Appendix J

Aquatic Fauna Study
prepared by Dave Wilson and Steve Brooks

Environmental Impact Statement for the proposed Trans Territory Underground Gas Pipeline

Aquatic Fauna Study

Prepared for: Alcan Engineering Pty. Ltd.

Prepared by: Dave Wilson and Steve Brooks for EcOz Environmental Services

Skua Nominees Pty. Ltd. T\A
EcOz Environmental Services

ABN 59 009 613 030

Street address:1st Floor Arkaba House, 13 The Esplanade
Postal address: GPO Box 381 Darwin NT 0801
Phone: (08) 8981 1100
Fax: (08) 8981 1102
Email: ecoz@ecoz.com.au

Skua Nominees Pty. Ltd. T\A
EcOz Environmental Services

ABN 59 009 613 030

Street address:1st Floor Arkaba House, 13 The Esplanade
Postal address: GPO Box 381 Darwin NT 0801
Phone: (08) 8981 1100
Fax: (08) 8981 1102
Email: ecoz@ecoz.com.au

Environmental Impact Statement for the proposed Trans Territory Underground Gas Pipeline

Aquatic Fauna Study

Document Number 77606-700-024

Prepared for: Alcan Engineering Pty. Ltd.

Prepared by: Dave Wilson and Steve Brooks for EcOz Environmental Services

DOCUMENT CONTROL	
Project number:	Wood0302
File ref:	Z:\OldServer\Documents\ecoz_projects\WOOD0302\03 Flora & Fauna\Flora Report\Drafts\R001 TTP Aquatic Fauna Report_FINAL.doc
Report by:	David Wilson, Steve Brooks
Reviewed by:	Stephanie Myles, Kylie Harvey
Final Review:	Noel Preece
Date:	8th November 2004
Document distribution:	Ceri Morgan (1 x digital copy) Stephen Ley (1 x digital copy) Una Phelan (1 x digital copy)

Reliance Statement

(1) This report:

(a) is for the benefit of and may be relied upon by:

(i) Alcan Inc. and each Related Body Corporate of Alcan Inc. (each an "**Alcan Group Company**"); and

(ii) Woodside Energy Limited or Eni Australia BV; and

(iii) each company engaged by any one or more of an Alcan Group Company, Woodside Energy Limited or Eni Australia BV,

for the Purpose (each such company being an "**Authorised Entity**"); and

(b) may be disclosed, to the extent required for the Purpose, to the directors, officers, employees, agents and advisers of an Authorised Entity.

(2) This report is provided on the understanding that Alcan Inc and Woodside Energy Ltd will provide EcOz Environmental Services with details of each Authorised Entity to whom this report has been made available within a reasonable period of time after receiving a written request from EcOz Environmental Services requesting those details.

(3) For the purposes of paragraph (1) above:

(a) "**Purpose**" means:

(i) in relation to an Alcan Group Company, purposes related to the development and implementation of any of the Gas Supply Project, the Gas Transportation Project, the Gasification Project or the Expansion Project including, without limitation in relation to any such project, obtaining advice, goods and services;

(ii) in relation an Authorised Entity other than an Alcan Group Company, for the purposes of providing advice, goods and services of any kind to an Alcan Group Company directly related to any of the Gas Supply Project, the Gas Transportation Project, the Gasification Project or the Expansion Project.

(b) "**Related Body Corporate**" has the meaning given to that term in Section 50 of the Corporations Act.

(c) "**Gasification Project**" means the project to convert the primary energy source for Gove Operations from oil to natural gas.

(d) "**Gove Operations**" means the alumina refinery operations of the Alcan Group of Companies in Nhulunbuy (Gove) in the Northern Territory.

(e) "**Expansion Project**" means the project to expand the alumina production capacity of the Gove Operations.

(f) "**Gas Supply Project**" means the project to acquire a long-term supply of natural gas for delivery to the Gove Operations.

(g) "**Gas Transportation Project**" means the project to develop a natural gas pipeline to transport natural gas to the Gove Operations.

EXECUTIVE SUMMARY

EcOz Environmental Services has been contracted by Alcan Engineering to undertake a study of the aquatic fauna in rivers and creeks proposed to be crossed by the Trans Territory Pipeline (TTP) project. The TTP will traverse 940 km in an east-west direction across the Top End of the Northern Territory. The pipeline will transport gas brought ashore near Wadeye from the Blacktip gas field to the Alcan Alumina Refinery on the Gove Peninsula in north-eastern Arnhem Land. Environmental assessment of the proposed TTP project requires an investigation of aquatic fauna that occurs, or is likely to occur, in rivers and creeks to be crossed by the proposed development.

Within this report, species are considered as being of conservation significance if they are listed under the *Environment Protection and Biodiversity Conservation Act 1999* or the *Territory Parks and Wildlife Conservation Act 2000*. Further legislation that may or may not be applicable to the activities carried out during construction of the pipeline include the *Water Act 2004* and the *Fisheries Act 2004*.

Methodology

Aquatic fauna surveys were conducted at 21 sites on 17 waterways that will be crossed by the proposed pipeline. The Katherine and Daly Rivers were not surveyed as the aquatic fauna in these rivers is well recorded. Twelve of these were surveyed in 2003 and nine were surveyed in 2004. The purpose of the surveys was to:

- Ascertain what species are present in the river and creek systems that are to be crossed;
- Gain a wider understanding of the aquatic environments to be crossed by the pipeline so that the potential impacts can be assessed and appropriate management practices can be implemented to mitigate potential impacts; and
- Identify any threatened aquatic species along the pipeline route that require special protection.

A desktop literature review was also conducted using records from the Museum and Art Gallery of the Northern Territory, Australian and New Guinea Fishes Association, NT Parks and Wildlife Service Threatened Species Information and the *EPBC Act 1999* online database.

Results

A total of 50 species representing 23 families were recorded during the field surveys. A further 13 species from four families (not recorded during the survey) were identified from the records of the NT Museum and Art Gallery and in Midgley (1980) and Midgley (1983). Eight of these were recorded only from the Daly system which was not sampled as part of this survey. A total of 63 species comprising 27 families are known from the aquatic systems that will be crossed by the proposed TTP pipeline.

The family Eleotridae (gudgeons) was represented by more species (seven) than any other recorded, followed closely by the grunters (family Terapontidae), the fork tailed catfish (family Ariidae) and rainbowfish (Melanotaeniidae) which were each represented by six species.

Habitats of significance

Across the Top End, aquatic ecosystems, and riparian zones in particular, are generally considered to be in good or fairly pristine condition with the main threatening processes being feral animals, grazing pressure and introduced weeds (Dept of Environment and Heritage web site [online] Australian Natural Resources Audit).

Perennial lagoons are crucial habitats for some species of fish, which require aquatic vegetation as well as providing important refuges in dry seasons and breeding grounds prior to floods (Herbert *et al*. 1995). Lagoons are crucial as refuges in the middle and upper reaches and are also known to harbour the complete diversity of aquatic plants in a catchment.

The Cato River is significant as it recorded the highest species diversity of the surveyed rivers and it yielded two fish species not previously recorded from the Northern Territory and a threatened amphibian species. These species were all recorded from swamps within associated monsoon rainforest patches at the study site. It is likely that other rivers within North Eastern Arnhem Land such as the Giddy, Goromuru and Habgood Rivers, will yield similar and additional new species with further sampling, extending the known ranges of many fish species in the Top End of the NT. Particular emphasis should be placed on areas that are surrounded by monsoon forest. The habitat of both the Daly and Katherine River systems would also be considered significant not only because of the high level of species diversity recorded from these rivers, but also the sheer size and volume of water that flows down this system.

Extensive coverage of the aquatic plant *Hanguana malayana* was observed along the banks and across the surface of the water into the Habgood River. This macrophyte was not observed on any of the other waterways and created a complex habitat over some quite deep water. The Gulf Saratoga *Scleropages jardinii,* which has a preference for habitat with overhanging vegetation, was extremely common at this site, most likely as a result of this habitat.

Species of significance

This survey was notable with the discovery of species previously not recorded from the Northern Territory, significant range extensions for several species, and some other yet undescribed species. The Aru Gudgeon *Oxyeleotris aruensis* located in the Cato River was a range extension known previously only from Aru Island near Southern New Guinea and the eastern side of the tip of Cape York, Queensland. Two further species of gobies were collected in the Cato River that were previously not recorded from the region. One has since been identified as *Glossogobius concavifrons* by MAGNT (Helen Larson pers. comm.). This species has previously been known from the Fly-Strickland system of Papua New Guinea and the northern region of Cape York Peninsula (Allen 1991). The second species of goby is an undescribed species of *Glossogobius* known commonly as Munro’s Goby or *Glossogobius sp 2* (Allen *et al*. 2002). The observation of the Freshwater Whipray *Himantura chaophraya,* also in the Cato River, represents the first record of this species in Arnhem Land. This species was previously only recorded from South Alligator and Daly Rivers in the NT (Midgley 1980; Allen *et al.* 2002). Further range extensions were recorded for the Exquisite Rainbowfish *Melanotaenia exquisita* in Dook Creek, Butler’s Grunter *Syncomistes butleri* in the Goyder River and Rocky Bottom Creek, the Primitive Archerfish *Toxotes lorentzi* in the Moyle River and Tom Turner Creek and the Penny Fish *Denariusa bandata* in Tom Turner Creek.

Potential impacts and mitigation measures

The following table provides a summary of the potential impacts of the pipeline project on aquatic fauna and aquatic habitats as well as recommended management practices to minimise any potential impacts.

Action	Potential Impact	Mitigation recommendations
Clearing of riparian vegetation	• Increased erosion, scouring and changes to channel morphology. • Increase in nutrient loadings and light penetration. • Increased proliferation of weeds. • Loss of species dependent on riparian habitat for shelter, breeding or feeding.	• Minimise the circumstances where excavation is carried out in water bodies or within riparian zones. • Remove the absolute minimum vegetation required and carry out clearing activities as early in the dry season as possible. • Hand clearing of bank slopes. • Minimise clearing of the outer bank. • Adhere to guidelines for the control of erosion and sedimentation at construction sites and NT soil conservation guidelines. • Rehabilitation works should be completed as soon as practical after disturbance.
Manufacturing processes and human activities	Impacts on water quality may include: • Increased in-stream water salinity. • Nutrient enrichment and eutrophication. • High water turbidity and siltation. • Pesticide contamination. • Localised heavy metal pollution.	• Design and implement a water monitoring program based on the ANZECC 2000 guidelines. • Design and construct fuel and chemical storage and wastewater treatment facilities to comply with Australian regulations and ensure they are located away from any

Action	Potential Impact	Mitigation recommendations
	• Increased acidity of inland waters. • Cold-water pollution. • Increased siltation may result in smothering of riffle areas, fish eggs and macrophytes.	watercourses. • Discourage personnel from using personal toiletries in watercourses.
Pipeline laying and river crossings	• Fish passage. • Debris may block waterways. • Excessive flow through the low-flow pipe. • Inadequate flow depth over causeways. • Waterfall effect caused by excessive fall in water levels across a causeway or pipe outlet. • Sediment run-off from approaching road crossings.	• Conduct in-steam work during the driest part of the year and complete as soon as possible. • Remove any temporary infrastructure as soon as practical after completing the works. • Restore the streambed as near as possible to the original condition. • Avoid crossing waterways at riffle zones or near sharp bends or sections of unstable channel. • Avoid crossing over meandering waterways. • Avoid works that may change the frequency or spacing of an existing pool-riffle system. • Avoid disturbances to sections of a channel that has been identified as an area of high conservation value or where threatened species occur. • Avoid removal of essential shade trees. • Conduct a site assessment at each proposed crossing to decide on the appropriate crossing type. • Follow the recommended construction practices for the chosen crossing types.
Hydrostatic testing of the pipeline	• Translocation of fish species or other aquatic organisms. • Introduction of diseased organisms • Offence under the *Fisheries Act* if water is translocated from one waterbody to another.	• Dispose of wastewater from hydrostatic testing in accordance with regulatory and Traditional Owner requirements. • Water drawn from marine sources should only be disposed of to an ocean outfall. • Surface water should be sterilised before release into another catchment. It should not be released into another watercourse.

Many aspects of the biology and ecology of native fishes are poorly known and nearly all the threatening processes are inadequately understood (Wager and Jackson 1993). The Freshwater Sawfish *Pristis microdon* is a diadromous species that typically occurs in the tidal areas of the large tropical rivers where high sediment loads are present as a result of the large tidal movement (Allen *et al.* 2002). Increased sediment loadings or minor changes in water chemistry as a result of the construction and operation of the TTP is anticipated to have little impact on this species. However, barriers to movement such as stream crossings, poorly designed culverts as well as gross water quality issues such as low dissolved oxygen levels present a much greater risk to this threatened species. Many of the species listed as data deficient could be similarly impacted upon by the above activities.

TABLE OF CONTENTS

TABLES

APPENDICES

ACKNOWLEDGEMENTS

Dr Helen Larson at the Northern Territory Museum and Art galleries for assistance with collection methods, collecting equipment acquisition and records from previous sampling studies.

Bernie Bostock for assistance sampling fishes on the King River and Bradshaw Creek.

Jim Dalton, Steve Tiffan and Paul Marriot for cooking good meals under difficult circumstances.

Nick Heijm, Anna Nolan, John Cook and Benedict Scambary for help with indigenous fish names and help with traditional owners knowledge about fishes.

Kevin Forbes and his sons for help with indigenous fish matters on the Wilton and Goyder Rivers.

Sambo Burra Burra for teaching us the Goyder River Song, the spangled perch song, the rainbird song and showing us the sacred trees at the Goyder River.

Aimee Brooks and Robyn Wilson for keeping home matters under control while their husbands were in the bush doing the field work.

1. INTRODUCTION

EcOz Environmental Services was contracted by Alcan Engineering Pty. Ltd. to undertake studies of the aquatic fauna in the areas proposed for development of the Trans Territory Pipeline (TTP). The TTP will traverse 940 km in an east-west direction across the Northern Territory transporting gas brought ashore near Wadeye from the Blacktip gas field to the Alcan Alumina Refinery on the Gove Peninsula in north-eastern Arnhem Land. An Environmental Impact Statement (EIS) is required to assess the potential impacts of the project and to develop environmental management strategies. This report on the aquatic fauna is intended to provide information to guide the assessment of potential impacts of the project, and will be included as a technical appendix to the EIS.

The assessment of aquatic fauna presented in this report is primarily concerned with documenting baseline information on the fish species that occur in the rivers and waterways that will be traversed by the proposed TTP route, and assessing the potential impacts of disturbance of these river and creek systems as a result of clearing riparian vegetation and tunnelling under the waterways to construct the pipeline.

The aquatic fauna study was undertaken to satisfy the requirements of the Guidelines and more specifically to provide baseline information to guide an assessment of the potential impacts of the proposal and the development of appropriate management strategies for the project. This report documents the findings of field surveys, consultations with traditional owners and reviews of existing information and databases, and identifies the potential effects of the TTP proposal on aquatic vegetation. Two freshwater fish specialists, Dave Wilson and Steve Brooks, undertook the field surveys and prepared this report.

2. STATUTORY OBLIGATIONS UNDER NT AND COMMONWEALTH LEGISLATION

The TTP proposal requires approval under the *Environmental Assessment Act* and *EPBC Act*. As part of this process the Northern Territory and Commonwealth Governments will set conditions of approval relating to the management of potential environmental impacts of the proposal. These conditions will be included in permit, lease or license conditions and in relevant management procedures (e.g. Environmental Management Plans) for the construction and operation of the project.

Other Northern Territory and Commonwealth legislation establishes statutory obligations for the protection of waterways and 'threatened' aquatic fauna. The implications of these Acts for the TTP proposal are briefly discussed below.

The proposal has been declared a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act* (*EPBC Act*) because it was considered likely to have significant impacts on listed threatened species and communities and listed migratory species. The proposal has also been declared as requiring assessment under the Northern Territory *Environmental Assessment Act*. The "Guidelines for Preparation of a Draft Environmental Impact Statement on the Trans Territory Underground Pipeline (Department of Infrastructure, Planning and Environment, January 2004)" detail the specific requirements of the EIS document that is to be prepared for the TTP proposal in accordance with Clause 8 of the Environmental Assessment Administrative Procedures of the *Environmental Assessment Act* and Chapter 4 Division 6 of the *EPBC Act*.

2.1. Territory Parks and Wildlife Conservation Act 2000

Threatened wildlife are automatically given a protected wildlife status under the *Territory Parks and Wildlife Conservation (TPWC) Act 2000*. Threatened species include those listed as either extinct in the wild, critically endangered, endangered or vulnerable. The *TPWC Act 2000* requires a person to apply for a permit to take or interfere with these species.

Several species of uncertain or threatened status may be present in the river systems to be traversed by the TTP including the Near Threatened Obbes Catfish *Porochilus obbesi*, 33 Data Deficient species and 23 species listed as Least Concern.

2.2. Environment Protection and Biodiversity Conservation Act 1999

The Australian Government mechanism for national environment protection and biodiversity conservation is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for:

- identification and listing of Threatened Species and Threatened Ecological Communities;
- development of Recovery Plans for listed species and ecological communities;
- recognition of Key Threatening Processes; and where appropriate
- reducing these processes through Threat Abatement Plans.

The *EPBC Act* establishes lists of nationally threatened species and ecological communities which are 'Matters of Environmental Significance' protected by the Act. A search of the *EPBC Act* Online Search Tool found that the vulnerable Freshwater Sawfish *Pristis microdon*, or suitable habitat for the species, may occur along the project route.

2.3. Water Act 2004

The *Water Act 2004* regulates the restriction of water flows within a waterway. The provisions of the *NT Water Act 2004* outline offences related to impeding water flows in a water way. The *Water Act* is an Act to provide for the investigation, allocation, use, control, protection, management and administration of water resources, and for related purposes. Persons are not permitted to obstruct the flow of water in a water way, take or use surface water except in accordance with a licence issued under the Act.

2.4. Fisheries Act 2004

If the construction of the TTP uses surface waters for road dust control or testing pipe pressures it will invoke the provisions of the *Water Act*. Water pumped from one catchment may be released in another thus inadvertently translocating organisms from one location to another. A translocation of "Aquatic Life" will be an offence against the provisions of the *Fisheries Act*.

3. METHODOLOGY

The methodologies used in the assessment of aquatic fauna for the TTP proposal were developed with the aim of adequately identifying and addressing the range of potential environmental issues associated with the proposal, and collating sufficient information to inform an assessment that satisfies the requirements of the Draft EIS Guidelines. Areas of potential interest, namely those waterways where the fish fauna have not previously been surveyed and where listed 'threatened' species may occur, were identified in consultation with the NT Museum. Field survey methodologies were developed to focus on establishing a baseline knowledge of the fish fauna that occur in these waterways. The survey methodologies were developed by the Curator of Fishes at the NT Museum and were provided to the NT Office of Environment and Heritage for review and comment prior to field survey work being conducted. The key data sources utilised in conducting desktop reviews, the methodologies employed in the conduct of field surveys and the limitations of our approach are discussed below.

3.1. Data sources

A desktop literature review and consultation was undertaken to identify the range of fish species, habitat types and environmental constraints present in the river and creek systems traversed by the proposed TTP route.

The main data sources reviewed were:

- Commonwealth Department of Environment and Heritage *EPBC Act 1999* online database (www.environment.gov.au) search. This database provides a list of species under the provisions of the *EPBC Act* that occur, or are likely to occur, in the project area.

- NT Parks and Wildlife Service Threatened Species Information http://www.nt.gov.au/ipe/pwcnt.

- Search of the Museums and Art Gallery Database and review of published and unpublished literature including other surveys and field work within the rivers of the Northern Territory.

- Search of the records of the Australian and New Guinea Fishes Association.

Last and Stevens (1994) was used for species identification and classification for shark and ray species. Allen *et al*. (2002) was used for all other freshwater fish species.

3.2. Field surveys

Surveys were conducted at 21 sites on 17 waterways that are crossed by the proposed pipeline route (**Table 1**). Twelve sites were surveyed in October and November 2003 whilst the remaining 9 sites were surveyed, once accessible after the wet season, in June 2004. The Katherine and Daly, the largest rivers crossed by the proposed TTP route were not surveyed because the aquatic fauna in these rivers is well known (Helen Larson pers. comm.).

The purpose of the surveys was to:

- Ascertain what species are present in the river and creek systems that are to be crossed;
- Gain a wider understanding of the aquatic environments to be crossed by the pipeline so that the potential impacts can be assessed and appropriate management practices can be implemented to mitigate potential impacts; and
- Identify any threatened aquatic species along the pipeline route that require special protection.

Table 1. Survey sites selected for aquatic fauna surveys along the proposed pipeline route.

Waterway	General Description of survey site	Latitude	Longitude
Mainoru River	Middle reach river with long quiet tree lined pools connected by short runs of faster water.	S13.95133	E133.96333
Krabakuk	Middle reaches of small seasonal creek, comprised of small drying waterholes. Rock and clay substrate. Tributary of Mainoru R.	S14.06662	E134.05246
Wilton River	Middle reach river with long wide pools connected by short sets of rapids.	S13.75333	E134.46000
Jasper Creek	Lower reaches, small pools connected by long slow runs, silt and boulder substrate.	S13.88600	E134.46150
Goyder River	Middle reach river with long wide tree lined pools connected by short sets of rapids.	S13.02800	E134.97667
Rocky Bottom Creek	Fast flowing stream with rock and sand substrate.	S12.90083	E135.01533
Barmgueikba Creek	A small fast flowing creek with some still pools between runs. Sandy substrate with some boulders.	S14.24900	E133.52767
Chambers River	Upper reaches of river surrounded with non-permanent waterholes. River contains small non-permanent waterholes. Muddy substrate with discoloured very turbid water. Flat plains with open woodland.	S14.53867	E133.31883
Dook Creek	Small stream dropping through low rock escarpment area onto flat plain. Boulders and sand substrate.	S14.47767	E132.97683
Maiwok Creek	Non-flowing small sandy creek with high banks flowing in a low hilly area. Flat black soil plains adjacent the creek.	S14.27817	E133.68400
King River	Long, wide deep pools with small fast runs at the ends. A substratum of sand and mud with the occasional boulder. Surrounded by low hills and open woodland.	S14.51017	E132.63500
Bradshaw Creek	A small stream with long pandanus covered pools ending with small rapids flowing through flat open woodland .	S14.49717	E131.34333
Tom Turner Creek	Long wide deep pools punctuated by small runs and swampy areas low gently sloping bank on flat open woodland.	S14.17317	E130.11417
Moyle River	A medium sized river with a moderate flow of clear water consisting of long pools ending in fast wide shallow sets of runs. The surrounding countryside is low rocky hills supporting open woodland.	S14.26867	E130.05400
Anopheles Creek	A small stream shaded by trees	S14.36300	E129.91913

Waterway	General Description of survey site	Latitude	Longitude
	flowing into small pools, one very large pool at sample site, approx 2 km long Flat open woodland with some grasslands nearby.		
Giddy River	A small river flowing across a sand substrate, a long deep pool at sample site but mostly narrow sandy river with a swamp upstream from site and another downstream from sample site.	S12.36330	E136.70960
Wonga Creek	Headwaters stream comprising of several large waterholes with fast water running over rock and waterfall approx. 3 metres high. Sloping ground with open woodland.	S12.45295	E136.57870
Cato River	Low hilly area with open woodland areas of monsoon forest along river at sample site. Long wide deep pools with wide shallow slow flowing areas between sandy substrate. Small swampy areas in the monsoon forest near river.	S12.41967	E136.38380
Richard River	A small upland stream with occasional long shallow pools with small runs and riffles. Running through open woodland with grass and sandpalm understorey plants.	S12.70038	E136.09697
Habgood River	Long deep pools with a sandy substrate punctuated by rocky barriers creating sets of rapids; the river flows through open woodland in sandy country.	S12.52405	E135.89987
Buckingham River	Short deep pools with an earthen substrate, plant-lined trickle at ends of the pools. The river flows through open woodland in low hilly sandy country.	S12.68638	E135.69038

3.2.1. Site selection

The waterways surveyed were selected following consultations with the Curator of Fishes at the NT Museum. Once in the field, local conditions and accessibility determined the actual site location on each of the waterways. Consultation with traditional owners or their representative was required at each site to ensure that no culturally sensitive areas were entered or disturbed during the surveys.

Sample sites did not necessarily correspond exactly with the proposed pipeline crossings. At times larger water bodies near the proposed crossing of the pipeline were selected if there were no major barriers to fish movement between the sample site and the crossing. These sites were identified as areas likely to contain the most number of fish species as well as the species of interest such as the Freshwater Sawfish and Freshwater Whipray.

3.2.2. Survey techniques

Survey site localities were recorded using a hand-held GPS. Water temperature, dissolved oxygen and conductivity were recorded by a YSI model 30 system, while pH was recorded using a TPS FL90 water quality meter as well as reagent test kits and alkalinity by an Aquasonic test kit. The maximum water depth was recorded for each site. Turbidity was recorded using a Secchi disk, or by observation. Each site was described with the nature of watercourse, substrate, banks and aquatic vegetation. Also, a photograph of each sampling site and a brief description of surrounding country was recorded (**Appendix 1**).

Sampling was undertaken by two people using a range of techniques which included: multi-panel gill-nets, fine-mesh seine, scoop-nets or push-nets, hook and line, dip-net and torch at night, and sight observations from the bank or by snorkelling. Each site was sampled for a day and night for accurate census of aquatic fauna, unless the waterbody was small and clearly not worthy of intensive sampling (e.g. a shallow creek). The existence of estuarine crocodiles in some waterbodies prevented snorkelling methods being used.

The two multi-panel gillnets are each 35 m long, with a drop of 2 m, and seven 5 m long panels each of a different mesh size: 26, 44, 58, 76, 100, 126, and 150 millimetres, knot to knot. The differing mesh sizes allowed sampling of a wide range of fish species and sizes (e.g. from small rainbow fish to adult barramundi). Wherever possible, the nets were set so that one was at a right angle to the bank, and one was parallel to the bank to capture fishes travelling down the centre of the waterbody as well as those moving along the bank close to shelter. The nets were tied or anchored and buoyed (working from a small dinghy) so that they remained stationary, and were left for approximately an hour in the afternoon, then re-set for another hour in the evening, with sunset occurring during the latter set, where possible. Gillnets were normally set for one hour, to prevent drowning any crocodiles and to minimise fish mortalities. The pattern and timing of deployment of the nets depended upon the topology of the water-body. Fish captured were identified, counted and released, with voucher material of each species being retained when possible. A permit from the Department of Business, Industry and Resource Development Fisheries Division was obtained to operate nets to collect samples (licence number 17901).

Sampling with push scoops was undertaken at each site through the in-stream habitat such as microphytes and undercut banks. Additional sampling with scoop nets and small aquarium dipnets was carried out at each locality at night. This enabled observation and capture of nocturnally active fish species such as eel-tailed catfish, and made capture of many other species less difficult.

Voucher specimens were euthanased with an overdose of anaesthetic then placed in a drum with formalin or 100% ethanol, preserved, labelled and deposited to the Museum and Art Gallery of the Northern Territory, Darwin (MAGNT), where they were sorted and their identification confirmed. They were then deposited as vouchers in the MAGNT reference collection. Specimens deposited in the collection will be registered, and habitat and physical data included in the MAGNT database.

Informal interviews with Traditional Owners and Pastoralists were conducted to ascertain their knowledge of species of fish that were present in the various rivers sampled. Field guides were provided to Traditional Owners to assist in the recognition of various species. The information gained from these interviews was used to supplement the information collected during the short survey periods and to identify species that are likely to occur in each waterway.

3.3. Assessment of conservation significance

The conservation significance of aquatic fauna was assessed with reference to the following:

- Species classified as ‘threatened’ and\or ‘protected’ in accordance with the *Territory Parks and Wildlife Conservation Act 2000*
- Species classified as ‘threatened’ in accordance with the *Environment Protection and Biodiversity Conservation Act 1999.*
- Near-threatened and regionally endemic species.
- Habitats of ‘threatened’ species and habitats with outstanding biodiversity values.

The conservation significance of aquatic fauna in the waterways crossed by the TTP route is discussed in **Section 5.**

4. RESULTS

4.1. Fishes

A total of 50 species representing 23 families were recorded during these surveys. A further 13 species from four new families (not recorded during the survey) were identified from the records of the NT Museum and Art Gallery and in Midgley (1980) and Midgley (1983). Eight of these were recorded only from the Daly system which was not sampled as part of this survey. Overall a total of 63 species comprising 27 families are known from the aquatic systems that will be crossed by the proposed TTP pipeline (**Table 2**).

The family Eleotridae (gudgeons) was represented by more species (seven) than any other recorded, followed closely by the grunters (family Terapontidae), the fork tailed catfish (family Ariidae) and Rainbowfish (Melanotaeniidae) which were each represented by six species.

Species diversity is dependent on a great range of factors including distance from the sea, size of river and catchment, permanency, habitat, water quality, presence of barriers to fish movement and season. Bishop and Forbes (1991) suggested that species diversity in monsoonal rivers varies dramatically over time, with species diversity in any one habitat decreasing as the dry season progresses. Given that these surveys were based on a single sampling event at a single site it is unlikely that all species likely to be present will be recorded. Herbert *et al*. (1995) considered that it would be unrealistic to expect that any survey group would catch all species of fish in a river system, as species composition varies diurnally and seasonally.

Museum records indicate that the Daly River, one of the largest and best-studied rivers in the NT, possesses the highest species diversity (49 species) of the proposed waterways to be crossed by the TTP. The waterway with the lowest number of species was the seasonal Krabakuk Creek, a tributary of the Mainoru River, where only two species of fish were identified. The highest number of species recorded during the actual surveys occurred on the Cato River with 24 species followed by 21 species on the Goyder River and 20 on the Habgood River. Though in stating this we must be careful to take into consideration the greater effort expended on both the Goyder and the Mainoru Rivers. Several days were spent at both of these sites awaiting the necessary approvals to continue.

This survey was notable with the discovery of species previously unrecorded from the Northern Territory, significant range extensions for several species and other yet undescribed species. The Aru gudgeon *Oxyeleotris aruensis* located in the Cato River was a range extension known previously only from Aru Island near Southern New Guinea and the eastern side of the tip of Cape York, Queensland. Two further species of gobies were collected in the Cato River that were previously unrecorded from the region. One has since been identified as *Glossogobius concavifrons* by MAGNT (Helen Larson pers. comm.). This species has previously been known from the Fly-Strickland system of Papua New Guinea and the northern region of Cape York Peninsula (Allen 1991). The second species of goby is an undescribed species of *Glossogobius* known commonly as Munro's Goby or *Glossogobius sp 2* (Allen *et al*. 2002). The observation of the Freshwater Whipray *Himantura chaophraya,* also in the Cato River, represents the first record of this species in Arnhem Land. This species was previously only recorded from South Alligator and Daly Rivers in the NT (Midgley 1980; Allen *et al.* 2002). Further range extensions were recorded for the Exquisite Rainbowfish *Melanotaenia exquisita* in Dook Creek, Butler's Grunter *Syncomistes butleri* in the Goyder River and Rocky Bottom Creek, the Primitive Archerfish *Toxotes lorentzi* in the Moyle River and Tom Turner Creek and the Penny Fish *Denariusa bandata* in Tom Turner Creek. This is discussed further along with species of significance in **section 5**.

Table 2. Fish species in waterways traversed by the proposed TTP route.

Scientific Name	Common Name	Moyle River	Anopheles Creek	Tom Turner Creek	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Bradshaw Creek	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Ambassis agrammus	Sailfin Glassfish				#				#									X			X		
Ambassis macleayi	Reticulated Glassfish				#	X		X		X	X	X		X	X		X			X		X	X
Ambassis muelleri	Western Glassfish				#	X		X	X		X			X	X								
Amniataba percoides	Barred Grunter	X	X		#	X		X	X	X	X	X	X	X			X	#		X		X	
Anodontiglanis dahli	Toothless Catfish				#	X			#			X			X								
Arius berneyi	Berney’s Catfish								#	X		#											
Arius graeffei	Lesser Salmon Catfish				#				#														
Arius leptaspis	Salmon Catfish				#	X			X	X	X									X			
Arius midgleyi	Shovel-nose Catfish				#							X			X	X	X						
Aseraggodes klunzingeri	Tailed Sole				#																		
Brachirus selheimi	Freshwater Sole				#			X															
Carcharhinus leucas	Bull Shark				#	*			#														
Cinetodus froggatti	Small-mouthed Catfish											#											
Craterocephalus stercusmuscarum	Fly-specked Hardyhead	X	X	X	#	X		X	X	X		X								X		X	X
Craterocephalus stramineus	Blackmast				#												X						
Denariusa bandata	Penny Fish			X	#															X			
Gerres filamentosus	Whipfin Silverbiddy																		X				
Glossamia aprion	Mouth Almighty	X	X	X	#	X		X	X	X	X	#	X	X	X	X	X	X	X	X		X	X
Glossogobius aureus	Golden Goby				#				#														
Glossogobius giurus	Flathead Goby				#	X			#	X	X	#				X	X						
Glossogobius sp. 1	Munro’s Goby																			X			

Scientific Name	Common Name	Moyle River	Anopheles Creek	Tom Turner Creek	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Bradshaw Creek	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Glossogobius concavifrons	Concave Goby																			X			
Hephaestus carbo	Coal Grunter									X	X							X	X	X		X	
Hephaestus fuliginosus	Sooty Grunter	X	X	X	#	X		X	#	X		X	X	X		X	X						
Himantura chaophraya	Freshwater Whipray				#															X			
Hypseleotris compressa	Carp Gudgeon				#													X					
Hypseleotris sp.	Katherine Gudgeon				#																		
Kurtus gulliveri	Nursery Fish				#																		
Lates calcarifer	Barramundi	X	X	X	#	X		X	X	X		X		X		X	X	X	X	X		X	
Leiopotherapon unicolor	Spangled Grunter	X	X	X	#	X		X	#	X	X	X	X	X	X	X	X	#	X		X	X	X
Liza alata	Diamond Mullet				#												X						
Lutjanus argentimaculatus	Mangrove Jack																	X					
Megalops cyprinoides	Ox-eye Herring	X	X	X	#					X				X	X		X	X	X	X		X	X
Melanotaenia australis	Western Rainbowfish	X	X	X	#											X	X						
Melanotaenia exquisita	Exquisit Rainbowfish				#							X											
Melanotaenia nigrans	Black-banded		X	X	#													X		X	X	X	X
Melanotaenia trifasciata	Banded Rainbowfish				#					X								X	X	X	X	X	
Melanotaenia splendida	Chequered Rainbowfish				#	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Mogurnda mogurnda	Purple Spotted Gudgeon	X	X	X	#	X	X	X	#			X	X	X			X	#	X	X	X	X	X
Nematalosa erebi	Bony Bream				#	X			X	X		#		X	X	X	X			X		X	
Neosilurus ater	Black Catfish	X	X	X	#	X				X	X	X						X	X	X		X	X
Neosilurus hyrtlii	Hyrtles Catfish	X	X		#	X			#			#	X	X	X	X			X		X	X	
Ophisternon gutterale	Swamp eel				#																		
Oxyeleotris aruensis	Aru Gudgeon																			X			
Oxyeleotris lineolate	Sleepy Cod				#	X		X	X	#		#											

Scientific Name	Common Name	Moyle River	Anopheles Creek	Tom Turner Creek	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Bradshaw Creek	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Oxyeleotris nullipora	Poreless Gudgeon																	X		X			X
Oxeleotris selheimi	Giant Gudgeon				#					X					X		X						
Pingalla midgleyi	Midgley's Grunter				#																		
Porochilus obbesi	Obbes Catfish				#																		
Porochilus rendahli	Rendahl's Catfish				#										X								X
Pristis microdon	Freshwater Sawfish				#	*			#														
Pseudomugil gertrudae	Spotted blue-eye			X	#													X		X		X	
Scatophagus argus	Spotted Scat				#																	X	
Scleropages jardinii	Gulf Saratoga					X				X										X		X	
Scortum barcoo	Barcoo Grunter								#														
Scortum ogilbyi	Gulf Grunter					X								X	X								
Selenotoca multifasciata	Striped Scat				#																	X	
Strongylura krefftii	Freshwater Longtom	X	X		#	X		X	X	X		#			X					X		X	
Syncomistes butleri	Butlers Grunter				#					X	X					X							
Thryssa scratchleyi	Freshwater Anchovy								X														
Toxotes chatareus	Common Archerfish				#	X		X	X	X	X	X	X	X	X	X	X			X			
Toxotes lorentzi	Primitive Archerfish	X	X		#																		

X Species recorded during field surveys

Species only recorded from river system in Museum records

* Landowners indicated presence in waterway but not recorded in current or previous surveys

4.2. Other aquatic fauna species

4.2.1. Crustaceans

Five species of crustacean were recorded during the surveys (**Table 3**). Two species of macrobrachium were not identified to species level during the survey. Voucher specimens for these were lodged with the Museum and Art Gallery of the NT for identification. At the time of preparation of this report these specimens remain unidentified.

Table 3. Species of crustaceans identified during surveys.

Common Name	Scientific Name	Locations Identified
Glass Shrimp	*Caradina sp*	Cato River Bradshaw Creek
Redclaw	*Cherax quadricarinatus*	Moyle River Anopheles Creek Tom Turner Creek Mainoru River Wilton River Goyder River Dook Creek
Cherabin	*Macrobrachium rosenbergii*	Mainoru River Dook Creek King River
Freshwater prawn	*Macrobrachium sp1*	Moyle River Anopheles Creek Tom Turner Creek Krabakuk Creek Goyder River Dook Creek Maiwok Creek Chambers River
Freshwater prawn	*Macrobrachium sp2*	Wonga Creek

4.2.2. Amphibians

The aquatic survey encountered eight species of amphibians (**Table 4**) including the Wood Frog *Rana daemeli* which is currently listed as vulnerable under NT legislation. *R daemeli* was identified at the Giddy and Cato River survey sites. The Cato River location represents a range extension for this species.

The introduced Cane Toad *Bufo marinus* was also identified at various locations and this is discussed further in **section 4.3**.

Table 4. Amphibian species identified during surveys.

Common Name	Scientific Name	Locations Identified
Northern Dwarf Tree Frog	*Litoria bicolor*	Dook Creek Giddy River
Rockhole Frog	*L. meiriana*	Dook Creek
Rocket Frog	*L. nasuta*	Wonga Creek Cato River Richard River Habgood River
Red Tree-frog (Desert Tree Frog)	*L. rubella*	Chambers River (sugar bag waterhole)
Wotjulum Frog	*L. wotjulumensis*	Dook Creek Giddy River Wonga Creek Cato River Richard River Habgood River Buckingham River
Unidentified sp.	*Crinia sp.*	Cato River Goyder River
Wood Frog	*Rana daemeli*	Giddy and Cato Rivers

4.2.3. Reptiles

Twelve species of reptiles were identified during the field surveys (**Table 5**). The Saltwater Crocodile *Crocodylus porosus*, which was spotted in the Habgood River and is likely to occur in all of the major waterways crossed by the pipeline route, is a listed migratory species and is protected under the *EPBC Act 1999*. The Pig-nosed Turtle *Carettochelys insculpta* is classified as Near Threatened under the NT legislation and Vulnerable under the IUCN Red List, and is currently proposed for listing as a threatened species under the *EPBC Act*. Although this species was not found during the surveys it is recorded from the Daly, Victoria, Alligator and possibly Roper River systems of the NT (Wilson and Swan 2003).

Table 5. Reptile species identified during surveys.

Common Name	Scientific Name	Locations Identified
Arafura File Snake	*Acrochordus arafurae*	Dook Creek
Brown Tree Snake	*Boiga irregularis*	Dook Creek
Skink sp.	*Carlia sp.*	Richard River
Freshwater Crocodile	*Crocodylus johnstoni*	Barmguerikba Creek Bradshaw Creek Wilton River Moil River Anopheles Creek
Saltwater Crocodile	*C. porosus*	Habgood River Cato River
Common Tree Snake	*Dendrelaphis punctulata*	Richard River
Two-lined Dragon	*Diporiphora bilineata*	Buckingham River
Northern Snapping Turtle	*Elseya dentata*	Mainoru Bradshaw Creek
Yellow-faced Turtle	*Emydura sp.*	Habgood River
Northern Red-faced Turtle	*Emydura victoriae*	Chambers River (sugar bag waterhole)
Gilbert's Dragon	*Lophognathus gilberti*	Maiwok Creek Chambers River (sugar bag waterhole)
Slaty-grey Snake	*Stegonotus cucullatus*	Anopheles Creek
Merten's Water Monitor	*Varanus mertensi*	Mainoru Barmguerikba Creek Wonga Creek

4.3. Introduced species

No introduced species of fish were found during the field surveys. No record of introduced fishes could be found at or from any of the study sites. There is a population of feral Guppies *Poecilia reticulata* and feral Platys *Xiphophorus variatus* (Axelrod *et al*. 1985) in the town billabong at Nhulunbuy which have been there since at least 1988 (Dave Wilson, personnel observation).

The Cane Toad *Bufo marinus* was common at all the study sites from east of the King River to the Giddy River. On the sample sites at Maiwok Creek there were several dead toads in various states of decay. Cane toad tadpoles were observed in a small swamp on the side of the Road a few kilometres east of the Mainoru River. According to the Mainoru Station owner, toads have been at that location for about five years since approximately 1999.

4.4. Aquatic flora

The ability of a waterway to support submerged aquatic plants depends on all the physical and biochemical properties that are necessary for plant growth being present under water. Some of the limiting constraints to submerged plant growth are physical such as low light caused by turbidity or thick streamside plant cover. Other limiting factors to plant growth can be chemical such as low amounts of carbon. The presence of inorganic carbon in the form of free dissolved carbon dioxide, carbonic acid, bicarbonates and carbonates influences submerged plant growth. Some species of local native aquatic plants such as Water Thyme *Hydrilla verticillata* have the ability to alter water quality by breaking the chemical bonds in calcium carbonate. This then drives the pH very high giving the species an advantage over other species such as *Eriocaulon setacean* that do not do well in water with a high pH (Cronk and Fennessy 2001; Sainty and Jacobs 1988; Boyd 1995).

Plant communities in submerged environments are divided into two basic categories, those that live in waters with a high amount of dissolved solids, such as the Daly and Mainoru Rivers, and those that live in waters with very small amounts of dissolved solids. The majority of the waters to be crossed by the proposed pipeline route fall into this latter category.

Some species of submerged aquatic plants are difficult to identify without the presence of flowers and seed and have only been identified to a Genus level (**Table 6**).

Table 6. Aquatic flora.

Waterway	Aquatic flora species identified
Mainoru River	*Chara sp* (algae), *Nitella sp* (algae), *Vallisneria nana* (ribbonweed), *Hydrilla verticillata* (water thyme, hydrilla), *Ottelia alismoides, Nymphaea violacea* (Blue flowering native water lily), *Triglochin sp* (water ribbons), *Schoenoplectus sp, Nelsonia campestris, Ceratopteris thalictroides* (native water sprite)
Wilton River	No submerged plants at sample site
Goyder River	*Aponogeton vanbruggenii* (NT lace plant)
Rocky Bottom Creek	*Vallisneria nana* (ribbonweed), *Nelsonia campestris, Limnophila brownii, Hygrophila angustifolia, Chara sp* (algae), Unidentified filament algae
Barmgueikba Creek	*Rotala occultiflora, Najas sp, Blyxa aubertii, Nymphaea violacea* (Blue flowering native water lily), *Limnophila aromatica, Hygrophila angustifolia*
Chambers River	*Nymphaea violacea* (Blue flowering native water lily), *Marselia drummondii* (rainbow nardoo), *Najas sp*
Dook Creek	*Nymphaea violacea* (blue flowering native water lily), *Nymphoides indica* (snowflake lily), *Limnophila brownii, Rotala occultiflora*
Maiwok Creek	No submerged aquatic plants at sample site
King River	*Nymphoides spongiosa, Microcarpaea minima, Limnophila brownii, Staurogyne leptocaulis, Vallisneria nana*

Waterway	Aquatic flora species identified
Bradshaw Creek	*Nitella sp* (algae)
Tom Turner Creek	*Limnophila fragrans*, *Eriocaulon setaceum*, *Nymphaea violacea* (blue flowering native water lily), *Fimbristylis sp*
Moyle River	*Myriophyllum sp* (water milfoil), *Limnophila chinensis*, *Nymphoides minima*, *Nymphaea violacea*
Anopheles Creek	Unidentified aquatic sedge species
Giddy River	*Blyxa aubertii*, *Limnophila fragrans*, *Chara sp.* (algae), *Eriocaulon setaceum*, *Utricularia fulva*, *Hygrophila angustifolia*
Wonga Creek	*Eriocaulon setaceum*, *Eriocaulon willdenovianum* *Chara sp* (algae) *Limnophila fragrans*
Cato River	*Nymphaea violacea* (blue flowering native water lily), *Limnophila aromatica*, *Eriocaulon setaceum*, *Eriocaulon willdenovianum*, *Blyxa aubertii*, *Limnophila fragrans*
Richard River	*Isachne sp*, *Microcarpaea minima*, *Xyris indica*, *Triglochin sp*, *Blyxa aubertii*, *Eriocaulon setaceum*, *Eriocaulon sp*, *Nelsonia campestris*, *Goodenia sp*
Habgood River	*Aponogeton sp*, *Limnophila chinensis*, *Limnophila aromatica*, *Isachne confusa*, *Utricularia fulva*, *Utricularia gibba*, *Utricularia australis*, *Hanguana malayana*, *Najas sp*, *Nymphoides sp* (yellow flower), *Nymphoides indica* (snowflake lily)
Buckingham River	*Nymphaea violacea* (Blue flowering native water lily), *Limnophila chinensis*, *Eriocaulon setaceum*, *Hygrophila angustifolia*, *Utricularia fulva*, *Utricularia sp*, *Triglochin sp*, *Eriocaulon sp* (small rosette growing submerse)

4.5. Water Quality

The physical and chemical qualities of water can be tested to give an indication of its suitability to support aquatic life. The qualities measured on the survey study sites were temperature, conductivity, pH, alkalinity, total hardness, dissolved oxygen and turbidity (**Table 7**).

Table 7 Water Quality Results.

River Name	Date	Temp ºC	pH	DO Mg/l	Hardness ppm	Ec µS/cm	Alk ppm	Turb mtrs
Mainoru River	Oct /03	29	7.8	6.1	270	646	180	>3
Wilton River	Oct /03	23	8.4	7.5	180	506	140	1.2
Goyder River	Oct/03	27	8.1	6.1	120	455	100	>6
Rocky Bottom Creek	Oct/03	30	8.1	7.15	100	464	100	1.8
Barmgueikba Creek	Oct/03	30	7.0	6.1	20	69	20	1.5
Chambers River	Oct/03	34	8.1	7.5	10	67.8	10	<0.05
Dook Creek	Oct/03	30	7.1	5.91	10	29.1	10	2.3
Maiwok Creek	Oct/03	35	7.8	5.97	220	691	180	>0.3
King River	Nov/03	29	6.8	-	<10	-	<10	0.35
Bradshaw Creek	Nov/03	31	7.8	-	140	-	110	0.5
Tom Turner Creek	Jun/04	23	-	3.18	<10	18.2	<10	3.5
Moyle River	Jun/04	24	-	8.05	<10	19.3	<10	>5
Anopheles Creek	Jun/04	20	-	6.25	<10	-	<10	1.2
Giddy River	Jul/04	27.7	7.43	6.62	<10	60.2	<10	2.8
Wonga Creek	Jul/04	29.8	5.32	7.72	<10	37	<10	3.2
Cato River	Jul/04	27	6.41	6.1	<10	36	<10	>3
Richard River	Jul/04	19.8	7.46	8.32	<10	36.5	<10	1.5
Habgood River	Jul/04	24.4	6.77	7.68	40	126.4	40	>5
Buckingham River	Jul/04	26.2	6.59	13.35	10	40.8	20	1.5

5. CONSERVATION SIGNIFICANCE

5.1. Habitats of ecological conservation significance

Across the Top End, aquatic ecosystems, and riparian zones in particular, are generally considered to be in good or fairly pristine condition with the main threatening processes being feral animals, grazing pressure and introduced weeds (Dept of Environment and Heritage web site [online] Australian National Resources Audit).

Herbert *et al.* (1995) concluded from an intensive three-year study on the freshwater fish and aquatic habitat of Cape York that perennial lagoons are crucial habitats for some species of fish, which appear to require aquatic vegetation. They are also important refuges in dry seasons and breeding grounds prior to floods. Lagoons are particularly crucial as refuges in the middle and upper reaches, where waterholes are few and far between. They are also known to harbour the complete diversity of aquatic plants in a catchment.

The Cato River is significant as it recorded the highest species diversity of the surveyed rivers and it yielded two species not previously recorded from the Northern Territory, the Aru Gudgeon *Oxyeleotris aruensis* and the Concave Goby *Glossogobius concavifrons* as well as a threatened amphibian, the Wood Frog *Rana daemeli*. These species were all recorded from swamps within associated monsoon rainforest patches at the study site. The species composition of this river is not dissimilar to that of the Jardine River in northern Cape York, with 22 of the 24 fish species recorded during this survey also being found in the Jardine (Allen and Hoese 1980; Byron and Blake 1993; Allen *et al*. 2002). It is likely that other rivers within North Eastern Arnhem Land such as the Giddy, Goromuru and Habgood Rivers, will yield similar and additional new species with further sampling, extending the known ranges of many fish species in the Top End of the NT. Particular emphasis should be placed on areas that are surrounded by monsoon forest.

Extensive coverage of the aquatic plant *Hanguana malayana* was observed along the banks and across the surface of the water into the Habgood River. This macrophyte was not observed on any of the other waterways and created a complex habitat over some quite deep water and was exclusive to this river. The Gulf Saratoga *Scleropages jardinii* which has a preference for habitat with overhanging vegetation, was extremely common at this site, most likely as a result of this habitat.

The habitat of both the Daly and Katherine River systems would also be considered significant not only because of the high level of species diversity recorded from these rivers, but also the sheer size and volume of water that flows down this system.

5.2. Aquatic fauna species of ecological conservation significance

Species of conservation significance include those species that are classified as ‘threatened’ and\or protected under NT and Commonwealth legislation, and species that are regionally restricted in their distribution. The locations, attributes and significance of aquatic species in relation to the TTP route are discussed below.

The Freshwater Sawfish *Pristis microdon* is listed as vulnerable under the *EPBC Act 1999* and is generally restricted to the larger upstream waterholes in the lower reaches of large river systems (Allen *et al.* 2002; Herbert *et al.* 1995). This species is not commonly found in lagoon-type habitats (Herbert *et al.* 1995). NT Museum records show that this species has been recorded in several of the larger rivers that will be crossed by the TTP including the Daly, Wilton and Mainoru Rivers. Historically, this species has been reported in the lower reaches of several rivers in Eastern Arnhem Land including the Goyder and Cato Rivers, however, these records are from areas far downstream of the proposed TTP route. It may also occur in the Mainoru River as was indicated from an interview with long time resident Ronnie Martin.

Obbes' Catfish *Porochilus obbesi,* which is currently listed as near threatened under the *TPWC Act 2000* prefers slow flowing streams, lagoons and shallow lakes with considerable macrophyte growth (Merrick and Schmida 1984; Herbert and Peeters 1995; Allen *et al.* 2002). This species is listed as uncommon by many authors (Merrick and Schmida 1984; Herbert and Peeters 1995; Allen *et al.* 2002) and has a rather disjunct distribution across Northern Australia. Given the largely cryptic nature of this species, it is likely that it will be found in many more rivers as further intensive sampling is undertaken throughout its known distribution. Along the TTP route this species is presently only recorded from the Daly system in Yam Creek (Allen 1989). However, Peter Unmack (http://www.peter.unmack.net/biogeog/html/appendices/appendixiv.html) considers that this record to be incorrect as Yam Creek is now believed to be part of the Adelaide River drainage. If this is the case, then this species has not in fact been recorded in the Daly Catchment and therefore is not known to occur along the TTP route.

5.3. Range Extensions and New Species

The identification of the Aru Gudgeon *Oxyeleotris aruensis* and Concave Goby *Glossogobius concavifrons* in the Cato River was an extension of the known range of these species only known from Southern New Guinea and the tip of Cape York Queensland. One further species of goby collected in the Cato River is presently undescribed but known commonly as Monroe's Goby *Glossogobius sp 2*. The observation of the Freshwater Whipray *Himantura chaophraya*, also in the Cato River, represents the first record of this species in Arnhem Land. This species was previously only recorded from the South Alligator and Daly Rivers in the NT (Midgley 1980; Allen *et al.* 2002).

The identification of Butler's Grunter *Syncomistes butleri* in the Goyder River and Rocky Bottom Creek was another range extension as this species. Previously it was known from Drysdale River in the west to the Liverpool River in the east and is considered to be common in all the upper reaches of the larger rivers in this region (Allen *et al.* 2002). The Primitive Archerfish *Toxotes lorentzi* was previously thought to be common within, but confined to, the region between the Daly and East Alligator rivers (Allen *et al*. 2002). This species was recorded in the Moyle River and Tom Turner Creek during the field surveys. Allen *et al.* (2002) describe the Penny Fish *Denariusa bandata* as seasonally abundant throughout a scattered distribution across Northern Australia and North Eastern Queensland, extending as far west as the Daly. This species was found to be common within the swamps adjacent to Tom Turner Creek.

The Exquisite Rainbowfish *Melanotaenia exquisita* is presently known from disjunct populations across northern Western Australia and the Northern Territory. This species is restricted to escarpment areas and within rivers that originate directly adjacent to waterfalls. This species was not previously known from the Roper catchment and was recorded in Dook Creek.

It would appear that few fish species in the Northern Territory are restricted or are endemic to single river systems. Unmack's (Unmack 1999) recent thesis on the biogeography of Australian freshwater fish describes only 3% or one endemic species in both the Arnhem and Daly Provinces. These provinces were determined by Unmack based on combination of river catchments and biogeographical zones and incorporate all coastal drainages within the Northern Territory.

6. POTENTIAL ENVIRONMENTAL EFFECTS AND MANAGEMENT RECOMMENDATIONS

The aquatic ecosystems that will be crossed by the TTP are considered on a national scale to be in relatively pristine condition. It is imperative therefore, that the TTP is constructed and operated in a manner that ensures minimal impact o these environments and those species listed as threatened under state and federal legislation.

6.1. Clearing of riparian vegetation, erosion and sedimentation

6.1.1. Effect

Riparian vegetation has been recognised as valuable habitat and vital to the functioning of stream ecosystems. The removal or modification of this can adversely affect every aspect of stream habitat. Riparian vegetation is in relatively good condition across the NT (Australian Natural Resources Atlas [online] Accessed September 2004). Even so, the condition of riparian zones in the NT is declining because of damage associated with proliferation of weeds, feral pigs and buffalo, and (in some cases) unrestricted access by livestock (Australian Natural Resources Atlas [online] Accessed September 2004).

Riparian vegetation is known to (Wager and Jackson 1993);

- maintain bank stability and channel morphology,
- provide a buffer which filters sediment, organic and inorganic nutrients from run off,
- provide in-stream habitat in the form of woody debris (snags), leaves and bark,
- maintain undercut banks by its presence,
- provide the major source of energy input in the form of vegetative material, terrestrial insects etc, and
- its removal often results in an increase in water temperatures and increased temperature fluctuation.

The clearing of riparian vegetation can result in increased erosion, scouring and changes to channel morphology. An increase in nutrient loadings and light penetration may result in unfavourable algal blooms and increases in water temperatures. Decreases in in-stream habitat may also occur with a loss of undercut banks, woody debris and leaves etc. Disturbance of riparian vegetation is also known to allow the proliferation of weed species. Arthington *et al.* (1983) have documented the adverse effects of Para Grass (*Brachiara mutica*) on native fish habitats in streams around Brisbane after the loss of native riparian vegetation.

Erosion and sedimentation modifies the morphology of channels and banks and increases the sediment load. Increased sediment loading may have a variety of effects including infilling of holes and channels, smothering of riffle areas and the associated invertebrate fauna, smothering of macrophytes, and smothering of fish eggs deposited in gravel substrates or attached to underwater surfaces (Wager and Jackson 1993). Hall (1991) found that 80% of freshwater fish species in Victoria produce eggs, which are susceptible to smothering by fine sediments. Despite very different species being identified during this survey, they represent a similar range of families and therefore fine sediments may impact on a similar proportion of the species diversity.

Culverts and crossings that restrict stream flow (thereby increasing water velocity) may also cause scouring of the stream bed and erosion of adjacent banks if the outlet or downstream is inadequately protected (Cotterell 1998).

6.1.2. Management

In order to limit the detrimental effects on rivers and steams, it is recommended that construction attempts to minimise the circumstances where excavation is carried out in water bodies or within riparian zones. Where it is required, the absolute minimum should be removed and clearing of riparian vegetation should be carried out as early in the dry season as possible to allow for sufficient revegetation. Hand clearing of bank slopes at the site minimises erosion and the need for rehabilitation. If possible, work to the outer bank should be minimised, as these are usually the most unstable bank and prone to erosion. Where vehicle traffic is expected in these zones, 'roadways' should be covered in gravel, particularly entry and exit areas. All works should adhere to guidelines for the control of erosion and sedimentation at construction sites and NT soil conservation guidelines. Rehabilitation works should be completed as soon as practical after the disturbance. Care should be taken not to establish weeds.

6.2. Water quality

6.2.1. Effect

Water picks up minerals from the surfaces it passes over or through (Reid 1972). It also picks up organic materials from biological activity. In areas of human habitation and agricultural activities it picks up waste materials from those activities. The largest threats to water quality in Australia's inland fresh waters are identified by the Department of Environment and Heritage as:

- Increasing in-stream water salinity;
- Nutrient enrichment and eutrophication;
- High water turbidity and siltation;
- Pesticide contamination of water and sediments;
- Localised heavy metal pollution;
- Increasing acidity of inland waters; and
- Cold-water pollution.

The threats to water quality are likely to result from manufacturing processes and human activities. These may include silting, spills of potentially hazardous and dangerous chemicals such as fuels and oils, and wastewater (camp and hydrostatic testing) disposal. The greatest risks to water quality include increased sediment loading and change of physiochemical properties of wastewater from both the camps and the hydrostatic testing of the pipeline.

Increased sediment loading may have a variety of effects including infilling of holes and channels, smothering of riffle areas and the associated invertebrate fauna, smothering of macrophytes, and smothering of fish eggs deposited in gravel substrates or attached to underwater surfaces (Wager and Jackson 1993). Berkman and Rabeni (1987) showed that silt affected the composition of fish assemblages, interfered with feeding of algivorous fish, and lowered the reproductive success of some spawning guilds (substrate and macrophyte spawners).

Biotic factors (morphology, competition, predator-prey interactions and resource partitioning) and habitat complexity influence distributions of animals in benign environments, but in harsh environments, the ability of the organism to tolerate or avoid physiochemical stress may be more critical to their success (Matthews 1998). Monsoonal rivers are considered harsh environments and many species other than the generalists will have difficulty coping with further physiochemical changes during the dry season, or low flow periods which may ultimately lead to their death.

6.2.2. Management

A water monitoring program based on the ANZECC 2000 guidelines should be established to assess ecosystem integrity throughout the construction period and during the first few years of operation to ensure nil to minimal impact of the crossings. This will involve the;

- Defining of water quality objectives;
- Selection of appropriate trigger values for selected indicators; and
- Establishment of a water quality monitoring program.

Design and construction of fuel and chemical storage, and wastewater treatment facilities should comply with Australian regulations and be located appropriate distances from any watercourses. Personnel should be discouraged from using personal toiletries in any watercourse or from swimming whilst wearing sunscreen and insect repellent.

Disposal of wastewater from hydrostatic testing according to regulatory and Traditional Owner requirements. In particular, water drawn from a marine source should only be disposed of to an ocean outfall. If surface water is used, it should be sterilised before release into another catchment. Under no circumstances should this water be released into a watercourse.

6.3. Fish passage

6.3.1. Effect

Many fish species travel up and down waterways as evidenced by huge aggregations of various species that can be observed at natural and un-natural barriers in rivers before, during and especially after the wet season (D. Wilson personal observation). Fish move for a range of reasons including feeding, breeding, escaping predators or dispersal. Many tropical freshwater fishes migrate up-river as the water level rises in the wet season and undergo lateral movements out onto the floodplains when conditions permit (Lowe-McConnell 1975). Some species are renowned for their ability to travel. One of the most widespread native fish, the Spangled Perch *Leiopotherapon unicolor* has a reputation for moving long distances upstream in a short time during periods of high rainfall to both breed and to disperse (Allen *et al*. 2002). Other species recorded during this survey, such as the Freshwater Sawfish *Pristis microdon*, Barramundi *Lates calcarifer*, Spotted Scat *Scatophagus argus*, Striped Scat *Selenotoca multifasciata*, Tarpon *Megalops cyprinoides*, and Mangrove Jacks *Lutjanus argentimaculatus* need to move downstream into saltwater to breed. The adults and juveniles of most of these species then return to freshwater (Allen *et al.* 2002).

Whilst there has been concern over the effects of dams and weirs on fish movements, simple structures such as road crossings also have significant effects. A poorly designed or installed culvert can affect the fish stocks of an entire drainage basin (Cotterell 1998). If a crossing or culvert is designed such that the channel width is restricted or a drop is created, the velocity of flowing water will be increased. Whilst fish are stimulated to move in response to floods, the water velocity in culverts or at crossings under flow conditions may exceed the swimming ability of many fish, therefore excluding these from upstream habitat that many species require.

Although usually low cost, causeways result in many problems for fish passage including:

- Debris blockage of the pipe;
- Excessive flow velocities through the low flow pipe;
- Inadequate flow depth over the causeway during minor stream flows;
- Excessive fall in the water level across the causeway or at the outlet of the low flow pipe creating a waterfall effect; and
- Sediment runoff from the approach roads (Fairfull and Witheridge 2003).

The *NT Water Act 2004* regulates the restriction of water flows within a waterway. The provisions of the *NT Water Act* establishes offences related to impeding water flows in a water way.

6.3.2. Management

As discussed in **section 6.1.2**, all in-stream work should be conducted during the driest part of the year and completed as quickly as possible. All temporary in-stream structures such as temporary crossings and bund walls should be removed as soon as practical after the works are completed and the streambed restored to as near as possible original condition. It is recommended that design and construction of any stream crossings follow the guidelines produced by Cotterell (1998), Witheridge (2002) and Fairfull and Witheridge (2003).

Each waterway proposed to be crossed by the TTP will require a site assessment in order to determine the most appropriate crossing for the site. It should be a primary objective to minimise the number of crossings that will be required. In addition, the following 5 principles should be followed (from Fairfull and Witheridge 2003):

1. Avoid crossing waterways at or near sharp bends, sections of unstable channel or major 'riffle' zones.
2. Avoid locating crossings over meandering waterways where such meandering is likely to continue in the future and may cause damage to the structure, erosion of the channel or misalignment with the channel in the future.
3. Avoid works that may change the frequency or spacing of an existing pool-riffle system.
4. Avoid disturbances to sections of a waterway channel or its associated bank vegetation, particularly those identified as areas of high conservation value or where threatened species are known to occur.
5. Avoid removal of essential shade trees, especially where there has already been a loss of natural vegetation cover.

Following the site assessment, consideration should be given to the most appropriate crossing type. **Table 8** details the recommended crossing types for various classifications of fish habitat (from Fairfull and Witheridge 2003).

Table 8. Recommended crossing types for various classifications of fish habitat (from Fairfull and Witheridge 2003).

Classification	**Characteristics of Waterway Type**	**Recommended Crossing Type in preferred order.**
Class 1 – Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge Arch structure Tunnel
Class 2 – Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge Arch structure Culvert (high priority should be given to a high flow design) Ford.
Class 3- Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna. Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert (high flow or medium flow designs should be given priority where affordable) Ford
Class 4 – Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events. No permanent aquatic flora present.	Culvert Causeway Ford

If an access track is to traverse the length of the pipeline, then structures will be required for river and creek crossings. Depending on the most appropriate structure decided upon for each crossing, the construction practices recommended in **Table 9** should be followed.

Table 9. Recommended construction practices for various types of water way crossings (from Fairfull and Witheridge 2003).

Crossing type	Recommended construction practices
Ford	• The deck of the ford should follow the natural bed elevation. • Where concrete is used, the surface will need an artificial roughness, at least along the lowest section of the crossing. Grouted rocks may be used instead of the concrete pad. • Do not use exposed-aggregate concrete finishing as its preparation can pollute.
Causeway	• Minimise the use of causeways where migratory fish species have been identified. • Construct the deck to follow the stream's natural cross section to achieve variable flow depths over the causeway. • Give appropriate consideration to fish passage and install low-flow pipes or boxes to carry the normal dry-weather flow.
Culvert	• Align the culvert with the downstream channel to minimise bank erosion. • Minimise the changes to the natural flow of the waterway through the culvert's wet cells. These should have a minimum depth of 0.2-0.5 m to encourage fish passage. • Designed to maximise the geometric similarities of the natural channel profile from the bed of the culvert up to a flow depth of 0.5 metres. • If a smooth bed is required, flow velocities for water depth up to 0.5 m should be no more than 0.3 m/s. • In sand and gravel-based streams, natural bed material should be placed along the bed of the wet cells or allowed to deposit in these cells. • In clay-based streams that do not experience movement of bed load sediment, artificial roughness can be created by grouting rounded stone across the bed of the wet cells. • Consideration should be given to adding artificial sidewall roughness along the walls immediately adjacent to the channel banks. • Construct pools at the inlet and outlet of the culvert. • Ensure the low-flow channel extends across the inlet and outlet aprons. • Use debris deflector walls to reduce blockages. • Maximise light penetration within the wet cells. • Avoid the formation of a perched culvert or damage to the stream bed, control erosion using rock protection or with a stabilised energy dissipation pool.
Bridges and Arch structures	• Avoid locating bridge piers or foundations within the main waterway channel. • Design and orientate bridge piers to avoid the formation of large-scale turbulence or erosion of the bed and banks. • Give appropriate consideration to fish passage requirements along floodplains. Locate bridge abutments away from the channel banks and consider the possibility of installing floodplain culverts adjacent to the main crossing. • Maximise light penetration under the bridge or arch to encourage fish passage. • Maximise bed and bank erosion control measures.

During construction and operation, all measures should be taken to minimise the restrictions of fish passage, the release of sediment into freshwater creeks or rivers and damage to or the removal of bank vegetation, particularly vegetation that shades the low-flow channel in the system (Fairfull and Witheridge 2003).

During operation of the pipeline, it is imperative that all waterway crossing structures be inspected and maintained on a regular basis. All in-stream maintenance should be scheduled for times of the year that will ensure a minimal environmental impact (Fairfull and Witheridge 2003). The dry season would be best for such activities as this should avoid critical periods of fish passage and seasonal high flows.

6.4. Translocation

6.4.1. Effect

The translocation of fish and other aquatic organisms may have a range of adverse effects. These include the introduction of diseased organisms, disturbance of ecosystems, loss of biogeographic information and loss of genetic diversity (Wager and Jackson 1993).

Water transferred from one catchment to another during the hydrostatic testing of the pipeline may carry biological material. In addition, machinery and equipment used in a watercourse may carry material into the next. It is an offence under the *Fisheries Act* to translocate aquatic life.

6.4.2. Management

Water used during hydrostatic testing should be disposed of as described in accordance with the requirements set out in **section 6.3.2**. All machinery and equipment that will be submersed or used in a waterway should be washed down and decontaminated before the next catchment river or waterway.

6.5. Impacts on aquatic fauna species of conservation significance

6.5.1. Effect

The pipeline crosses various rivers known to contain threatened and data deficient fish species. The literature review and interviews conducted with landholders and traditional owners determined that the Freshwater Sawfish *Pristis microdon* is known to occur in the Daly, Wilton and Mainoru River catchments on the TTP route. A further 32 data deficient (DD) species were recorded during the survey. At least a single DD species was found at each site surveyed excluding Krabakuk Creek. The Daly River recorded the highest species diversity and contained 20 species listed as data deficient. A single data deficient species was found at both the Moyle River and Maiwok Creek.

The near-threatened Pig-nosed Turtle *Carettochelys insculpta* is likely to occur in various river systems to be traversed by the pipeline. The Wood Frog *Rana daemeli* which is listed as vulnerable was located on the Giddy and Cato Rivers.

Many aspects of the biology and ecology of native fishes are poorly known. In addition, nearly all the threatening processes are inadequately understood (Wager and Jackson 1993). The Freshwater Sawfish *Pristis microdon* is a diadromous species that typically occurs in the tidal areas of the large tropical rivers where high sediment loads are present as a result of the large tidal movement (Allen *et al.* 2002). Increased sediment loadings or minor changes in water chemistry as a result of the construction and operation of the TTP is anticipated to have little impact on this species. However, barriers to movement such as stream crossings, poorly designed culverts as well as gross water quality issues such as low dissolved oxygen levels present a much greater risk to this threatened species.

Many of the species listed as data deficient will be similarly impacted upon by the above activities. For example, the Exquisite Rainbowfish *Melanotaenia exquisita* is restricted to the upper reaches of rivers and creeks within escarpment areas and would not normally be exposed to high sediment loadings. The Coal Grunter *Hephaestus carbo* inhabits clear rapid streams (Allen *et al*. 2002) and requires clean gravel beds in runs or riffles with a moderate flow. The eggs settle into the spaces in the substrate between the gravel particles where well-oxygenated water will pass the eggs. Cadwallader and Backhouse (1993) determined that siltation was directly linked to the decline in numbers of the Macquarie Perch *Macquaria australasica* which has similar spawning requirements. Therefore, increased siltation may impact on fish development and embryo survival.

6.5.2. Management

Impacts on threatened species or those of conservation significance will be minimised if the management recommendations in **sections 6.1.2, 6.2.2, 6.3.2, 6.4.2** and **6.5.2** are implemented.

7. REFERENCES

Allen, G. R. (1991) *Field Guide to the Freshwater Fishes of New Guinea*. Christensen Research Institute, Madang, Papuae New Guinea.

Allen, G. R. (1989) *Freshwater Fishes of Australia*. T.F.H., New Jersey.

Allen, G.R. and Hoese, D.F. (1980) A Collection of Fishes from Cape York Peninsula, Australia. *Journal of the Royal Society of Western Australia 63: 2: 53-61.*

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

Arthington, A.H., McKay, R.J., Milton, D.A. (1983) Effects of Urban Development and Habitat Alteration on the Distribution and Abundance of Native and Exotic Fish in the Brisbane Region, Queensland. *Australian Journal of Ecology 8:87-101.*

Axelrod, H.R. Burgess, W.E. Pronek, N. Walls, J.G. (1985) *Atlas of Freshwater Aquarium Fishes*. TFH, New Jersey.

Berkman, H.E. and C.F.Rabeni, (1987) Effect of Siltation on Stream Fish Communities. *Env. Biol. Fish. 18:285-95.*

Boyd, C.E., (1995) *Bottom Soils, Sediment, and Pond Aquaculture*. Chapman & Hall , New York.

Bishop, K.A and Forbes, M.A. (1991) The freshwater fishes of northern Australia In: Haynes, C.D., Ridgpath, M.G. and Williams, M.A.J. (eds) *Monsoonal Australia. landscape, ecology and man in the northern lowlands*. *pp 79-107*. A. A. Balkema: Rotterdam.

Byron, G. and Blake, D. (1983) Distribution and Abundance of Freshwater Fish on Northern Cape York Peninsula. Cape York Peninsula Scientific Expedition 1992: Royal Geographical Society of Queensland.

Cadwallader, P.L and G.N.Backhouse, (1983) *A Guide to the Freshwater Fish of Victoria*. Victorian Government Printing Office, Melbourne.

Cogger, H.G., (1992) *Reptiles and Amphibians of Australia revised Edition*. Reed International Books, Chatswood NSW.

Cotterell, E. (1998) *Fish Passage in Streams – Fisheries Guidelines for Design of Stream Crossings*. Fisheries Group, Queensland Department of Primary Industries, Brisbane.

Cowie I., Short P.S., Osterkamp-Madsen M., (2000) *Floodplain Flora, a flora of the coastal floodplain of the Northern Territory, Australia*. Published by CSIRO, Canberra.

Cronk J.K., Fennessy M.S. (2001) *Wetland Plants, Biology and Ecology*. Lewis Publishers, London NewYork and Washington.

Department of Business, Industry and resource Development, Fisheries Division: fish kills [online]. http://www.fisheries.nt.gov.au/

Department of Environment and Heritage list of threatened species [online]. Available at: http://www.deh.gov.au/cgi-bin/sprat/public/publicthreatenedlist downloaded 13 August 2004.

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

Frogwatch NT. [online] http://www.frogwatch.org.au/index.cfm

Herbert, B. and Peeters, J., (1995) *Freshwater Fishes of Far North Queensland*. DPI, Queensland.

Herbert, B.W., Peters, J.A., Graham, P.A. and Hogan, A.E. (1995). *Freshwater Fish and Aquatic Habitat Survey of Cape York Peninsula*. Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General of Queensland, Brisbane, Department of the Environment, Sport and Territories, Canberra, Queensland Department of Primary Industries, Brisbane.

Hall. D.N. 1991 *Management Plan for Freshwater Fishes in Major Gippsland Rivers: Water Resources Requirements*. Arthur Rylah Institute for Environmental Research, Technical Report 107.

Jones, D. & Morgan, G., (1994) *A field guide to Crustaceans of Australian Waters*. Reed Publishing, Chatswood, NSW.

Last, P.R. and Stevens, J.D. (1994) *Sharks and Rays of Australia*. CSIRO Australia.

Larson, H. (2004) Personnel Communication.

Larson, H.K. & Martin, K.C., (1989) *Freshwater Fishes of the Northern Territory*. Northern Territory Museum of Arts and Sciences Handbook.

Lowe-McConnell, R.H. (1975) *Fish Communities in Tropical Freshwaters*. Longman, New York.

Matthews, W.J. (1998) *Patterns in Freshwater Fish Ecology*. Chapman & Hall. New York.

Merrick, J., Schmida, G. (1984) *Australian Freshwater Fishes, Biology and Management*. Griffin Press, Netley, South Australia.

Midgley, S.H. 1980. *The Daly River, Katherine River, King River, Dry River, Flora River, Fergusson River, Fish River, Douglas River in the Northern Territory. A biological resource study of fresh waters conducted during August-September 1980*. Unpublished report to NT Fisheries.

Midgley, S.H. 1983. *The rivers of Arnhem Land and the Towns River. An account of a biological resource study of fresh waters conducted during July to August 1983*. Unpublished report to NT Fisheries.

Reid K. (1972) *Fresh Water*. Aldus Books, London.

Sainty G.R., Jacobs S.W.L. (1988) *Waterplants in Australia*. Published by CSIRO Division of Water Resources, Australia.

Sattler, P. and C. Creighton (eds). 2002. Terrestrial Biodiversity Assessment 2002. National Land and Water Resources Audit, Canberra [online] Available from; http://audit.ea.gov.au/anra/vegetation/docs/biodiversity/bio_assess_contents.cfm [Accessed 2004 September].

Unmack P.J., (1999) *Biogeography of Australian Freshwater Fishes*. Masters thesis, Arizona State University

Wager, R and Jackson, P. (1993) *The Action Plan for Australian Freshwater Fishes*. ANCA, Canberra, Australia.

Wilson, D.N. (1999) Freshwater Sawfish *Pristis microdon*. Australia & New Guinea Fishes Association' A-Z Notebook of native Freshwater Fishes. *ANGFA Bulletin 41*.

Wilson, D. (2004) Personnel Observation.

Wilson, S. and Swan, G. (2003) *A Complete Guide to Reptiles of Australia*. Reed, NSW.

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

Appendix 1
Photos of Survey Sites

Appendix 1 Survey Site Photos

Mainoru River Survey Site

Wilton River Survey Site

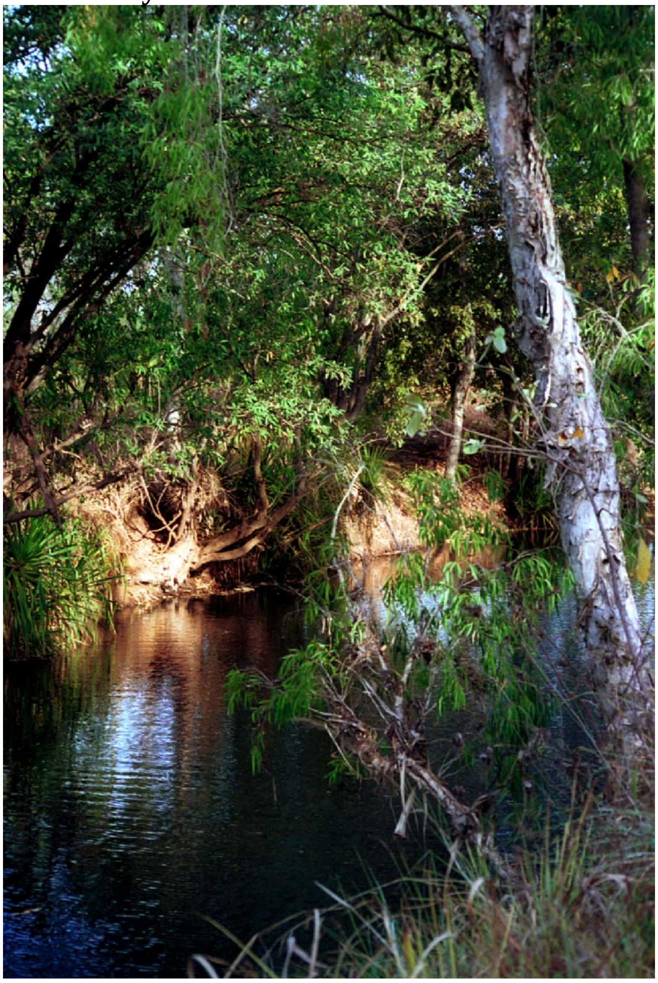
Appendix 1 Survey Site Photos

Goyder River Survey Site

Rocky Bottom Creek Survey Site

Appendix 1 Survey Site Photos

Barmgueikba Creek Survey Site

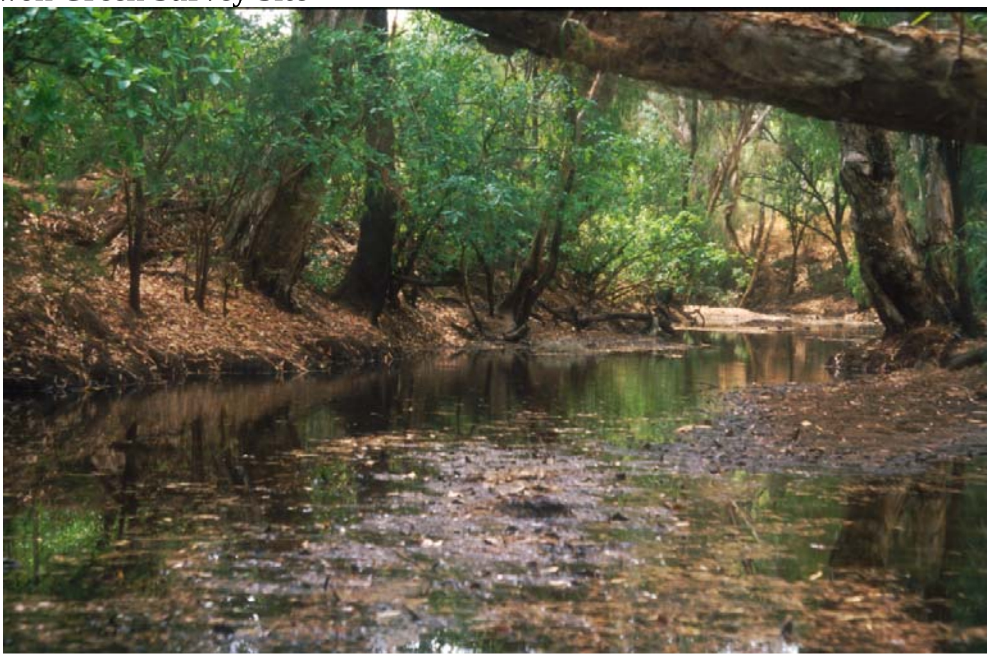


Chambers River Survey Site

Appendix 1 Survey Site Photos

Dook Creek Survey Site

Maiwok Creek Survey Site



Appendix 1 Survey Site Photos

King River Survey Site

Bradshaw Creek Survey Site

Appendix 1 Survey Site Photos

Tom Turner Creek Survey Site

Moyle River Survey Site

Appendix 1 Survey Site Photos

Anopheles Creek Survey Site

Giddy River Survey Site

Appendix 1 Survey Site Photos

Wonga Creek Survey Site

Cato River Survey Site

Appendix 1 Survey Site Photos

Richard River Survey Site

Habgood River Survey Site

Appendix 1 Survey Site Photos

Buckingham River Survey Site