments, there will be still reaches of those catchments that will maintain similar edge habitat macroinvertebrate communities.

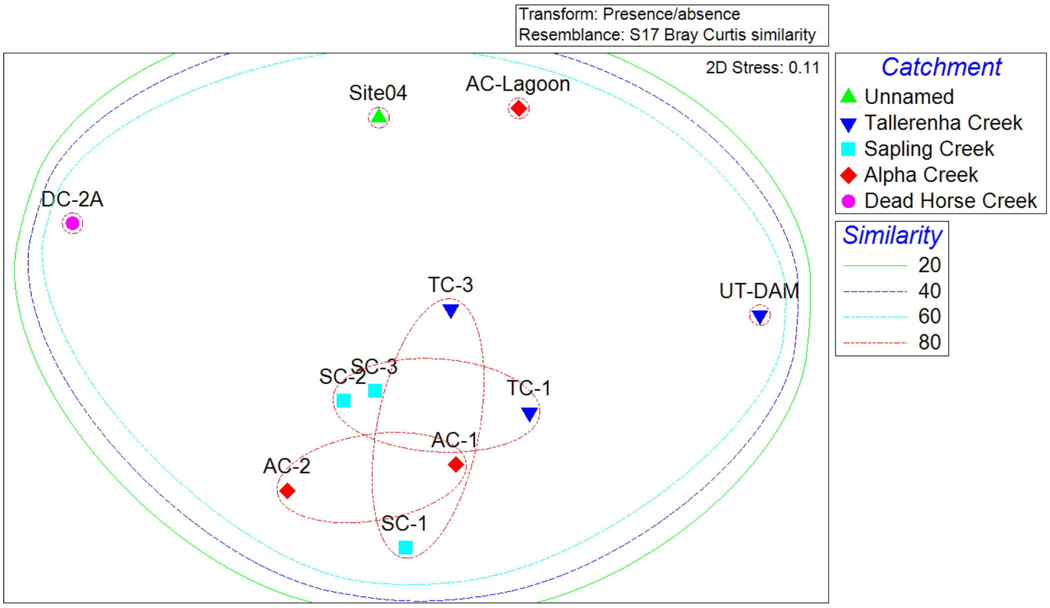

Figure 3-23: NMDS plots of July 2011 edge habitat data based on catchment

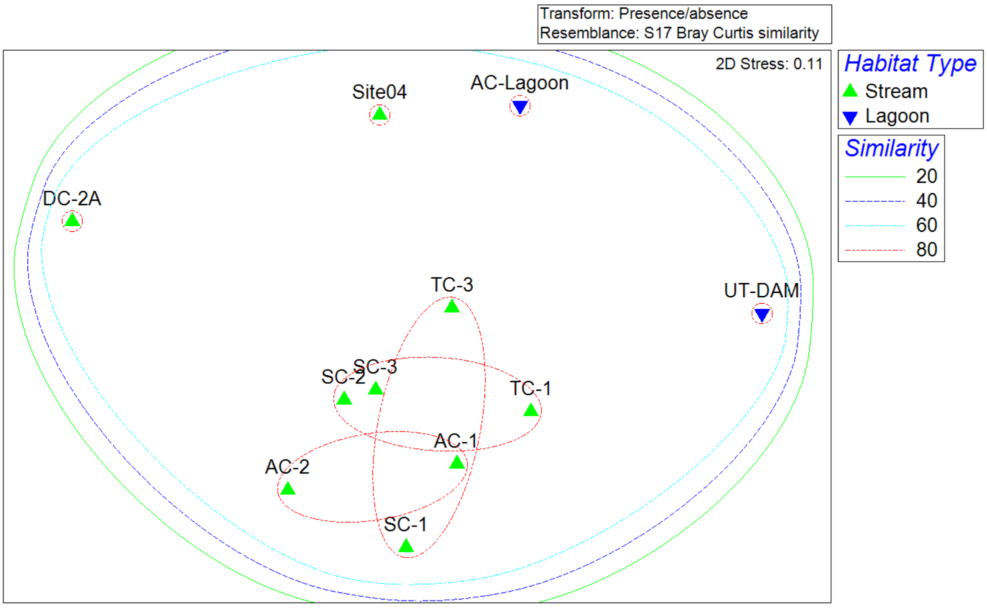

Figure 3-24: NMDS plots of July 2011 edge habitat data based on stream versus lagoon habitat

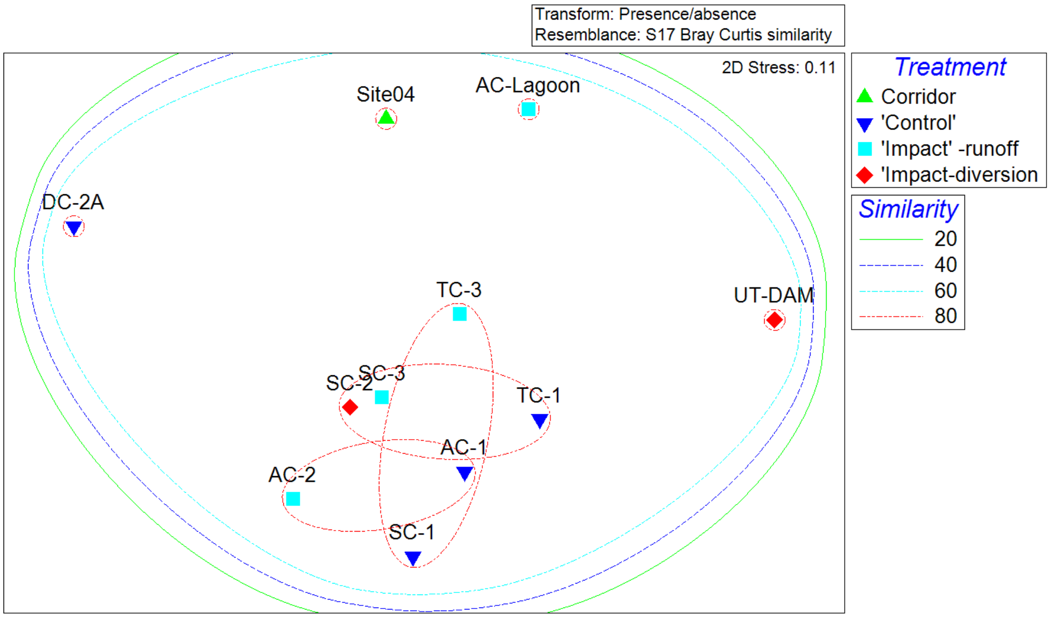

Figure 3-25: NMDS plots of July 2011 edge habitat data based on location with respect to the SGCP

3.5.4 Fish

3.5.4.1 Biogeography

The Burdekin River's fish fauna is distinctive, containing elements of the fauna from both northern and eastern Australia. The distribution of two biogeographically distinct fish fauna within the catchment is largely due to the presence of the Burdekin Falls at the lower quarter of the river's length providing an impassable barrier for many fish species (Pusey et al. 1998).

A total of 76 species identified in literature and other information sources occur in the Burdekin Basin. Of those, 58 are Australian species, including three potentially misidentified taxa and two species considered to have been introduced from other river basins (Yellowbelly -*Macquaria ambigua* and Eel-tailed Catfish, *Tandanus tandanus*). In addition there are 17 exotic species listed, most of which have been introduced into the Ross River. Among these, the highly invasive Tilapia (*Oreochromis mossambicus*) is now in the upper Burdekin River, including the Belyando catchment and continues to spread. Species that are now found outside their natural range include Sleepy Cod (*Oxyeleotris lineolatus)*, Barramundi (*Lates calcarifer)* and Sooty Grunter (*Hephaestrus fuliginosus*) (Alluvium, 2007). Two species are endemic to the Burdekin River, the Small-headed Grunter (*Scortum parviceps*) and the Soft-spined Catfish *(Neosilurus mollepsiculum)* (GHD, 2010).

Historically fish assemblages below the Burdekin Falls were characterised by piscivorous fish (feed on fish), whereas such species were largely absent from upstream reaches. In recent decades, however, there have been numerous translocations of piscivorous fish species into the upper reaches of the Burdekin catchment mainly to satisfy recreational fishing demands (Pusey et al. 2006).

While a large number of species have been recorded throughout the Burdekin catchment many species are not highly abundant within this system or have not been recorded for some time (Pusey et al. 2004). Table 3-5 shows the fish species that have been recorded in the Belyando River system. This list contains only 20 of the 76 species previously recorded in the Burdekin catchment. Considering the low stream order of sites sampled across the SGCP area, it was considered unlikely that even most of these species would be present in the current surveys. For example, Snub-nosed Garfish (*Arrhamphus sclerolepis*) are a catadromous species (move downstream to spawn), so are generally found in areas with more direct connectivity to the lower catchment. Long-finned Eels (*Anguilla reinhardtii*) have been shown to be restricted from upper Burdekin reaches by the Burdekin Falls Dam and its presence in the Belyando catchment is based on historical records prior to that barrier construction (Alluvium, 2007). Hence it would not be expected to occur in the study area.

On the other hand, Small-headed Grunter was once listed as 'Rare' under the *EPBC Act*, because it was thought to occur only to the upper arm of Burdekin River. However, this was changed following advice to the Federal Government by Dr Brad Pusey (Griffith University) and personal communications from Dr Damien Burrows (ACTFR) who indicated that this species is relatively common and is found elsewhere in the catchment including the Suttor-Belyando River complex. On this basis, Dr Pusey requested that the status of Small-headed Grunter be reclassified to 'indeterminate' or 'unlisted' (DEWHA, 2009b). While the authors of this report have only observed Small-headed Grunter in clear, perennial flowing water in streams dominated by rocks and sand, which are not the conditions common to this study area, it could still potentially be present.

Monitoring in the SGCP study area by ALS and Aquateco only recorded 11 of the 20 species historically recorded from the Belyando catchment. This included two exotic pest fish species (Gambusia [*Gambusia holbrooki*] and Tilapia) and one translocated species (Yellowbelly) (Table 3-6). AARC (2010) recorded seven species from 16 sites within the Belyando River catchment as part of the nearby Alpha Coal Project. All species in that study were also recorded in this study, notwithstanding that AARC (2010) stated that they caught "Carp Gudgeon – *Hypseleotris compressa*", which was probably Western Carp Gudgeon (*Hypseleotris klungzingeri)* or Midgely's Carp Gudgeon (*Hyseleotris* sp.) given that *H. compressa* are Empire Gudgeons and these do not occur in the Belyando catchment. The AARC (2010) did not find any of the translocated or exotic fish species that were recorded in this study.

Table 3-5: Potential fish assemblages within the upper reaches of the Burdekin River System based on Department of Primary Industries and Fisheries (DPIF) surveys and databases. * denotes exotic species, # denotes translocated species and + denotes species with migratory requirements.

Common Name	Scientific Name
Agassiz's Glassfish	*Ambassis agassizii*
Snub-nosed Garfish +	*Arrhamphus sclerolepis*
Fly-speckled Hardyhead	*Craterocephalus stercusmuscarum*
Mosquitofish *	*Gambusia holbrooki*
Western Carp Gudgeon	*Hypseleotris klunzingeri*
Midgley's Carp Gudgeon	*Hypseleotris* sp.1
Spangled Perch	*Leiopotherapon unicolor*
Golden Perch #	*Macquaria ambigua*
Eastern Rainbowfish	*Melanotaenia splendida*
Purple-spotted Gudgeon	*Mogurnda adspersa*
Bony Bream	*Nematalosa erebi*
Black Catfish	*Neosilurus ater*
Hyrtl's Tandan	*Neosilurus hyrtlii*
Soft-spined Catfish	*Neosilurus mollepsiculum*
Sleepy Cod	*Oxyeleotris lineolatus*
Flathead Gudgeon	*Philypnodon grandiceps*
Rendahl's Catfish	*Porochilus rendahli*
Small-headed Grunter	*Scortum parviceps*
Tilapia*	*Oreochromis mossambicus*
Long-finned Eel +	*Anguilla reinhardtii*

3.5.4.2 Diversity and Abundance

Seven species were recorded from two sites in the April 2010 survey, albeit that *Hypseoletris* species were pooled for that study and at least two species belonging to this genus occur in the study area. Ten species from 11 sites were recorded in July 2011. Two of the additional species recorded in July 2011 were not native to the study area (Tilapia and Yellowbelly). The other two additional species in 2011 arose due to the differentiation of *Hypseoletris* species in July 2011 and due to a single specimen of Bony Bream (*Nematalosa erebi*) being recorded in July 2011.

2010 catches were numerically dominated by Spangled Perch (Figure 3-26), though a disproportionate number were caught at site SC-2 (Aquateco, 2010). Purple-spotted Gudgeon (*Mogurnda adspersa)* and Eastern Rainbowfish (*Melanotaenia splendida*) were relatively well represented in both years' catches (Figure 3-26 and Figure 3-27), though *M. adspersa* heavily dominated 2011 catches. Western Carp Gudgeon were far more commonly caught in July 2011 than in April 2010 (Figure 3-26 and Figure 3-27).

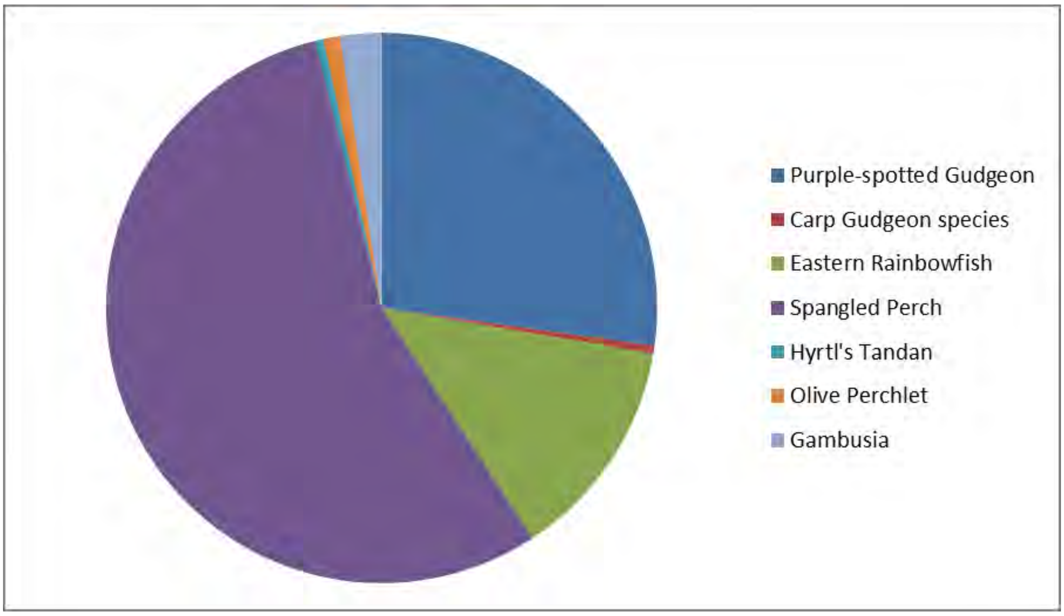

Figure 3-26: Relative abundance of fish capture in April 2010

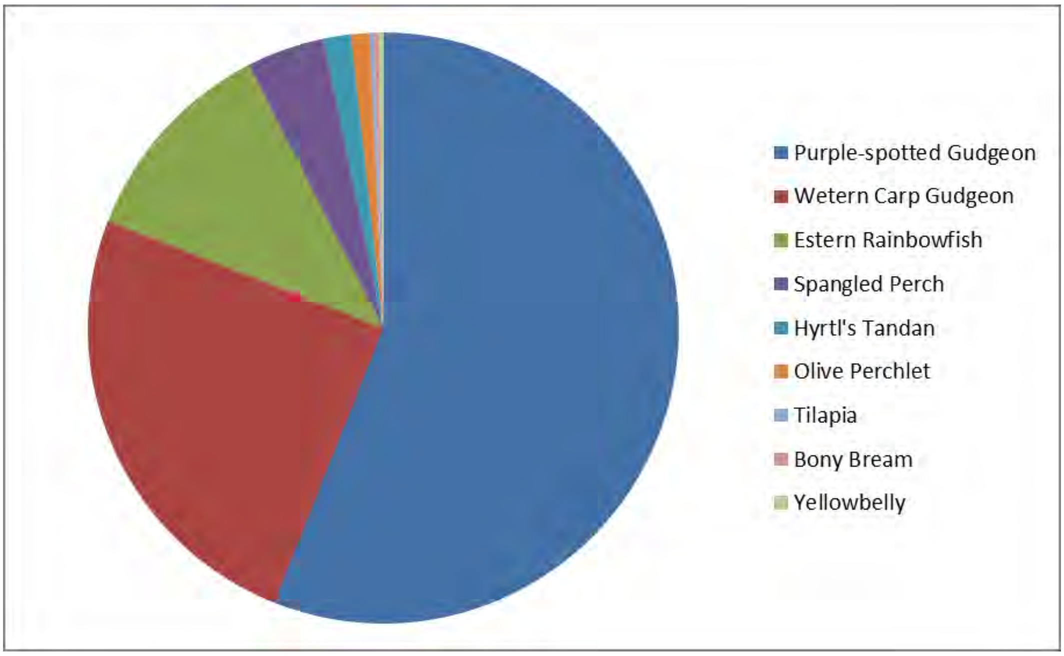

Figure 3-27: Relative abundance of fish capture in July 2011

3.5.4.3 Community Composition and Distribution Patterns

As well as being among the numerically dominant species in the 2010 and 2011 catch, Purple-spotted Gudgeon was the most commonly observed species across the sites sampled. It was only absent from site TC-1 (Table 3-6), though habitat conditions at that site would likely support this species. Western Carp Gudgeon, Spangled Perch and Eastern Rainbowfish were among the other fairly ubiquitous fish species recorded in the study area (Table 3-6). This accords with expectations based on statements made by GHD (2010) that those species prefer shallow, slow moving sand dominated pool habitats, frequently found within the Project area. The most common species recorded were Eastern Rainbowfish and Spangled Perch. These species have a wide distribution and occur in a range of habitat types (Allen et al. 2003), so it is not surprising that these species were recorded at most sites in this study. Eastern Rainbowfish are usually abundant wherever they occur and often form aggregations near the water surface (Allen et al. 2003), which would make this species easier to catch. Spangled Perch are regarded as a remarkably hardy species potentially capable of surviving droughts by aestivating in wet mud or under moist leaf litter on the bottom of ephemeral waterholes. Hence, they are ideally suited to the ephemeral streams of the study area.

While the distribution of other species was more restricted and some species were only recorded at particular sites, based on their biology, there is no reason why they would not potentially be present at other locations within the study area. There was no pattern to suggest any clear difference between stream and wetland habitat fish communities. However, it is possible that Sleepy Cod are present in the deeper zones of the wetlands sampled, as this species favours such habitat where there is structure such as standing timber.

Anecdotal information from local landowners in the study area is that it Tilapia are present in Alpha Creek and in some farm dams (Reid Bauman, Monklands property owner, pers. comm., 2011), but none were recorded in Alpha Creek in either 2010 or 2011. Wetland habitat, such as the site where it was recorded in July 2011, and farm dams often support large juvenile populations of Tilapia, so its detection in July 2011 in a wetland adjacent Alpha Creek, albeit in very low numbers, is still cause for concern. Tilapia are thought to be more tolerant of polluted conditions than native fish, so if the SGCP was to increase pollution levels in Alpha Creek, it could be to the advantage of this species and their resultant proliferation could compound the direct impacts of pollution on native fish.

The restricted abundance and distribution of Bony Bream recorded in the study area is somewhat unexpected, as this species prefers slow stream and pool habitat of the sort encountered in the study area. Flows associated with the 2010/11 wet season may have had a profound impact on the local population of this species.

Three macrocrustacean taxa were recorded in the July 2011 study: *Macrobrachium* spp. (Freshwater Prawn), Atyid Shrimp and the yabby, *Cherax destructor.* Freshwater prawns were fairly ubiquitous. Atyid Shrimp were only recorded from fish sample catches at two sites, but were among the macroinvertebrate sample by-catch at AC-1 and AC-Lagoon. Yabbies were present in all catchments except Alpha Creek and was not recorded from wetland habitat. In April 2010, relatively large numbers of yabbies were caught at both the SC-2 (Sapling Creek) and AC-1 (Alpha Creek sites) (Aquateco, 2010). Another macrocrustacean, *Austrothelphusa* sp. (Freshwater Crab) was recorded at both sites in April 2010, but were not recorded in July 2011.

3.5.4.4 Physical Condition

Most fish captured were in good physical condition. However, fungal growth was observed on an Eastern Rainbowfish specimen at site AC-1, while a recently dead Spangled Perch was observed on the bank at site TC-3. It is unclear whether these observations were a response to environmental stress and if so, what factors were responsible.

3.5.4.5 Rare and Threatened Species

None of the endemic fish species recorded during April 2010 and July 2011 or historically known to the Belyando catchment are listed as threatened species under either State or Commonwealth legislation. AARC (2010) for the Alpha Coal Project EIS list Murray Cod (*Maccullochella peelii peelii*) as a listed vulnerable species occurring in the Central Highlands region, but this species is not known historically to the Belyando River system.

Note that the Biodiversity Assessment and Mapping Methodology (EPA, 2002) provides a list of bio-regionally significant species for the SGCP bioregions. Appendix 7 of this document lists 'Priority Fauna Taxa Other Than EVR Taxa' and among these, there are two species which occur in the parts of the Brigalow Belt and Desert Upland regions covered by the Belyando catchment. These are Midgley's Carp Gudgeon and Southern Purple-spotted Gudgeon. It is unclear why Midgley's Carp Gudgeon was listed as a non-EVR priority species and no information is provided in EPA (2002). No particular threats are currently listed for this species. The inclusion of the Southern Purple-spotted Gudgeon is that the southern population is listed as threatened in NSW and threats to this population continue to this day, particularly in the Murray-Darling Basin. Given the location of the SGCP, it is more likely that the Purple Spotted Gudgeon specimens captured were from the non-threatened northern population. Indeed this species was one of the most commonly caught species in the SGCP in this study, suggesting that it is locally abundant and has a viable population.

3.5.4.6 Introduced Species

The two exotic and one translocated species were not recorded in large numbers. However, Mosquitofish and Tilapia are regarded as noxious pest species and have the ability to proliferate under disturbed conditions, which is of direct relevance to the SGCP.

Table 3-6: Distribution of fish and macrocrustacean species among the various study sites (based on 2010 and 2011 data)

Site	Site 04	TC-1	TC-3	SC-1	SC-2	SC-3	AC-1	AC-2	DC-2A	AC-Dam	UT-Dam
Eastern Rainbowfish		X	X		X		X	X		X	
Purple-spotted Gudgeon	X		X		X	X	X	X	X	X	X
Western Carp Gudgeon	X	X	X			X	X		X	X	X
Midgely’s Carp Gudgeon										X	
Spangled Perch			X	X	X	X	X	X		X	
Olive Perchlet		X					X			X	X
Hyrtl’s Tandan			X				X	X		X	
Tilapia										X	
Bony Bream			X								
Yellowbelly			X								
Mosquitofish							X				
Freshwater Prawn	X		X		X		X	X		X	
Atyid Shrimp	X		X								
Yabby	X	X			X	X			X		

3.5.4.7 'Migratory' Species

The two fish species that occur in the Belyando River catchment that undertake movement for spawning, Long-finned Eel and Snub-nosed Garfish, are unlikely to occur in the SGCP area. Therefore, the creation of barriers as part of the SGCP will not affect those species. There may still be a host of potadromous (move wholly within freshwater reaches) species within the upper Burdekin Basin for which inter-basin movement is critical for their recruitment success and longer terms species vigour in terms of genetic viability (Alluvium, 2007). The small localised scale of barrier creation as part of the SGCP will not affect inter-basin movement for those potadromous species, but it might have some effect on their local population status. For instance, various studies have suggested that adult Spangled Perch undertake spawning-related movement at the start of the wet season, though this is not confirmed as movement is neither uniformly upstream nor downstream (Pusey et al. 2004). There is also some evidence that Eastern Rainbowfish undergoes upstream migration in intermittent streams, although mass migration seems to be uncommon (Pusey et al. 2004). While there is little quantitative information concerning the movement biology of Olive Perchlet, this species appears to undertake mass upstream dispersal movements often cued or facilitated by elevated discharges (Pusey et al. 2004). In addition, while originally thought to be a relatively sedentary species, recent studies have shown that large numbers of Carp Gudgeon attempt to move through fishways (Baumgartner 2003). Whether these movements reflect local dispersal or foraging movements is unknown.

Spangled Perch are one of the better species in terms of negotiating through fish passage barriers (DPI, 2009a), so it is potentially less vulnerable to fish barrier impacts than some of the other species present. Moreover, Spangled Perch are widely distributed, so any fish passage-related impacts associated with the SGCP would not affect the long term viability of their population within the broader study region.

3.5.4.8 Fish Habitat Areas

Fish Habitat Areas (FHAs) play an essential role in sustaining local and regional fisheries and are protected under the Fisheries Act. FHAs in the Burdekin River catchment are confined to coastal rivers and adjacent coastline such as the Bohle River, Burdekin River, Bowling Green Bay and Cleveland Bay. There are no FHA's within or adjacent to the SGCP area, so the SGCP will not affect any FHA.

3.5.4.9 Physiological Tolerances

Ephemeral streams are subject to wide physico-chemical fluctuations. This is reflected in the species composition of fish found in these types of waterways, and notably their tolerance to a wide range of water physico-chemical qualities (McNeil, 2005). The species recorded in the SGCP study area can be described as generalists that are distributed widely within the broader region and, in some cases, within Australia. For instance, Spangled Perch is the second-most widespread of Australia's freshwater fish species and is often very abundant when present (Pusey et al. 2004). Purple-spotted Gudgeon are a relatively common species of coastal drainages of Eastern Australia north of the Clarence River, NSW. It is found in a range of lentic and lotic habitats, most commonly in slow flowing and weedy areas of rivers, creeks and billabongs. However, it has also been recorded from shallows with moderately high flow velocities (Pusey et al. 2004). Eastern Rainbowfish is a very widely distributed species along the east coast of Queensland and is usually abundant where it occurs (Pusey et al. 2004). The wide distribution and high abundance are largely due to the fact the Eastern Rainbowfish are not dependent on any particular substrate or habitat type, although they do show a preference for slower moving streams and those that are relatively free of aquatic vegetation (Pusey et al. 2004). Olive Perchlet are a relatively widespread species occurring in coastal and inland drainages of Eastern Australia. It is generally common across this range, and often locally abundant. Olive Perchlet are found in a variety of freshwater habitats including still or slow-moving parts of large-lowland rivers, upland rivers and small coastal streams. Carp Gudgeon are widespread and common throughout the Eastern seaboard of Australia (Pusey et al. 2004). This group of species is found in slow-flowing or still waters, normally associated with aquatic vegetation.

Physiological tolerances to water quality for most of the species caught in the study area have not been verified empirically, but have been estimated from their distribution ranges. AARC (2010) summarised the available literature in relation to pH and dissolved oxygen (DO) (Table 3-7). Many fish are tolerant of mildly acidic conditions, which might be of relevance if the SGCP has any potential acid rock drainage-related impacts. Many of the species listed in this table can tolerate low DO levels, at least for a short period. Interestingly, a number of Purple-spotted Gudgeon and Carp Gudgeon were caught at DC-2A in July 2011, where DO saturation was <10%, which confirms observations made in Table 3-7 for the former, while suggesting that Carp Gudgeon share a similar tolerance to Purple-spotted Gudgeon with regards to DO. The generally low DO levels across the study area (see water quality section below) might explain the lack of Bony Bream caught.

Turbidity tolerance for Australian native fish is poorly known, but it is likely that they can withstand short periods of very high turbidity as occurs naturally with heavy rainfall events. They are, however, unlikely to tolerate elevated turbidity levels over extended periods. Suspended sediment can clog or damage gill membranes, causing poor health or mortality in extreme cases. Sub-lethal effects include reduced predation success for visual predators, reduced breeding success in species that rely on visual cues for spawning (e.g. Eastern Rainbowfish) and reduced prey and shelter abundance through sediment effects on plant growth, macroinvertebrates and their habitats. In this study, many of the waterways sampled were turbid, yet fish were still present. The most surprising result with respect to turbidity was the propensity of Purple-spotted Gudgeon and Carp Gudgeon to survive in water of >1000 NTU.

These results suggests that the fish community in the study is potentially capable of tolerating short periods of degraded water quality that might be associated with mine runoff or discharge with regards to pH, DO and turbidity.

Table 3-7: Physiological tolerance of native fish species of the study area to pH and DO (AARC, 2010)

Species	pH Tolerance	Dissolved Oxygen Tolerance
Spangled Perch	4-10.2	n/a
Bony Bream	4.8 -8.6	Intolerant of hypoxia
Olive Perchlet	6.3 -9.9	0.3 -19.5 mg/L
Purple-spotted Gudgeon	n/a	Can withstand short periods of low oxygen levels
Eastern Rainbowfish	5-9.2	n/a
Hyrtl's Tandan	<9.1	Can withstand mildly anoxic conditions (DO >1.5 mg/L)
Carp Gudgeon	5-91	n/a

3.5.5 Aquatic Reptiles and Mammals

3.5.5.1 Composition and Distribution

Two crocodile and five turtle species are known to occur in the Burdekin River catchment (GHD, 2011). Overall, numbers of both species of crocodile in the Burdekin Catchment are small and Estuarine Crocodiles (*Crocodylus porosus*) only extend as far up the catchment as Burdekin River Dam wall, while Freshwater Crocodile (*Crocodylus johnstoni*) were translocated to the Burdekin River Catchment as part of pet trading and a small breeding population exists in this catchment (DERM, 2010b *In* GHD, 2010). As such, neither is expected to occur in the Project area.

Turtle species occurring in the study area include:

- *Chelodina canni* (Cann's Long-necked Turtle);
- *Emydura macquarii* krefftii (Krefft's Turtle);
- *Elseya irwini* (Irwin's Turtle);
- *Elseya latisternum* (Saw-shelled Turtle); and
- *Chelodina longicollis* (Snake-necked Turtle)

There are also unverified records of the Northern Long-necked Turtle (*Chelodina rugosa*) in this catchment (GHD, 2010).

Of the above turtle species, Krefft's Turtle is a generalist (GHD, 2010) and could be present within the SGCP area. Cann's Long-necked Turtle and the Snake-necked Turtle prefers off-river habitat (GHD, 2010), so could occur in either the farms dams within the MLA or in wetlands such as the lagoon adjacent to Alpha Creek, though this is less likely for the latter whose distribution is restricted to the southern region of the Burdekin catchment (Cann, 2008 *In* GHD, 2010). Saw-shelled Turtle also prefer off-river waterbodies, but particularly those with diverse in-stream habitat structure (GHD, 2010). The off-river waterbodies assessed as part of this study did not have particularly diverse habitat structure, though one had large woody debris and submerged macrophytes as well as standing timber (UT-Dam). Irwin's Turtle prefers permanently flowing, sandy stream habitat with abundant macrophytes and woody debris of the Bowen, Broken and Burdekin Rivers, so would not be likely to be present within the SGCP area.

Platypus (*Ornithorhynchus anatinus*) are known to occur in the Burdekin River catchment. While they are listed as being Special Least Concern wildlife under the NCA, they are regarded as being of inherent value and importance for maintaining aquatic ecosystems (GHD, 2010). They are also of evolutionary and cultural heritage significance and are regarded by some as indicators of stream health. Platypus prefer permanently inundated waterways that provide habitat throughout the year and are usually restricted to reaches that offer suitable burrow construction habitat (e.g. consolidated earthen banks, featuring riparian vegetation roots, undercut banks and/or trailing vegetation (Grant and Temple-Smith, 1998 *In* GHD, 2010). Given the ephemeral nature of the stream habitats within the SGCP area, few Platypus are expected to be found there. Alpha Creek offers the greatest potential habitat for Platypus of the streams in the area. Off-river water bodies surveyed during this study lacked the steep banks required for burrow construction.

Surveys of turtles were performed using baited fyke and turtle nets at both sites in April 2010. No turtles were captured at either site. No Platypus were observed during that field survey, and inspections of the banks did not reveal any burrows or pathways of these animals (Aquateco, 2010). Similarly, no incidental sightings of turtles or Platypus were made during the 2011 survey.

3.5.5.2 Rare and Threatened Taxa

None of the turtle species known to occur in the Burdekin Catchment are currently listed as protected under the EPBC Act and NCA, but Irwin's Turtle is endemic to the Burdekin Catchment and is listed as a high priority for conservation under DERM's "Back on Track" prioritisation framework for the conservation of Queensland wildlife (GHD, 2010).

AARC (2010) for the Alpha Coal Project EIS listed Fitzroy River Turtle (*Rheodytes leukops*) as a vulnerable species occurring in the Central Highlands region, but that species occurs exclusively in the Fitzroy River Basin, so would not be expected to occur in the Project area.

Due to its likely absence from the SGCP area, the endemic Irwin's Turtle will not be affected directly by the SGCP.

3.6 Surface Water Aquatic Flora

3.6.1 Diversity and Abundance

A total of 55 aquatic-dependent flora species are known to the Burdekin River Catchment (Inglis and Howell, 2009 *In* GHD, 2010). Of these 12 species live in the aquatic zone as opposed to the riparian zone.

Generally, the sites surveyed as part of this study lacked abundant macrophyte cover, with the exception of UT-Dam and SC-Dam. Emergent species were the dominant form represented and no floating forms were recorded. This is typical of what would be expected in an ephemeral stream habitat as emergent macrophytes are able to survive in the predominantly dry conditions and are less subject to severe fluctuations in water level in general.

Aquateco (2010) recorded six macrophytes from two sites, though that list included two native grass species (Table 3-8). Those species were present at many of the sites sampled in July 2011, but were not counted as macrophytes for that study based on the fact that that they occurred predominantly on the upper bank, well above the waterline. Umbrella Sedge and Jointed Rush are exotic species, the remainder are native.

Table 3-8: Macrophyte species recorded during the April 2010 survey (Aquateco, 2010).

Scientific name	Common name	SC-2	AC-2
Cyperus eragrostis	Umbrella Sedge	y	y
Bolboschoenus fluviatilus	Marsh Clubrush	-	y
Diplachne fusca	Brown Beetle Grass	y	-
Leptochloa digitata	Umbrella Canegrass	y	y
Juncus usitatus	Common Rush	y	-
Juncus articulatus	Jointed Rush	y	-

ALS recorded two species of native, submerged macrophyte at UT-Dam in July 2011, Water Nymph (*Najas tenuifolia)* and Red Water Milfoil (*Myriophyllum verrucosum)*. Both were abundant on the margins of this dam, which lies within the proposed open pit mining area. These two submerged macrophyte species are unique within the SGCP area to our knowledge (though are widely distributed in Queensland). The SGCP could potentially result in the permanent loss of these two species from the local area as a result of mine pit construction.

Stream Club Rush *(Bolboschoenus fluviatilus)* was recorded at UT-Dam and at Site 04 in July 2011, but not elsewhere in 2011. The emergent native species, Smart Weed (*Persicaria* sp.) was only recorded at SC-2 in July 2011. Common Rush (*Juncus usitatus)* was recorded at SC-2 dam in 2011, while. Lomandra (*Lomandra* sp.) was commonly observed at sites in Sapling Creek and Alpha Creek.

Paragrass (*Urochloa mutica*), declared noxious ponded pasture weed, was present at both UT-Dam and SC-Dam. This species was not recorded in April 2010 as no dams were surveyed at that time.

3.6.2 Rare and Threatened Species

AARC (2010) listed Queensland Lace Plant (*Aponogeton queenslandicus),* Blake's Spikerush *(Eleocharis blakeana)* and Water Milfoil *(Myriophyllum implicatum)* among the macrophytes listed as rare under the NCA within the Central Highlands. However, *Water Milfoil* and Blake's Spikerush do not occur in the Burdekin Catchment (Inglis and Howell, 2009 *In* GHD, 2010) and Queensland Lace Plant is listed as 'Least Concern' under the *NCA.*

Queensland Lace Plant has been recorded in Central Queensland and only inhabits temporary freshwater pools with clay bottoms with abundant sunlight (Stephens and Dowling, 2002). Most of the sites monitored as part of this study were dominated by sand beds, though SC-2, SC-3, AC-Dam and DC-2A all had a higher proportion mud/clay. While not observed at these sites, Queensland Lace Plant may occur at other times of year at these sites and other similar habitats within the Project area. Consideration should be given to further monitoring of these sites for Queensland Lace Plant prior to and after the construction phase to assess whether or not there is any potential for the SGCP to impact on this species.

3.6.2.1 Weed Species

A total of 17 declared weed species are recognised from the Burdekin Catchment. This includes three weeds of national significance, one class 1 species under the *Land Protection (Pest and Stock Route Management) Act 2002* and eight aquatic-dependent species class 2 pest plants. Of these, only Paragrass was recorded within the Project area and, where it occurred, it was only present in small patches within farm dams.

3.7 Surface Water Quality

The waterways studied throughout this sampling program are ephemeral. Ephemeral streams contain water for only a short period of time following rainfall events and these rainfall events can be irregular and unpredictable (Boulton and Brock, 1999). The application of guidelines to ephemeral waters is problematic as currently there are no physico-chemical guidelines for ephemeral streams in Australia. Due to the absence of specific water quality guidelines for ephemeral systems, the Queensland Water Quality Guidelines (DERM, 2009a) for slightly disturbed upland stream and reservoir/dam habitat of Central Queensland were used as the primary set of trigger levels/ranges for assessment. The trigger values/ranges used for electrical conductivity (EC) were based on the 75th percentile value recorded by DERM at five sites in the Belyando-Suttor River catchment (DERM, 2009) on 271 occasions. ANZECC and ARMCANZ (2000) values apply to wetland habitats of Central Queensland as no specific guidelines have been developed as yet for such habitat. They also apply to reservoir and dam habitat with respect to EC. Note, however, that there is no upper limit for EC for wetland habitat given in the ANZECC & ARMCANZ (2000) guidelines. The lower range value for EC in wetlands given in ANZECC & ARMCANZ (2000) is 90µS/cm.

Available data on ephemeral streams in central Queensland, in particular those located in the Burdekin Basin (Roth et al., 2002), display a wide fluctuation in factors such as pH, dissolved oxygen (DO), EC, and temperature (Williams, 2006; DERM, 2009b). A review of historical water quality data in the Burdekin Basin conducted by ACARP (2005) revealed that most upland river sites generally displayed water quality characteristics that would not meet generic ANZECC and ARMCANZ (2000) guideline values. Accordingly, water quality parameters outside the recommended ranges may simply reflect natural local conditions based on local geology and geomorphology. Also, the drying out of stream pool and wetland habitat tends to have a concentrating effect on dissolved salts, metals and nutrients, while turbidity and dissolved oxygen are also often outside recommended ranges during the late drying phase due to stagnation and the ready re-suspension of bottom sediment. Hence, water quality results for ephemeral streams need to be interpreted with caution.

3.7.1 Electrical Conductivity

Results presented in Table 3-9 and Table 3-10 show that EC levels were frequently outside the recommended range for Central Queensland. Sites in Tallarenha Creek and Alpha Creek consistently exceeded the upper trigger level and for site AC-1, this occurred in both April 2010 and July 2011. Site TC-1 recorded a very high EC level, but that site featured a very small isolated pool in the late stages of drying. EC levels in Sapling Creek were within the recommended range in July 2011, but site SC-2 was above the upper trigger level for EC in April 2010. EC levels in the two dams (UT-Dam and SC-Dam), the natural lagoon in the Sapling Creek catchment (AC-Lagoon) and Site 04 were relatively low. EC levels for UT-Dam, SC-Dam and Site 04 within both the Central Queensland and ANZECC & ARMCANZ (2000) guidelines. However, AC-lagoon recorded EC levels lower than the Central Queensland and ANZECC & ARMCANZ (2000) guideline lower limit for EC in wetland habitat (90µS/cm).

3.7.2 pH

Like EC, pH measurements were frequently outside the recommended range for Central Queensland upland stream habitat (DERM, 2009a), though all sites recorded pH within the broader 6.0-8.0 range put forward in the ANZECC & ARMCANZ (2000) guidelines. Sites assessed as part of this study could be had water ranging between mildly acidic to mildly basic, tending towards neutral.

3.7.3 Dissolved Oxygen

With the exception of sites TC-3, SC-3 and UT-Dam, all sites recorded DO saturation levels below the DERM (2009a) and ANZECC & ARMCANZ (2000) levels. Very low DO levels were recorded at sites SC-2 and AC-1 in April 2010 and at sites SC-2, DC-2A and AC-Lagoon in July 2011. Low DO levels, in most instances, likely reflect the lack of flow at the time readings were taken, but this would not explain the low DO levels in Alpha Creek in July 2011 where surface flow was still present. Sites with very low DO levels all had predominantly mud/silt substratum and other sources of organic material and were in the late stages of drying out. Lack of flow, combined with a high biological and/or chemical oxygen demand associated with the breakdown of organics probably account for the observed low DO levels observed at these sites. Contrastingly, DO levels at SC-3 and UT-Dam were supersaturated. DO levels at SC-3 were above the DERM (2009a) upper limit for Central Queensland upland streams and reservoir/dam habitat. High DO levels at UT-Dam were probably a reflection of high rates of photosynthesis associated with the dense macrophyte growth at this site. At SC-3, photosynthesis associated with algal productivity might account for this phenomenon as algal scum was observed on the water surface at this site.

Note that *in situ* readings for DO were taken at different times of the day and only on two occasions or less, so do not necessarily reflect the true ranges of DO conditions at that site. Hence, the above comparisons with guideline levels must be interpreted with caution.

3.7.4 Turbidity

With the exception of Site 04, TC-1 and the two Alpha Creek sites, all sites sampled in July 2011 recorded turbidity levels in excess of recommended guideline levels. Very high turbidity levels were recorded at site SC-2 in both April 2010 and July 2011, but the highest turbidity recorded was > 1000 NTU at DC-2A. This was probably due to the fact that these sites had mud/silt substratum. Further, water levels were low at the time SC-2 and DC-2A were surveyed, such that the muddy sediments at those sites would have been readily resuspended. Also, both sites were heavily impacted by cattle access to the waterway, with bank erosion and trampling of bed sediments further exacerbating turbidity levels. Turbidity levels for the two dam sites (UT-Dam and SC-Dam) were relatively low and only marginally exceeded guideline levels. The low turbidity level recorded at TC-1 could potentially have been due to the sand/gravel dominated bed present at this site, groundwater influence on surface water quality, or a combination of both.

3.7.5 Alkalinity

Alkalinity is a measure of water hardness based on calcium carbonate concentration. It is an important measure in two ways. Firstly, calcium is vital for macroinvertebrate exoskeleton development (particularly for molluscs). Secondly, water hardness affects metal bioavailability and toxicity. Soft water (alkalinity <60mg/L) offers lesser buffering capacity in terms of limiting metal bioavailability and toxicity and also a more limited supply of calcium for macroinvertebrate exoskeleton development. In addition, EC levels are partly determined by the amount of calcium ions present.

Based on alkalinity levels recorded in July 2011, conditions within the study area range from very soft to very hard water (Table 3-10). All sites within Sapling Creek, as well as all dam and lagoon sites featured low alkalinity (soft water). Site 04 recorded an alkalinity indicative of soft -moderate water hardness. Among these, SC-3 and AC-lagoon were the only sites that would potentially receive runoff and discharge from the SGCP. In theory, those sites would be more vulnerable to any enhanced metal bioavailability associated with discharge or runoff from the SGCP compared to receiving waters in Tallarenha Creek and Alpha Creek, which feature higher alkalinity (hard water).

3.7.6 Heavy Metals

Surface water monitoring for the SGCP EIS has included four rounds of water sample collection and analysis covering sites on Alpha Creek, Sapling Creek, Tallarenha Creek and Dead Horse Creek at various times between April and June 2011. Those samples were tested for a range of heavy metals in both dissolved and total concentration form.

Results from the WRM water quality sample collection and analysis showed that a number of metals, including aluminium, cadmium, copper, iron, nickel, selenium and vanadium, had total concentrations above the ANZECC & ARMCANZ (2000) guideline levels for slightly to moderately disturbed aquatic ecosystems. Among these, the metals that most often exceeded guideline levels, at times by fair margins, were aluminium and iron. More importantly, the dissolved form of both aluminium and iron also regularly exceeded those guideline levels, indicating that these metals were in bioavailable form at concentrations considered potentially toxic to aquatic fauna, even prior to any mine construction. Dissolved copper and selenium were also occasionally found to exceed ANZECC & ARMCANZ (2000) guideline levels, but generally at concentrations at or mildly exceeding those levels.

Spatially, the mid and lower reaches of Sapling Creek recorded the highest dissolved aluminium and iron concentrations. Alpha Creek tended to have elevated dissolved aluminium concentrations at times, but not elevated dissolved iron concentrations. Tallarenha Creek recorded elevated dissolved aluminium concentrations at all three monitoring sites in June and elevated dissolved iron and selenium concentrations at the upstream and downstream site at this time. In April, a slightly elevated dissolved copper concentration was recorded at the upstream Tallarenha Creek monitoring site. The one site monitored in Dead Horse Creek had elevated dissolved aluminium and iron levels.

Based on the metal concentration and alkalinity data outlined above, there is a real risk that, if not tightly controlled, runoff into Sapling Creek during mine construction and the release of mine affected water into the Sapling Creek catchment could enhance the already high levels of bioavailable metals (particularly aluminium and iron) in a catchment with low buffering capacity due to its low alkalinity. This could, in turn, result in a decline in the condition of the aquatic community in Sapling Creek. The aquatic fauna community of AC-Lagoon might also be affected adversely by contaminated water from overland runoff from Sapling Creek during high flows or from Alpha Creek as water levels rise to inundate AC-Lagoon. It too has a low buffering capacity with respect to mitigating the toxic effects of heavy metals due to its relatively soft water and low DO.

3.7.7 Summary

The study area was characterised, in part or whole, by EC, DO, pH and turbidity levels outside the recommended ranges, though this is not unexpected for ephemeral stream systems at different stages of drying out, for which local water quality guidelines are yet to be developed.

There were some key differences between stream and wetland/reservoir/dam habitat water quality, with the latter characterised by relatively low EC, alkalinity and turbidity levels. Reinforcing statements made above, Site 04 shared very similar water quality to the wetland /reservoir/dam habitat sites, essentially functioning as a wetland at the time of sampling.

Water quality in stream and dam/wetland habitat was partly a function of flow conditions, sediment type, degree of bed and bank disturbance and presence/absence of aquatic plants and algae. DO levels were generally low, which for stream habitat other than Alpha Creek, probably relates to lack of flow. The contribution of plant and algal photosynthesis probably accounted for sites that featured supersaturated DO levels. The presence of organic rich sediment and detritus and lack of flows probably accounted for the very low (hypoxic) DO levels observed at certain sites. Many sites recorded high turbidity levels, but organic rich sediment, combined with low water levels and heavy bed and bank erosion through cattle access explained the very high turbidity levels at certain sites.

Based on alkalinity levels recorded in July 2011, conditions within the study area range from very soft water to very hard water. In terms of receiving waters, the lower reaches of Sapling Creek and the lagoon adjacent Alpha Creek (AC-lagoon) featured soft water, whereas Tallarenha Creek and Alpha Creek featured hard water. Hence, the receiving waters most vulnerable to enhanced metal bioavailability associated with discharge or runoff from the SGCP are the lower reaches of Sapling Creek and the lagoon adjacent Alpha Creek. This is made all the more important given that water quality data collected for the SGCP area indicated that dissolved aluminium and iron concentrations above guideline levels have been recorded in Sapling Creek even prior to any mining activity being undertaken.

Table 3-9: ***In Situ*** **water quality results from Aquateco (2010). Values for DO % saturation were estimated based on water temperature. Trigger level/ranges based on ARMCANZ (2000) values and DERM (2009b) values for upland slightly to moderately disturbed upland stream and reservoir/dam habitat of Central Queensland. ANZECC & ARMCANZ (2000) trigger values are shown in bold. Reservoir and dam trigger values are shown in italics. Recorded values outside the recommended DERM (2009a) range are shown in red.**

Parameter	Guideline limit / range	SC-2	AC-1
Water Temperature (˚C)	N/A	20.5	25.22
Electrical Conductivity (µS/cm)	168 µS/cm (**250 µS/cm**)	324	172
pH	6.5 -7.5 (6.5-8.0) (**6.0-8.0**)	6.45	6.54
DO (mg/L)	N/A	1.80	3.46
DO (% saturation)	90-110 % (**90-120**)	20	50
Turbidity (NTU)	25 NTU (*1-20 NTU*) (**15 NTU**)	832	94

Table 3-10: ***In situ*** **water quality results from July 2011. Trigger level/ranges based on ARMCANZ (2000) values and DERM (2009b) values for upland slightly to moderately disturbed upland stream and reservoir/dam habitat of Central Queensland. ANZECC & ARMCANZ (2000) trigger values are shown in bold. Reservoir and dam trigger values are shown in italics. Recorded values outside the recommended DERM (2009a) range are shown in red.**

Sample details / Parameter	Guideline limit / range	Site 04	TC-1	TC-3	SC-1	SC-2	SC-3	AC-1	AC-2	DC-2	AC-Lagoon	UT-Dam	SC-Dam
Sample Collection Time (24h)		1315	750	1500	1000	1300	1530	1130	1440	915	740	1135	1100
Sample Depth (m)		0.3	0.10	0.20	0.40	0.2	0.10	0.40	0.30	0.05	0.25	0.10	0.05
Water Temperature (°C)	N/A	15.35	12.61	15.37	9.92	11.90	17.63	12.21	11.92	9.00	10.48	19.04	15.53
Electrical Conductivity (µS/cm)	168 µS/cm (**250 µS/cm**)	101	599	223	145	144	150	287	268	305	66	71	62
pH	6.5 -7.5 (6.5-8.0) (**6.0-8.0**)	7.3	7.65	7.85	6.63	6.22	7.68	7.95	7.59	7.36	6.47	7.26	6.62
DO (mg/L)	N/A	6.9	7.08	9.06	9.59	5.24	10.80	7.92	7.37	1.07	4.85	10.9	7.78
DO (% saturation)	90-110 % (**90-120**)	70.8	66.7	95.1	85.0	49.0	117.2	73.9	77.8	9.4	43.4	117.6	78.0
Turbidity (NTU)	25 NTU (*1-20 NTU*) (**15 NTU**)	22.7	8.4	80.4	197.0	854.0	204.0	22.2	16.5	>1000	162.0	26.1	32.8
Total Alkalinity (mg/L)	N/A	55	115	115	20	16	40	175	175	175	30	45	32

3.8 Groundwater Fauna

3.8.1 Stygofauna Ecological Requirements

Stygofauna are groundwater invertebrates intricately linked to the aquifer environment and are adapted to the relative stability of their surroundings. Compared to surface environments, groundwater fluctuates less in level and in physico-chemical variables such as EC, temperature, and pH (Hancock et al. 2005). Groundwater ecosystems also generally have lower DO and less readily available organic matter than surface water environments (Humphreys 2002). As there is no direct photosynthesis in aquifers, stygofauna rely on connections to the land surface to provide them with food. These connections may be hydrological, with infiltrating water bringing dissolved or particulate organic matter to form the basis of subterranean food webs, or it may be more direct, with tree roots that extend below the water table providing leachates or organic carbon or fine rootlets for food (Hancock et al 2005). Generally, stygofauna biodiversity is highest near the water table and declines with depth (Datry et al 2005). Stygofauna biodiversity is also higher in areas of recharge where the water table is close (<10m) to the land surface (Humphreys 2000, Hancock and Boulton 2008). This is because the water table is likely to have the highest concentration of oxygen and organic matter. Stygofauna still occur at considerable depth below the water table, but are fewer in number, have lower diversity, and may be different species (Datry et al 2005). In some karstic aquifers, where there is relatively high vertical exchange, or flow does not come into contact with large microbial surface areas (such as occurs in sedimentary aquifers), stygofaunal communities can occur at depths exceeding 100m (Humphreys 2000).

Stygofauna appear to prefer water with EC less than 5,000µS/cm. Stygofauna have been collected in bores with EC up to 18,000µS/cm, so it is still quite possible to collect animals in salinities in excess of 10,000µS/cm. Other variables thought to be suitable for stygofauna are a shallow water table (<20m), moderate concentrations of DO (2-3mg/L), and pH between about 6.2 and 7.2 (Hancock 2008).

In Australia, stygofauna are known from alluvial, limestone, fractured rock, and calcrete aquifers (Hancock et al 2005; Humphreys 2008). As yet, no species are known from coal aquifers apart from a copepod from central Queensland that occurred in a shallow seam adjacent to an alluvial aquifer (ALS *unpublished*). As stygofauna require a space to live, the porosity of the sediments, degree of fracturing, or extent of cavity development must be sufficient, as must the connectivity between the living spaces.

There are three critical factors that make stygofauna communities in aquifers vulnerable to the impacts of human activity:

- Many species need stable conditions, and groundwater communities require links to the surface environment to provide organic matter and oxygen. If that linkage is cut off, the stygofauna community in the area affected could decline over time;

- It is likely that stygofauna are able to tolerate natural fluctuations in water level, electrical conductivity, and temperature, and this has been demonstrated experimentally (Tomlinson *unpublished*) for stygofaunal amphipods, copepods, and syncarids. However, drawdown that is too rapid, or creates too much separation between the land surface and the water table, could lead to loss of biodiversity. Likewise, an increase in EC could also reduce biodiversity; and
- The third critical factor that makes stygofauna vulnerable to human activity is their high degree of endemism (Humphreys 2008). Unlike many surface-dwelling aquatic invertebrates, stygofauna do not have aerially dispersing life stages. To migrate between areas, stygofauna must be able to swim or crawl, and any barriers to this, such as an area of lower porosity, sections of poor water quality, or other disruptions, prevent natural species migration. This also means that stygofauna are poorly equipped to re-colonise an area once it has been disturbed.

Many species of stygofauna are restricted to small geographical areas. This is particularly the case in non-alluvial aquifers such as some of the calcrete aquifers in Western Australia, where one or more species are known only from a single aquifer, or part of an aquifer (Humphreys 2002). This means that any process that threatens the aquifer, potentially threatens an entire species. There is also a high degree of endemism in alluvial aquifers, even between adjacent systems (Hancock and Boulton 2008). However, providing there is sufficient hydrological connectivity within the aquifer, and physico-chemical conditions are suitable, the distribution of species will not be restricted to small parts of an aquifer.

3.8.2 Relevant Stygofauna Studies

The National Water Commission (NWC) has reported (NWC Waterlines, 2011) that extensive gaps exist in our knowledge of the distribution, composition and biodiversity value of Australian stygofauna. Despite this incomplete inventory it is apparent that stygofauna are present across a variety of Australian subsurface environments and are generally characterised by high diversity and local-scale endemicity. They are also often of high scientific interest; for example, the occurrence of the only known southern hemisphere representatives of several phyletic relict lineages.

In Australia, at least 750 stygofauna species have been described (Humphreys 2008), but this is a conservative estimate of total continental biodiversity as more than 66% of known species come from just two regions of Western Australia (Humphreys 2008) and large parts of Australia remain unsurveyed. In Queensland there are approximately 40 species of stygofauna known, but this estimate will certainly increase as more surveys are conducted and taxonomic knowledge improves.

Several small surveys have confirmed the presence of at least four stygofaunal taxa (one Copepoda, two Bathynellacea, and one Amphipoda) in the Bowen Basin. To date, two species are known from near Clermont, one near Collinsville, and one near Nebo. These were collected from alluvial/sedimentary aquifers rather than coal seam aquifers. The likely reason for this is that the water in the alluvial aquifers has lower EC than coal seam aquifers. ALS is not aware of any stygofauna collected from the Galilee Basin in central western Queensland, although this may reflect the fact that very little (if any) stygofauna sampling has taken place in this part of Queensland.

Only one stygofauna taxon is known from a coal seam aquifer - a species of harpacticoid collected from central Queensland (ALS *unpublished*). This specimen occurred in a shallow coal seam (50m deep), with low EC (<2,000uS/cm), a moderate to high amount of fracturing, and a good connection to a small alluvial aquifer.

One coal mining area that has a longer history of stygofauna sampling is the Hunter Valley, where surveys of alluvial aquifers were conducted between 2000 and 2008. Surveys of the groundwater/surface water interface along the Hunter River between Singleton and Glenbawn Dam from 2000 and 2003 found a diverse community of stygofauna (Hancock 2004). A follow-up project from 2004 to 2008 surveyed groundwater monitoring bores in agricultural areas and on several mine sites of the upper Hunter Valley (Hancock and Boulton 2008). This latter work found at least 40 taxa new to science (this number is likely to increase since not all specimens have yet been identified to species) and confirmed that stygofauna can exist in areas dominated by coal mining. It is worth mentioning that although the Hunter Valley has one of the richest known communities of stygofauna in Australia, no animals were collected from coal seams. All of the bores that contained stygofauna were in alluvial aquifers of the Hunter River and its tributaries. This may reflect a sampling bias, since most of the bores surveyed entered alluvium rather than coal seams, and the presence of stygofauna in coal seams should not be ruled out. However, it is likely that the majority of taxa in the Hunter Valley do live in alluvial aquifers, which is also likely to be the case for stygofauna in the QLD Surat Basin.

In terms of the Galilee Basin stygofauna community, AARC undertook a pilot study-scale survey for the Alpha Coal Project and Kevin's Corner Project EIS studies, which involved the surveying of 28 bores between March and June 2010. ALS processed the sample collected from that study and identified the fauna collected. A single cyclopoid copepod was collected from one of those bores in March 2010. This animal was identified as *Macrocyclops albidus* (Jurine, 1820), a cosmopolitan surface-dwelling copepod that is occasionally collected from groundwater. This species is a widespread surface species known from Australia, America, and Europe. The bore it was collected from was located on a large floodplain between two rivers and is approximately 900m from the nearest river, so it is likely that the species migrates between aquifer and surface water when the rivers flow. Based on those results, AARC concluded that 'no significant stygofauna populations were found in the impact area of the Alpha Coal Project, so mining here is unlikely to significantly threaten stygofauna.' However, they did note that their study design targeted coal seam aquifers rather than alluvial aquifers due to the nature of the bores available and that stygofauna might occur in alluvial aquifers not identified or sampled by their pilot study.

3.8.3 Processes That Threaten Stygofauna

Stygofauna are potentially threatened by activities that change the quality or quantity of groundwater, disrupt connectivity between the surface and aquifer, or remove living space. This has become a particular issue for mining proponents over the last decade or so, principally because of the perceived biodiversity value of stygofauna and the fact that little is known of their environmental water requirements.

Mining operations incorporate a range of water affecting activities in their operations, including some or all of the following (SKM, 2010):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- Desalination for potable supply (with subsequent brine disposal);
- Dust suppression;
- Tailings disposal;
- Rock storages;
- Backfilling and rehabilitation works;
- Water diversions and surface sealing;
- Hazardous and dangerous goods storage; and
- Water storages including waste water ponds.

In recognition of the above mining activities, direct effects on GDE's may be as follows:

- Quantity (groundwater levels, pressures and fluxes);
- Quality (concentrations of salts and other important water quality constituents);
- Groundwater interactions (interactions between groundwater systems and between groundwater and surface systems); and
- Physical disruption of aquifers (excavation of mining pits and underground workings).

The existence and extent of these water affecting activities, and their potential impact on local to regional scale groundwater resources, will depend largely on the scale of the mining operation, mining method, and process water requirements, as well as climatic and geological setting.

3.8.4 Stygofauna Survey Results

3.8.4.1 Stygoauna Collected

The fauna collected from SGCP as part of the stygofauna survey are presented in Table 3-11. These include one Beetle (Coleoptera: Hydraenidae), one Worm (Oligochaeata: Naididae) and one Springtail (Collembola). All of these taxa are common surface water aquatic macroinvertebrate taxa. No stygofauna were recorded. This corroborates the findings of the pilot stygofauna survey for the Alpha Coal Project and Kevin's Corner Project EIS by AARC (2010). It is noteworthy that the four groundwater bores identified below that recorded surface water aquatic macroinvertebrate taxa were all uncovered. Ingress of surface water fauna into the groundwater bore could have occurred during recent flooding events. The presence of surface water aquatic fauna in the groundwater bores is of no significance to the stygofauna assessment for the EIS.

Table 3-11: Fauna collected from South Galilee Coal Project stygofauna survey bores.

BORE ID	Stygofauna Recovered	Other Fauna Recovered	Family	Genus	Species
BH90C	NIL	NIL	-	-	-
CK169C	NIL	13 Coleoptera	Hydraenidae	*c.f. Hydraena*	*Larvae*
BH35	NIL	NIL	-	-	-
BH116	NIL	NIL	-	-	-
BH108	NIL	NIL	-	-	-
BH35C	NIL	NIL	-	-	-
BH107	NIL	NIL	-	-	-
BH118	NIL	NIL	-	-	-
CK157C	NIL	NIL	-	-	-
Near VW02	NIL	NIL	-	-	-
BH29C	NIL	NIL	-	-	-
CK108C	NIL	NIL	-	-	-
Windmill 1	NIL	4 Oligochaeta	Naididae	*Nais*	*sp.*
CK106	NIL	NIL	-	-	-
CK159	NIL	NIL	-	-	-
BH28C	NIL	NIL	-	-	-
MB03	NIL	NIL	-	-	-
BH115	NIL	NIL	-	-	-
CK163	NIL	NIL	-	-	-
Windmill 2	NIL	7 Oligochaeta	Naididae	*Nais*	*sp.*
BH112	NIL	4 Collembola 4 Coleoptera	Oncopoduridae Hydraenidae	*Oncopodura* *c.f. Hydraena*	*sp.* *Larvae*

The absence of stygofauna from the 22 groundwater bores sampled in the SGCP area is significant and suggests the presence of stygofauna in the SGCP area is unlikely. The 22 groundwater bores selected for sampling were well spread geographically across the MLA and bore selection targeted the main aquifer types within the study area. A second round of stygofauna sampling in the 2012 post-wet season to fully accord with the WA guidelines (2003 & 2007) will confirm this.

3.8.4.2 *In situ* Groundwater Quality

In situ groundwater quality was measured by bailing the groundwater bore immediately prior to stygofauna sampling (Table 3-12). DO values should be considered as an estimate only as groundwater samples would have been agitated and potentially aerated during the bailing process.

Table 3-12: *In situ* water quality from each of the 22 groundwater bores sampled for stygofauna (June 2011)

BORE ID	Water Temperature (ºC)	pH (units)	EC (µS/cm)	DO (% saturation)	DO (mg/L)
BH90C	24.57	8.51	1,421	14.0	1.16
CK169C	25.29	8.05	4,085	12.6	1.02
BH35	25.09	7.89	748	23.3	1.93
BH116	25.16	8.23	1,170	13.5	1.11
BH108	26.19	8.08	1,461	22.4	1.81
BH35C	24.76	8.23	762	30.3	2.49
BH107	24.55	7.98	1,202	9.2	0.77
BH118	25.02	7.86	871	11.4	0.94
CK157C	22.80	8.22	287	12.0	1.04
Near VW02	25.91	7.94	2,733	16.8	1.36
BH29C	26.68	7.95	1,125	16.3	1.30
CK108C	25.03	8.15	3,163	14.4	1.18
Windmill 1	23.93	7.74	673	15.0	1.24
CK106	23.28	8.10	1,088	9.9	0.84
CK159	23.68	8.08	987	16.0	1.35
BH28C	24.10	8.12	3,745	12.6	1.05
MB03	24.47	8.35	3,100	11.5	0.96
BH115	26.23	7.98	1,565	9.7	0.78
CK163	25.69	8.11	1,521	15.4	1.25
Windmill 2	23.92	7.68	3,413	42.3	3.55
BH112	25.14	7.76	5,341	7.4	0.61

Salinity is a major determinant of stygofauna species presence (Pinder *et al*, 2005). Stygofauna appear to prefer water with EC (as a measure of salinity) less than 5,000µS/cm. Stygofauna have been collected in bores with EC up to 18,000µS/cm (ALS *unpublished*), so it is still quite possible to collect animals in salinities in excess of 10,000µS/cm. Other variables thought to be suitable for stygofauna are a shallow water table (<20m), moderate concentrations of DO (2-3 mg/L), and pH between about 6.2 and 7.2 (Hancock 2008).

The groundwater quality survey results demonstrate that salinity in the SGCP is within the range where stygofauna are likely to be found (i.e. < 5 000µS/cm) and this was the case for all 22 bores sampled where average salinity was 1,839.3µS/cm. Water temperature was normal for groundwater bores and pH tended to be higher than optimal for the presence of stygofauna (i.e. average pH was 7.68), however, this is not considered a limiting factor for the presence of stygofauna.

3.8.5 Troglofauna

3.8.5.1 Troglofauna Habitat

The occurrence of troglofauna is strongly influenced by geology. Troglofauna require small subterranean fissures and voids for habitat. Lateral connectivity of these voids is important because it enables animals to move about underground, while vertical connectivity through to the surface is important for supplying carbon and nutrients. Subterranean geological features such as dykes and major faults may act as barriers to dispersal of troglofauna and may lead to species having highly restricted ranges (Bennelongia, 2009).

3.8.5.2 Potential Impacts of Mining on Troglofauna

The activities most likely to lead to direct impacts on troglofauna species is loss of habitat and activities that cause a reduction in habitat (e.g. pit excavation). Other threatening activities are poorly understood and their ecological impacts are rarely studied (Bennelongia, 2009). However, these activities are more likely to reduce population size than cause extinction and are associated with a variety of secondary impacts including:

- Dewatering resulting in a lowering of the water table may reduce subterranean humidity, and therefore impact on troglofauna habitat. The extent to which humidity below the vadose zone is affected by depth to the water table is unclear;
- The physical effects of explosions. Blasting may have an indirect detrimental effect through altered underground structure (usually rock fragmentation and collapse of voids);
- Overburden stockpiles and waste dumps. These artificial landforms may cause localised reduction in rainfall recharge (and associated entry of nutrients and dissolved organic matter) under the stockpiles. Effects on water recharge are likely to be less than the impact of dewatering; and
- Aquifer recharge with poor water quality. The quality of recharge water declines during, and after, mining operations as a result of rock break up and soil disturbance. Pore spaces in rock strata used by troglofauna can be affected.

3.8.5.3 Troglofauna Survey Results

Previous troglofauna assessments of Queensland have focussed on cave habitats. Troglofauna communities are known from the Chillagoe, Undarra, and Rope Ladder Caves in north Queensland. The fauna of these caves includes plant hoppers, cockroaches, centipedes, spiders and isopods (Howarth and Stone 1990, Weinstein and Slaney 1995, Eberhard and Humphreys 2003). The troglofauna sampling in the SGCP area is the first non-cavernous survey in central Queensland.

The fauna collected from SGCP troglofauna survey are listed in Table 3-13. All taxa collected in the SGCP troglofauna traps are commonly encountered in soil habitats (Coleman *et al.* 2004) and this is likely to be the origin of these animals, either by falling into the bore, or being already present in the leaf-litter despite pre-treatment. Although a subsample of the organic matter was examined under a microscope and no animals found, it is possible that a small number of reproductively capable nematodes may have survived microwaving and either been missed during inspection or not included in sub-sampling. However, a more plausible explanation is that the taxa fell into the bore from the surface and subsequently colonised the traps. Recent flooding prior to sampling may have also washed some taxa into boreholes.

Oribatid mites, springtails, and terrestrial insect taxa are commonly collected as bycatch during surveys for subterranean invertebrates using boreholes (S. Halse pers. comm., S. Eberhard pers. comm., P. Hancock pers. obs.), particularly in bores where the casing extends only a short distance above the ground.

Nematodes and Oligochaetes are also known from caves, subterranean aquatic and surface aquatic habitats. Nematodes were present in eight bores and Oligochaetes present in high numbers in one bore. In the SGCP area, the traps that contained fauna were set between 47 and 60m below ground surface, and no troglofaunal Oligochaetes or nematodes are known from this depth. Very little organic matter is likely to be present in the solid geologies at such depths, particularly if there is minimal fracturing. It is difficult to state definitively that these animals are troglofauna given the scant taxonomic knowledge of the worm fauna in Queensland. The difficulties in identifying Oligochaetes and Nematodes are recognised in Guidance Statement 54 and 54a, where exceptions are made for requirement to identify these groups to species (EPA 2003, 2007).

Sufficient living space is critical for troglofauna, and this is influenced by geology and the extent of weathering or fracturing. Significant open caverns are not expected to extend far below the land surface. Information on the amount of available pore space in the SGCP area is scant. Generally, the void space available in strata associated with coal seam geologies is limited at depths of 47m compared to other rock types known to suit troglofauna such as karst, calcrete, pesoliths, or lava tubes. This makes the presence of fauna at the depths sampled by ALS highly unlikely. Photographs from five fully cored HQ drill holes taken during PFS drilling in 2010 were examined (Figure 3-28). The drill hole cores were located along strike and down dip from the D1 subcrop and spaced evenly from the north to the south of the MLA in order to get a wide spectrum across the SGCP study area. Particular attention was paid to the area between 30-60m below surface level as this particular zone is predominantly between the Base of Tertiary (BHTE) and the Base of Weathering (BHWE). The zone between the BHTE and the BHWE is comprised primarily of weathered Permian Claystone with abundant limonitic weathering predominantly around the Bedding Planes. The Claystone is competent and voids are rarely observed. Structurally the area is tectonically stable and only rare locally displaced shearing and jointing was observed. This confirms that the general lack of void spaces available in the strata would preclude the presence of troglofauna.

Weathered sandstone beside Sapling Creek (approximate location 55K 449200 E, 7373600 S) showed superficial hollows and cavities up to 15cm across and 12cm deep (Figure 3-29). These cavities did not appear to extend far into the rock, nor were there substantial connections between cavities. Where the sandstone outcrop met the confining clay layer marking the bed of the creek, no cavities were found, so it is unlikely that troglofauna were present at this point.

Another critical requirement for troglofauna is food, which arrives underground via conduits or fractures linked to the surface. With increasing depth below the surface, organic matter becomes increasingly scarce, as do any animals that rely on it. Tree roots are known to create both a link to the surface and a source of organic matter for shallow (<20m below ground) troglofauna communities (Schneider 2011, Jasinska et al 1996). It is possible that roots from living or dead trees have penetrated as far as 47m in the SGCP area, providing a rapid conduit for water and organic matter. However, there is no evidence to support this.

The impact of subterranean humidity on the quality of troglofauna habitat is poorly studied, however, it may represent a risk to troglofauna species in some cases. For this reason ALS measured the air temperature and relative humidity both externally at the entrance to the bore as well as within the bore at a depth of 30m (Table 3-14). In all cases relative humidity was significantly higher within the bore suggesting a suitable habitat for the presence of troglofauna, if indeed they exist within the MLA. Stygofauna may also be able to avoid undesirable effects of habitat drying by moving deeper into the substrate if suitable habitat exists at depth.

Table 3-13: Terrestrial fauna collected from SGCP troglofauna traps

Bore ID	Nematoda	Coleoptera (Adult)	Coleoptera (Larvae)	Oribatida	Oligochaeta (Enchytreidae)
BH15C	-	-	-	-	-
BH28C	40	-	-	-	-
BH83C	1 040	-	-	-	-
BH109	2 880	-	-	-	-
BH112	48	1	-	-	-
CK163	48	-	-	-	-
CK169C	-	31	23	-	-
BH07C	2	-	-	-	-
BH88	960	-	-	-	-
BH90C	-	-	-	-	-
BH100	-	-	-	-	-
BH100C	-	-	-	-	-
BH111	-	-	-	66	-
BH114	-	-	-	-	-
BH120	-	-	-	-	-
BH121	-	-	-	-	-
BH123	116	-	-	-	-
CK167	-	-	-	-	-
CHK172	-	-	-	-	207
SP137	-	-	-	-	-
SP141	-	-	-	-	-
SP137C	-	-	-	-	-

Figure 3-28: Photographs from three fully cored HQ drill holes between 30 – 60m showing lack of void spaces for troglofauna.

Figure 3-29: Weathered sandstone outcrops along Sapling Creek. Pen in lower photo is 13.5cm long.

Table 3-14: **Humidity and Air Temperature at Surface and 30m within Bore.**

BORE ID	Relative Humidity at Surface (% RH)	Air Temperature at Surface (°C)	Relative Humidity within Bore (% RH)	Air Temperature within Bore (°C)
BH15C	47%	24.4	73%	25.8
BH28C	70%	17.6	94%	21.2
BH83C	70%	18.4	94%	20.8
BH109	56%	22.3	92%	23.2
BH112	73%	17.4	95%	21.3
CK163	54%	24.4	90%	25.0
CK169C	55%	20.0	92%	23.1
BH07C	60%	20.5	94%	23.8
BH88	59%	29.8	57%	26.8
BH90C	59%	23.3	91%	24.6
BH100	50%	25.0	68%	25.3
BH100C	50%	25.0	73%	25.2
BH111	55%	24.4	90%	25.3
BH114	48%	26.6	82%	27.0
BH120	54%	22.9	92%	25.1
BH121	42%	25.1	85%	26.8
BH123	44%	25.3	89%	25.7
CK167	60%	26.3	78%	25.6
CHK172	59%	25.3	71%	25.6
SP137	42%	25.1	53%	24.3
SP141	67%	22.0	76%	24.1
SP137C	42%	25.1	41%	24.7

4 Impact Assessment and Mitigation Measures

4.1 Surface Water Aquatic Ecosystems

The Project area contains a variety of waterway types, including dams which support quite unique habitat and aquatic flora species compared to the adjacent stream habitat. While there are examples of existing disturbance from cattle access to creeks, road and creek crossing construction, small scale riparian vegetation clearing and potentially agricultural runoff, many of the sites surveyed were remote and close to natural condition in terms of physical habitat. Water quality in the Project area was often poor with respect to EC, DO, pH and turbidity, but this is not unexpected for ephemeral stream habitat at different stages of the hydrograph. In terms of the aquatic flora and fauna supported by waterways in the Project area, there are no species of high conservation value that have been positively identified and most of the fish and macroinvertebrates present are generalists. However, the macroinvertebrate community was diverse and was of a composition either close to reference or better than reference condition at all sites monitored in July 2011. It also contained a number of PET and other pollution-sensitive taxa that might be vulnerable to the impacts of mine runoff. Based on this, it is essential to identify and quantify potential impacts on these aquatic ecosystem features and develop mitigation measures to reduce the risk of such potential impacts.

4.1.1 Construction Phase

Activities associated with the construction phase with the potential to impact on the surface water aquatic ecosystem values in the Project include:

- Pit construction;
- Diversion of low order stream habitat around the pit areas;
- Removal of riparian vegetation from streams both within the infrastructure corridor and the MLA;
- Instream works associated with road, rail and conveyor crossings; and
- Movement of vehicles and the plant to and from and around the construction site.

The potential impacts of these activities are detailed below.

4.1.1.1 Habitat loss

Open pit mining for the SGCP will result in the permanent loss of low order stream habitat and lacustrine habitat. The potentially impacted low order stream habitat, while largely physically intact, is dry for much of the year and is, of lesser habitat value to local aquatic fauna. It is also likely to be replicated outside the MLA. Dranage channels and a stream diversion will divert flow around the open pit mining area, so upstream reaches will be physically connected to downstream reaches, albeit by a modified physical habitat. The potential loss of the dams on the unnamed tributary of Tallarenha Creek and Sapling Creek is of greater concern. The former was the only site assessed that featured any submerged macrophyte species and, in that respect, was relatively unique within the study area. Both dams appear to remain inundated for long periods of time, so are likely to support migratory birds from time to time as well as macroinvertebrate and fish fauna, though the aquatic fauna of those dams is not particularly unique.

In order to compensate for the lost habitat and provide habitat suitable for aquatic fauna to move into and through, the stream diversions should ideally mimic the natural materials and geometry of the stream reaches lost. The Australian Coal Association Research Program (ACARP) have conducted research into 'Design and Rehabilitation Criteria for Bowen Basin River Diversions' (Earth Tech, 2002) and the Department of Natural Resources and Mines have created the 'Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry' (undated). It is recommended that these be referred to for improved environmental performance of the creek diversions required. Key considerations for creek diversion construction should be to:

- Carry out clearing of riparian vegetation for the proposed creek diversion in a staged manner, to allow fauna to migrate to adjacent habitat areas;
- Carry out works during the dry season when minimal (if any) water is present, so as to reduce impacts on water quality and fish movements; and
- The creek diversion rehabilitation should be monitored to ensure the vegetation is stable and self-sustaining.

4.1.1.2 Riparian Vegetation Clearing and Modification

Riparian vegetation provides bank stabilisation, shading of stream habitat, organic material and large woody debris as a food and shelter source for aquatic fauna and it helps retain water in stream systems. As such, a loss of riparian associated with the SGCP could decrease stream integrity and functioning. Apart from in sections of stream and lacustrine systems that will be permanently lost from within the open pit mining area, some riparian vegetation disturbance and clearing will be required for road and other infrastructure crossings. The number of such crossings is yet to be determined, but at each crossing location, riparian vegetation clearing is expected to occur within confined corridors and the impacts would be highly localised. Offsets for riparian vegetation are assessed and described in the Terrestrial Ecology Assessment (METServe, 2011).

There is the possibility that cleared sections could be affected by weed invasion, which if left unchecked, could affect downstream reaches, but this can be managed if precautionary weed control measures are put in place. These include, but are not limited to:

- A Weed and Pest Management Plan should be developed to propose and monitor the success of control strategies for pest plant and animal species within the Project site;
- A rehabilitation monitoring programme should be developed for the SGCP;
- Reasonable steps should be taken to keep land free from Class 2 pests such as Parthenium (*Parthenium hysterophorus*) and Lantana (*Lantana camara*) which are known to occur in the study region;

- Measures to control the spread of these weeds including vehicle washdowns should be adopted across the Project;
- New staff should be informed of the species of weed likely to be encountered on the Project site and what to do if they see them, as part of their site inductions;
- The location of known weed infestations (particularly Parthenium) should be monitored prior to construction and any new infestations encountered during construction reported to the Environmental Officer;
- Care to be taken when removing topsoil in known weed areas; and
- Construction sites to be rehabilitated as soon as possible, preferably with excavated topsoil from the same area so that native plant seed stock is given a chance to recolonise the area (provided the soil is not suspected of containing weed seeds).

4.1.1.3 Modification to Instream Habitat

There may be a requirement for disturbance of instream habitat through crossing construction where either new creek crossings or temporary weirs are built, or if pylons need to be placed in creeks to support bridges. Such impacts would generally be short term and localised if the appropriate precautions were put in place as far as construction methods and timing in relation to seasonal rainfall are concerned. Further reductions in the potential for such impacts can be achieved through minimising the number of creek crossings or temporary levees required, where possible and using bridge crossing designs that minimise the number of pylons required, or only require pylons on upper banks for support.

4.1.1.4 Fish Passage Barriers

Fish passage barriers will potentially be created as part of the SGCP, but most of these will likely be temporary in nature. Temporary barriers could arise through temporary levee construction to support other infrastructure construction, including road, rail and conveyor crossings and the Sapling Creek stream diversion. Permanent barriers might only arise if creek crossings are poorly designed and resemble that adjacent site AC-1, for example. Under the *Fisheries Act,* construction of waterway barrier works, such as road crossings, pipeline crossings and culverts that limit fish stock access and movement require a developmental approval under the *Sustainable Planning 2009 Act* assessed against the relevant provisions of the Fisheries Act. This development application process is likely to ultimately provide for appropriate creek crossing construction.

Given their likely temporary nature and the fact that none of the fish species present in the study area are obligate migratory species, such barriers are likely to have minimal impact on the resident fish community.

4.1.1.5 Runoff or Chemical Spillages during Construction

Earthworks associated with the construction phase have the potential to result in sediment mobilisation to waterways through direct disturbance to bed and banks, runoff from stockpiled material or the clearing of vegetation near waterways. While some of the resident fish species in receiving waters have been demonstrated in this study to tolerate very high turbidity in the short term, there are a number of pollution-sensitive macroinvertebrate species present that could be detrimentally affected by such impacts. Hence, they are to be avoided wherever possible. The key mitigation actions to counter such impacts include:

- Wherever practicable, avoid construction works near streams. If possible a buffer of at least 100m from the banks of waterways should be maintained;
- Where the avoidance of construction works in, near, or adjacent to streams is not practicable, these works should be performed during the dry season. If exposed soils cannot be rehabilitated prior to the wet season, appropriate barriers to reduce sediment transport (e.g. silt curtains) should be installed well before significant rainfall occurs. Such measures must be adequate to cope with the very heavy rainfall events experienced at the site;
- Where possible, carry out construction in stages such that cleared areas can be rehabilitated quickly while construction progresses;
- Stockpiled excavated earth material should be kept well away from waterways and bunded such that runoff does not enter the waterway, but is captured in a temporary storage reservoir and either treated or removed from site; and
- The use of vegetation such as grasses and macrophytes as sediment filters should be considered where practicable. Where this is not practicable, geotextile, rip rap and stabilisation techniques should be considered.

Apart from the potential for increased sediment mobilisation, chemical spills could arise through traffic accidents or through chemicals not being stored appropriately. Those spills would most likely involve grease and oils and, in most cases, spills would be small and localised, such that minimal environmental harm occurs. However, there is a slight chance that large spills could occur or that other toxic chemicals could be involved. To reduce the risks of such spills and their associated impacts:

- Current best practice for the management of fuels, oils and chemicals on site must be adhered to at all times;
- All chemicals should be stored appropriately in a secure area with MSDS for each chemical stored and spills kits made readily available in that area;
- Construction staff to be trained in how to use spill kits to contain spills;
- All spills are to be reported, no matter how minor, and the impacts and reasons for their occurrence investigated. In the event of fuel, chemical or oil spills outside of bunded areas the material must be contained to prevent transport into waterways. Removal and secure disposal of contaminated soils and rehabilitation of exposed soil should be performed;
- All chemical loads are to be properly secured during transport and MSDS sheets for each are to be stored with the transport vehicle. Checks should be made before loading which chemicals can be stored with which; and
- Safe driving and general safe work practices should be applied when transporting chemicals. It is assumed that random drug and alcohol testing would be applied to all staff on site, including drivers of chemical transport and earthworks vehicles.

4.1.1.6 Alteration of Stream and Floodplain Hydrology

The construction of the mine pits, on-site water management infrastructure and the stream diversion channel will alter the local hydrology. The Sapling Creek stream diversion will result in the creation of entirely new aquatic habitat within the footprint area. Rainfall on the mine site that would otherwise flow directly into creeks will be retained in the surface water management infrastructure and only released periodically when either the quality of that water or the flow volumes in the receiving waters are suitable. This could result in reduced flows downstream, which in turn, could reduce aquatic ecosystem functioning in affected reaches and/or create greater habitat fragmentation of stream habitat in such reaches. The lower reaches of Sapling Creek and the lagoon adjacent Alpha Creek are the most vulnerable to such effects. While these waterbodies are ephemeral and are dry for much of the year, they do represent refugial habitat and, in the case of the lagoon, uncommon habitat within the study area. Comprehensive surface water and groundwater assessments have been undertaken for the SGCP by WRM and Heritage Computing / Geoaxiom respectively. Minimal impacts are expected to occur as a result of altered stream and floodplain hydrology associated with the Project. However, this prediction is based on first principle theory only, not hydrological modelling. It also does not take into account the role of groundwater hydrology in sustaining the potentially affected waterways and how that might be influenced by pit and underground mine construction.

4.1.1.7 Fauna Mortality

There is a potential for semi-aquatic fauna such as turtles to be killed accidentally during riparian vegetation clearing or during instream works. Those associated with isolated pools are most at risk due to their inability to move quickly into alternate habitat during construction. While no turtle species of conservation significance occur in the Project area, mortalities associated with construction still have the potential to reduce the local populations of the species present.

Cann's Long-necked Turtle and Snake-necked Turtle are known to undertake long, overland migrations for nesting and in response to habitat degradation (Cann, 1998 *In* GHD, 2010) and may wander unwittingly into construction areas. In addition, the increased traffic in the Project area could result in an increased frequency of turtle road kills.

To reduce such impacts:

- A turtle spotter should be deployed during any construction near waterways so that turtles spotted can be captured and removed temporarily from site while construction is underway;
- Construction areas should be fenced where practicable, so that turtles are excluded from accessing those areas;
- Develop an aquatic fauna relocation plan that describes the appropriate relocation methodologies for each turtle species; and
- Reduced speed limits should be put in place near waterways and staff trained to look out for turtles in order to reduce road kills.

4.1.2 Operation Phase

The key activities associated the operation phase of the SGCP include:

- Pit excavation and dewatering;
- Underground mining;
- Processing, handling and transport of ore material; and
- Managing water on-site.

The potential impacts associated with these activities and the mitigation options recommended for reducing the risks of those impacts are discussed below.

4.1.2.1 Releases of Mine Water

Various surface water management components are proposed to collect and store mine runoff and water from pit dewatering. Surface water management infrastructure will be designed to contain and manage runoff from a 1 in 1,000 year rainfall event. The quality and release of any water within SGCP water management infrastructure will be managed in accordance with the Environmental Authority for the SGCP.

A network of monitoring sites and a sampling regime should be set up under a Receiving Water Monitoring Program (REMP) before mine operation commences. This would allow 'baseline' data to be collected for comparison with post-operation phase data as part of the auditing process. Physico-chemical water quality parameters should be continuously logged at gauging stations upstream and downstream of the release point (or in an unaffected adjacent catchment of similar nature no upstream reaches are available). Results of water quality monitoring should be interpreted by comparison with relevant guidelines, or the trigger levels set out in the EA. In order to obtain sensible trigger levels for some of the water quality parameters that, based n the results of this study, are likely to meet guideline criteria, it is recommended that, eventually when there are sufficient data available, the ANZECC & ARMCANZ (2000) guidelines is used as a basis for developing local water quality objectives for the Project area.

4.1.2.2 Coal Dust Emissions and Spills During Haulage

There is the potential for coal dust emissions to enter and contaminate waterways, particularly with respect to heavy metals (Swer and Singh, 2003 *In* GHD, 2010). This could have a negative impact on aquatic fauna if levels reach a sufficient level. However, GHD (2010) summarise the results of studies that have found that coal dust is generally confined to a small area either side of haul tracks and, as such, waterways are less likely to be contaminated by coal dust during transport. To further limit the potential for coal dust contamination of waterways:

- An Air Quality Management Plan should be developed and implemented;
- Covered coal wagons should be used where practicable to minimise the loss of coal particles during transport;
- Ballast bridges should be constructed over waterways so that the risk of direct inputs of coal dust is reduced;

- Train wagons should not be overloaded;
- Train wagons should be washed regularly;
- Undertake best practice coal loading and unloading procedures;
- Train operators to operate in accordance with procedures in the Air Quality Management Plan; and
- An Erosion and Sediment Management Plan should be developed that incorporates a section on reducing the runoff of coal dust into waterways. This should outline how coal dust from the CHPP is to be contained and treated.

4.1.3 Subsidence

Underground mining has the potential to result in the subsidence of stream bed and banks. The main streams potentially affected within the Project area are low order streams that are of limited value to aquatic flora and fauna in terms of habitat. However, slumped bed and banks in these creeks may lead to high levels of sediment mobilisation into Tallarenha and eventually into Alpha Creek. This could have severe impacts on aquatic fauna and habitat quality in those systems. Advice from North Moranbah Mine staff who deal regularly with underground coal mining and subsidence issues is that the risks of subsidence is greater the closer underground mining is to the surface. There are no industry standard methods for managing subsidence issues associated with underground mining in Australia, but North Moranbah Mine have adopted mitigation strategies used successfully at Goonyella Mine, which might be applicable to the SGCP. These include pre-ripping of the surface prior to underground mining, which reduces the scale of subsidence should it occur, and inserting pylons immediately downstream of where subsidence occurs to act as groynes to divert sediment runoff from downstream reaches.

4.1.3.1 Proliferation of Pest Fauna

As noted in this study, noxious fish species (e.g. Tilapia) already occur in the study area and have a high propensity to spread. Tilapia are an aggressive species when nesting and also consumes macroinvertebrates that native species might otherwise eat. Noxious species such as Tilapia often do better compared to native species under degraded habitat conditions. As above, the SGCP has the potential to degrade the aquatic ecosystems in the study area in a number of ways, if not properly managed. While there is no feasible way of controlling Tilapia abundance or spread directly once they are established, AMCI should at least minimise the risk of aquatic environment degradation a much as possible through the mitigation measures identified above so that tilapia are not favoured over native fish species. The location and spread of Tilapia should continue to be monitored during the life of the mine as part of the Weed and Pest Management Plan.

4.2 Cumulative Impacts

Cumulative impacts refer to the potential for SGCP operations to contribute to the sum of emanations from all mines, agricultural or industrial activities in the catchment. There are a number of proposed coal mines in the study region including Alpha Coal Project, Galilee Coal Project; Carmichael Coal Project;

Kevin's Corner Coal Project and the Macmines Coal Project. In the context of the aquatic environment, there are two potential contributions that these mines may make to local and regional impacts:

- Altered catchment hydrology, with associated ecological and fluvial geomorphological implications; and
- Reduction in water quality in the downstream environment, with associated ecological and social implications.

All mines are within the Belyando River catchment and cumulatively cover a relatively large percentage of the upper tributaries of this river. The proposed mining operations within the area operate in similar ecological areas (ephemeral creeks and drainage paths) within the Belyando River catchment. There is the potential for cumulative effects of all these mines impacting upon the Belyando River at a local level. In periods of high flow, where runoff from these mines cannot easily be contained, combined runoff impacts could potentially extend into the Burdekin River and beyond to coastal lagoons of the Great Barrier Marine Park. As such, EMP guidelines should ensure mine operations minimise impacts to waterways by managing potential for any waterway contamination, especially during periods of river flow. This may require sediment pond design and construction catering for extreme event floods as well as undertaking best practice on-site mine wastewater management. At 35,720km^2, the Belyando River is the second largest sub-catchment of the Burdekin River Catchment (130,000km^2). As such the potential for regional cumulative impacts to impact on the Great Barrier Reef, if managed within defined EMP guidelines, are expected to be minimal.

4.3 Groundwater Dependent Ecosystems

4.3.1 Stygofauna

A total of 22 groundwater bores were sampled for stygofauna in the 2011 post-wet season, however, no stygofauna were recovered from any of the bores sampled. The bores sampled in this study have potential to contain stygofauna based on the current SWL and generally high water quality and deserve a substantial sampling effort in order to be able to conclude with some certainty about the presence/absence of stygofauna within the SGCP area. Recent sampling by ALS (*unpublished*) within the Galilee Basin to the north of the SGCP has recovered stygofauna, so based on this experience, the SGCP MLA is considered to be prospective for the presence of stygofauna.

The absence of stygofauna from the SGCP groundwater bores may be due to unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality (e.g. toxicants) or sampling from a recently drilled or recently disturbed bore that has yet to stabilise and attract stygofauna. Replicated sampling across two seasons is also a requirement in the WA Guidelines (2003 and 2007) to account for the generally high spatial and temporal variability of stygofauna both within and between bore holes. ALS believe that due to the suitability of the SGCP groundwater for inhabitation by stygofauna, a second round of stygofauna sampling during the post-wet season 2012 should be conducted.

Based on a second round of sampling in the 2012 post-wet season there will be two possible outcomes:

(a) If no stygofauna are recovered from a second sampling event then it should be concluded (based on two comprehensive sampling events) that stygofauna do not occur within the SGCP MLA, and on that basis, should not be considered a relevant environment factor. No further sampling would be recommended.

(b) If stygofauna are recovered from a second sampling event then based on the conservation significance and ecological requirements of the animals collected, the objective should be to maintain the abundance, diversity, geographic distribution and productivity of stygofauna at species and ecosystem levels through avoidance or management of threatening processes.

4.3.1.1 Factors that Threaten Stygofauna

Mining proposals, where stygofauna are considered to be a relevant environmental factor, need to be closely assessed with respect to the extent of the proposed groundwater drawdown zone and the likely impacts on groundwater quality. Both of these activities, over time, may cause prospective stygofauna habitat to be degraded or lost with the potential for significant impact on groundwater communities.

Mining operations incorporate a range of water affecting activities in their operations, that have the potential to cause some degree of change in natural water regimes, including some or all of the following (SKM, 2010):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- Desalination for potable supply (with subsequent brine disposal);
- Dust suppression;
- Seepage;
- Tailings disposal;
- Rock storages;
- Backfilling and rehabilitation works;
- Water diversions and surface sealing;
- Hazardous and dangerous goods storage; and
- Water storages including waste water ponds.

In recognition of the above mining activities, direct effects on GDE's may be as follows:

- Quantity (groundwater levels, pressures and fluxes);
- Quality (concentrations of salts and other toxic water quality constituents);
- Groundwater interactions (interactions between groundwater systems and between groundwater and surface systems); and

- Physical disruption of aquifers (excavation of mining pits and underground workings).

The existence and extent of these water affecting activities, and their potential impact on local to regional scale groundwater resources and subsequently on GDE's (and stygofauna in particular) will depend largely on the scale of the SGCP mining operation, mining method, and process water requirements, as well as the climatic and geological setting.

4.3.1.2 Implications of Threatening Processes

Water Resources

Water resources might be influenced by mining activities in two important ways, namely (a) aquifer storage depletion (e.g. groundwater pumping or evaporative discharge); and (b) aquifer storage enhancement (e.g. as a result of seepage from mine facilities such as water ponds and tailings storages). Through aquifer storage depletion (water table decline) the natural water regime may be influenced by the SGCP mining operation with subsequent detrimental impacts on stygofauna (which are obligate groundwater dependent animals). This has become a particular issue for mining proponents over the last decade, principally because of their perceived biodiversity significance and the fact that little is known of their environmental water requirements.

Lithology and Soils

Geology and soil type will influence recharge (and seepage) potential as well as catchment yields. Some rock types can provide suitable capping material for tailings and rock storages and have a beneficial impact on stygofauna by protecting impacts on groundwater quality. Other rock types, however, can present hazards such as Acid Mine Drainage that may cause long-term impacts to surface water drainages if not managed properly. Significant changes to groundwater quality will impact detrimentally on stygofauna.

Mine Process

The SGCP will generate waste material through processing operations although coal mining does not have large treatment requirements for the beneficiation process when compared with some other commodity groups (e.g. precious metals). The waste stream from the mine process can have varying levels of contaminants (both native and added through beneficiation). The safe storage of these wastes during mine operations and post-closure will be an important consideration in protecting groundwater quality and managing potential impacts on stygofauna.

Mining Method

SGCP open cut mining operations will involve excavation below the water table and will require active dewatering using a range of procedures. The effect of these dewatering operations manifests itself as groundwater drawdown around the mine pits which may extend for large distances depending on mine life, target depth of dewatering and aquifer hydraulic parameters (permeability and storage). If stygofauna are recovered from the SGCP MLA following a second round of sampling in 2012 it will be important to assess the location and distribution of these stygofauna against the aquifer from which they originated and the forecasted drawdown zone (zone of impact) over the life of the mine. A rapid decline in the water table would be detrimental to stygofauna, however, laboratory research has shown that stygofauna can cope with a small and slow decline in aquifer storage. Evaporative losses of water and concentration of salts in the SGCP mine pit extending below the water table is also something to consider post mine closure.

Mine Maturity

The SGCP is a greenfield mining operation that will take place within a variety of groundwater regimes most of which will have been impacted to some degree by agricultural activities. Establishing a baseline prior to the commencement of operations is important in order for the mine to gauge the effects of its operations on existing groundwater conditions through the construction and operation phases. In order for ALS to determine if stygofauna should be considered a relevant environment factor in the SGCP EIS, a second round of sampling is recommended for the 2012 post-wet season.

4.3.1.3 Cumulative Effects

In relation to mining, cumulative effects can arise from:

- The compounding effects of a single mining or processing operation;
- Interference effects between multiple mining and processing operations; and
- Interaction between mining and non-mining activities.

Cumulative effects may result from a number of activities interacting with the environment. The nature and scale of these effects can vary significantly, depending on factors such as the type of activity performed, the proximity of activities to each other and the characteristics of the surrounding natural, social and economic environments (Brereton and Moran, 2008). They may also be caused by the synergistic and antagonistic effects of different individual activities, as well as the temporal or spatial characteristics of the activities. Importantly, cumulative effects are not necessarily just additive (SKM, 2010).

For the SGCP, quantification of the direct cumulative effects of mining on the region's groundwater systems will need to be considered, particularly the potential for mine water affecting activities to impact on:

- Groundwater quantity (i.e. alteration to groundwater levels and fluxes);
- Groundwater quality (i.e. alteration to regional salinity levels and concentrations of other important toxicants);
- Groundwater – surface water interaction (i.e. reduction to levels of interaction between groundwater and surface systems e.g. reduced baseflow to streams, reduced recharge of aquifers and a reduced water table depth); and
- Physical disruption to aquifers (i.e. will the SGCP contribute to the permanent disruption of a groundwater system).

All of the above cumulative effects impact on groundwater quantity and quality and ultimately on obligate groundwater dependent fauna (stygofauna).

On the basis that stygofauna are recovered following a second sampling event in 2012 it is recommended that an annual stygofauna monitoring program be implemented during the operational phase of the SGCP mine as well as through the closure phase to assess long-term impacts and to inform management plans.

4.3.2 Hyporheic Fauna

No hyporheic faunal samples were collected as part of this project as no true hyporheic zone exists within Sapling Creek at the locality chosen for sampling. Further hyporheic sampling is not recommended.

4.3.3 Troglofauna

The invertebrates collected with the troglofauna traps included oligochaete and nematode worms, oribatid mites, and several beetles. It was not possible to identify the fauna to species given the poorly known taxonomy for all of these groups in Queensland. However, all of the taxa are commonly encountered in soil communities and this is likely to be the origin of the animals collected during the survey carried out as part of this study. Bore entrances were close to the land surface, so fauna were likely to have entered the bore through these. Several months before sampling, there was heavy rainfall and flooding in the SGCP area. Overland flow entering the boreholes could also have washed soil fauna into the bores.

Troglofauna are unlikely to occur in the SGCP area, but if they were present, it would probably be in the void spaces of unconsolidated sediments overlying the Permian strata. As all boreholes are cased (and unslotted) for the top 47m of the vertical profile, access to this part of the stratigraphy was not possible. It is recommended that if further investigations be conducted with regards to this faunal group, the bores sampled should be designed specifically with troglofauna sampling in mind.

DERM requires project proponents to follow the Western Australia Guidance Statements 54 and 54a (EPA 2003, 2007), which recommend two rounds of sampling for a total of 60 samples in areas known to have diverse troglofauna communities. However, in areas where the chance of troglofauna is low, allowance is made for fewer samples to be collected. The Permian geology in the SGCP area contains no known voids or sufficient fractures suitable for troglofauna, so it is unlikely that the site supports a diverse subterranean terrestrial fauna. The lack of troglofauna to date and the unfavourable habitat conditions present suggests that a significant troglofauna community does not exist within the SGCP and is therefore not considered to be a relevant environmental factor in the SGCP EIS. No additional sampling of troglofauna in the SGCP area is recommended or warranted.

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