PNG LNG Project: UPSTREAM

Aquatic Fauna Impact Assessment

December 2008

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EXECUTIVE SUMMARY

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site. Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG for over the 30-year life of the project.

The objectives of this project were to collect field baseline data in order to describe the pre-development aquatic habitats and fauna and to collect data to inform an impact assessment for the project.

A range of aquatic habitats was observed to occur in the study area, which can be classified as:

- Clear-water streams;
- Sink hole streams;
- Swamps and other standing waterbodies; and
- Large turbid rivers.

Faunal assemblages differed in each of these habitats and it is hypothesised that altitude, habitat type and sediment regime are the primary factors controlling the diversity and abundance of fishes and other aquatic fauna in the project area. Many of the upstream areas sampled were at high altitude and at the highest altitudes in, for example, the Juha area and the Karius area (up to 1,300 m in elevation), only one fish species was identified. In lower-altitude areas, the fish communities were generally more diverse, but in the large rivers of the Hegigio and Tagari, naturally high sediment loads and high flows experienced at the time of sampling limited the number of species recorded.

No rare, endemic or endangered aquatic species were identified at the sites sampled. All species recorded are common and widespread throughout southern PNG. However, some obscure habitats were not sampled. These included sinkholes and some standing waterbodies. While these habitats have been identified as potentially sensitive, both from the point of view of the potential occurrence of rare species or the low resilience of the habitat itself, the project is not expected to intersect or interact with such habitats.

There is negligible utilisation of aquatic resources in the far-upstream segment of the project area, with the possible exception of the area of the proposed Hides Gas Conditioning Plant (HGCP), which is located near the town of Nogoli. Fishes in the Juha to Hides area are mostly small-bodied species and there are few very settlements in the area.

Of the potential project-related impacts assessed in this report, sediment is believed to be the stressor of greatest significance to aquatic habitats and fauna. In particular, increased mobilisation of sediment to watercourses in the construction phase has the most potential to cause aquatic impacts. The construction phase is a concentrated, relatively short phase of the project, and while the potential impacts of this phase are considered to be greater than that of the operations phase, they should be short-lived.

The primary mechanisms of sediment mobilisation to watercourses are likely to be:

- Runoff from the cleared right of way (RoW), exacerbated during intense rainfall periods;
- Runoff from any sediment stockpiles, exacerbated during intense rainfall periods;
- Side-casting of soils associated with the construction of the right of way (RoW), exacerbated in areas with particularly steep slopes;
- Construction of RoW watercourse crossings, including trenching of the pipeline; and
- Construction of bridges to span large rivers.

Overall, the potential impacts of this project on aquatic habitats and fauna are considered to be minor. The main factors mitigating the severity of the potential impacts are:

- The limited area of disturbance;
- The absence of rare, endemic or endangered species;
- The low sensitivity (high resilience) of large turbid rivers;
- The opportunity to fine-tune the RoW alignment to avoid obscure or potentially sensitive habitats (e.g. sinkholes).

Other mitigation and management measures are recommended to ameliorate potential aquatic impacts.

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Aquatic Fauna Impact Assessment

December 2008

Table of Contents

Tables

Figures

Plates

Appendices

1 INTRODUCTION

1.1 Background

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site.

Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG for over the 30-year life of the project.

A list of the proposed developments is provided below, and Figure 1-1 shows a schematic of facilities and pipelines:

Upstream Development Components

- Hides gas field development:
    - Seven wellpads with a total of eight new wells and re-completion of two existing wells;
    - Hides gathering system including gas flowlines from new and re-completed Hides wells;
    - Hides spineline and mono-ethylene glycol (MEG) Pipeline in the same right of way (ROW);
    - Hides Gas Conditioning Plant.
    - Hides–Kutubu Condensate Pipeline in the same ROW as the LNG Project Gas Pipeline;
- Juha gas field development:
    - Three new wellpads with four new wells;
    - Juha gathering system including gas flowlines from new Juha wells;
    - Juha spinelines and MEG Pipeline in the same ROWs;
    - Juha Production Facility;

    - Juha–Hides pipelines right of way (ROW) containing three pipelines including Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline.

- Angore gas field development:

    - Two new wellpads with two new wells;

    - Angore gathering system including gas flowlines from new Angore wells;

    - Angore spineline and Angore MEG Pipeline to Hides Gas Conditioning Plant, both in the same ROW.

- Gas from existing fields:

    - Gas treatment at the Agogo Production Facility and a new Agogo Gas Pipeline from the Agogo Production Facility to LNG Project Gas Pipeline;

    - Gas treatment at the Gobe Production Facility and a new Gobe Gas Pipeline from the Gobe Production Facility to LNG Project Gas Pipeline;

    - Gas treatment at the Kutubu Central Processing Facility and a new Kutubu Gas Pipeline from the Kutubu Central Processing Facility to the LNG Project Gas Pipeline;

    - South East Hedinia gas field development: one new wellpad and two new wells; new gathering system including gas flow lines from the South East Hedinia new wells to the Kutubu Central Processing Facility in the same ROW as the Kutubu Gas Pipeline.

- Kopi scraper station.

- LNG Project Gas Pipeline:

    - Onshore: from Hides Gas Conditioning Plant to Omati River Landfall;

    - Offshore: Omati River Landfall to Caution Bay Landfall.

LNG Facilities Development Components

- Onshore LNG Plant including gas processing and liquefaction trains, storage tanks, flare system and utilities;

- Marine facilities including jetty, LNG and condensate export berths, materials offloading facility and tug moorage.

Supporting Facilities and Infrastructure

In addition to the principal gas production, processing and transport, and LNG production and export facilities, the project will involve the following permanent infrastructure and facilities:

- New roads and upgrade of existing roads;
- New bridges and upgrade of existing bridges;
- Upgrade of two existing airfields (upstream at Komo and Tari);
- New helipads (multiple);
- New wharf and an upgrade of the existing Kopi roll-on, roll-off facility;
- Water supply systems and pipelines, wastewater and waste management facilities;
- Operations Camps (at Hides, Juha and Tari);
- A series of temporary works and access roads will also be required during the construction phase, including:
    - Construction camps (multiple);
    - Material/pipe laydown areas.

The present report deals only with the upstream components of the project. This report is designated as Hydrobiology (2008a) and the downstream segment aquatic fauna report is Hydrobiology 2008b. Coffey Natural Systems contracted Hydrobiology to undertake aquatic ecological studies for the upstream segment of the project to inform an aquatic fauna impact assessment. Hydrobiology was also contracted to undertake baseline water and sediment quality sampling, and hydrology and sediment transport studies in the upstream segment of the project, which will not be covered in this report, but instead presented in separate volumes (Hydrobiology 2008c and 2008e respectively).

There are other components of the upstream segment of the project that are not dealt with in this report as they were handled in previous EISs. These include:

- Development of five new wellpads, upgrading of two existing wellpads, bringing the total number of wellpads to seven, and eight new wells in the Hides field; and
- Development of two new wellpads and two new wells in the Angore Field.

1.2 Objectives

The objectives of this project were to:

- Review existing data and collect new baseline data that will assist with characterising aquatic fauna and habitats occurring in, and adjacent to, the areas potentially affected by the construction of the pipeline and non-linear project components;

- Identify significant species, including known rare species and those previously undescribed, occurring in and adjacent to the areas potentially affected by the construction of the pipeline and non-linear project components;

- Assess the sensitivity of aquatic fauna to the increased turbidity and sediment loads associated with construction activities;

- Use the above information to predict potential impacts, based on likelihood of impact, relative exposure to the impact by rare or undescribed species and the sensitivity of particular species or their critical habitats to impacts potentially associated with the project; and

- Put forward recommendations that will aid in mitigating potential impacts.

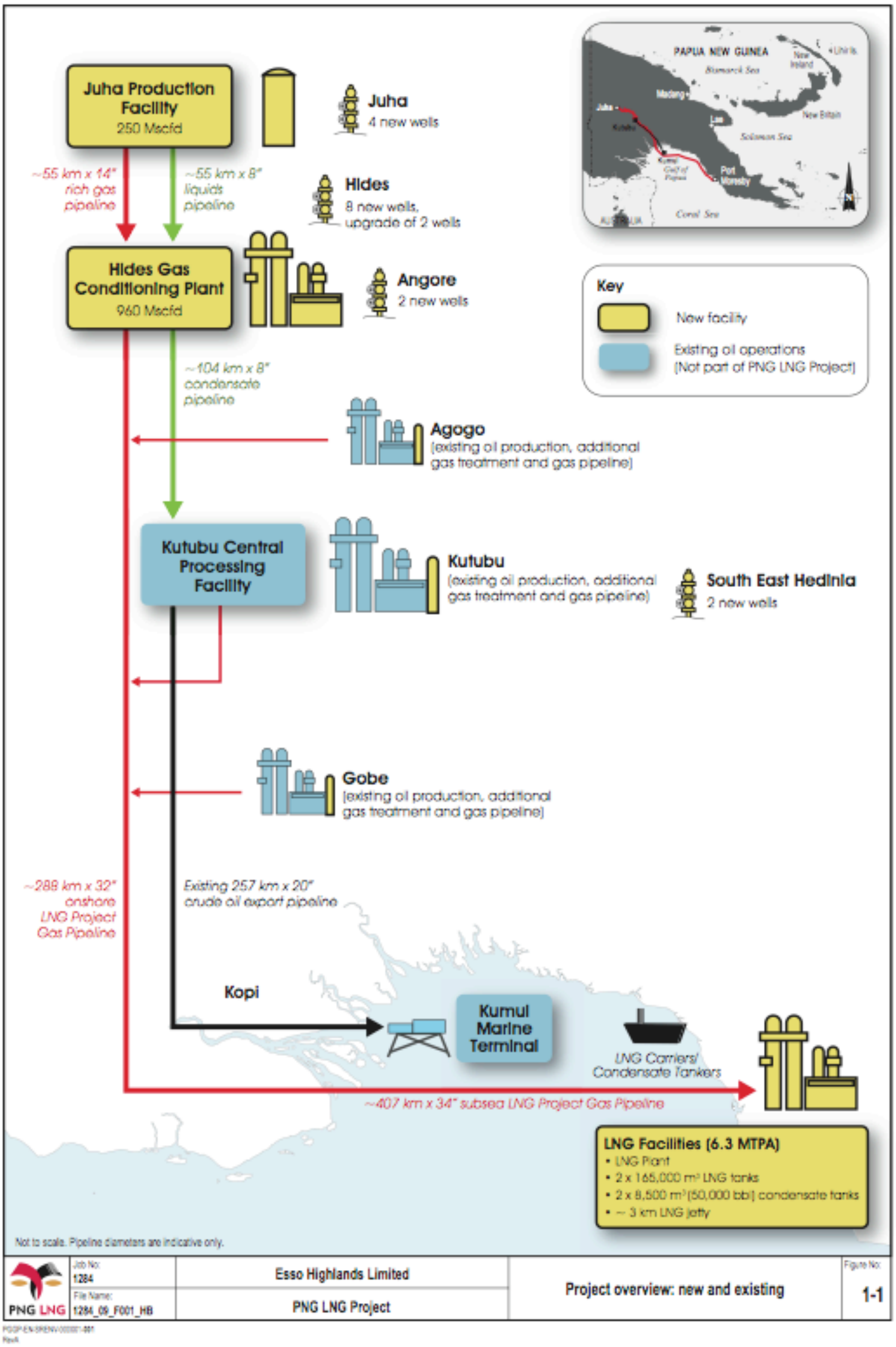


Figure 1-1 Project overview - new and existing

2 METHODS

2.1 Study Sites

Study sites for the Juha to Hides segment of the project were dictated by the location of fly camps that were established for biodiversity baseline studies. These fly camps were positioned to provide access to representative habitat types likely to be encountered along the upstream pipeline route, with due consideration to safety and logistical considerations (e.g. proximity to potential flash flood risks). In addition, since completion of the field survey, the pipeline has undergone several alignment iterations. These two facts explain why sites are not located on the exact pipeline route in some cases. From the fly camps, the field team walked to sampling locations that were able to be reached, by foot, on cut trails. Therefore, the emphasis of the fieldwork at the fly camps was to sample the range of habitats likely to be encountered along the pipeline route from Juha to Hides.

Sampling around the proposed Hides Gas Conditioning Plant (HGCP) was designed to provide baseline data for sites downstream and upstream (control) of the proposed plant site. Tributary streams draining the proposed plant site and the mainstream Tagari River were sampled. Control sites consisted of a tributary stream outside the catchment of the proposed plant site and the mainstream Tagari River upstream of the development area. Further, the area around the Homa to Idauwi pipeline deviation options was sampled by targeting suitable sites at, or downstream of, tributary crossing points and in the Hegigio River, upstream and downstream of the potential impact area.

Figure 2-1 shows sampling sites in each of these study areas.

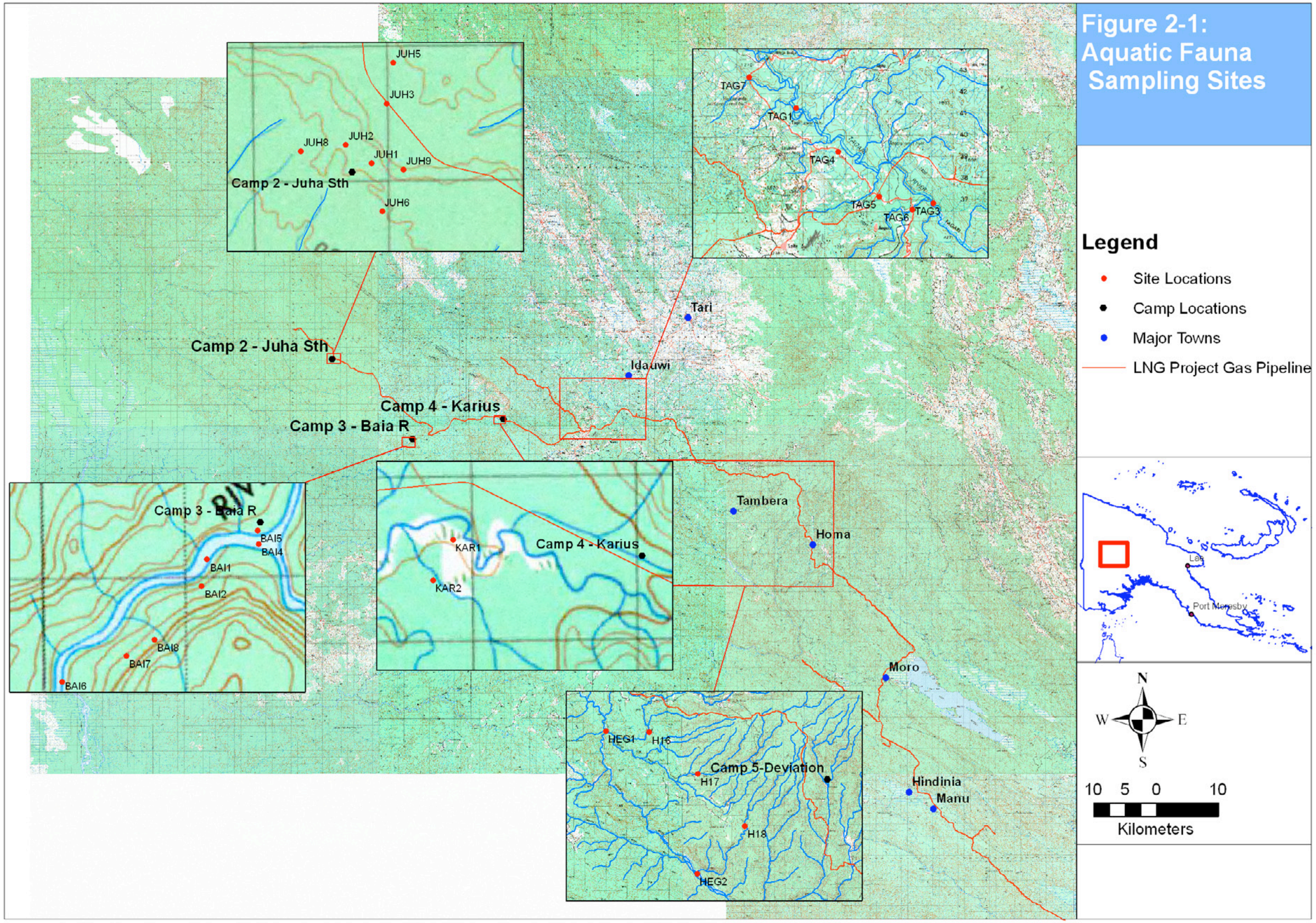


Figure 2-1 Location of aquatic fauna sampling sites

Table 2-1 lists the sampling methods used at each site. In addition to the aquatic fauna sampling, a water and sediment sampling study was undertaken concurrently. The water and sediment sampling program will be discussed in a separate report (Hydrobiology 2008c).

Sampling was conducted from 10 February to 4 March 2008. There is little seasonality in rainfall or temperatures in this region, although rainfall is affected to some degree by monsoon activity during November to May (McAlpine *et al*. 1983). Therefore, sampling was conducted during the wetter part of the year, but the variation in rainfall is not likely to cause significant seasonal variation in aquatic communities in this area. Rainfall, and thus flow conditions, has more of an effect on the ability for the sampling methods to operate optimally. High flow conditions were experienced in the Baia, Tagari and Hegigio rivers, which limited the ability for fieldworkers to safely access mid-stream habitats. This may have resulted in an under-representation of some species. However, as will be described herein, previous data were available for some rivers and we do not believe that the potential under-estimate of fish communities is significant for the purposes of this impact assessment.

Table 2-1 Sampling methods employed at each site.

Area	Site	Coordinates Deg	Min	Deg	Min	Habitat	Fish Sampling Method	Macroinvertebrates
Juha	JUH1	5	54.191	142	26.176	Swamp	Trapping	No
Juha	JUH2	5	54.116	142	26.073	Clear-water stream	Electrofishing, trapping	Yes – not analysed
Juha	JUH3	5	53.95	142	26.24	Sinkhole creek	Electrofishing	Yes
Juha	JUH5	5	53.785	142	26.268	Sinkhole creek	Water and Sediment Quality site only	No
Juha	JUH6	5	54.384	142	26.218	Clear-water stream	Electrofishing	Yes
Juha	JUH8	5	54.14	142	25.893	Clear-water stream	Water and Sediment Quality site only	No
Juha	JUH9	5	54.218	142	26.305	Clear-water stream	Electrofishing	No
Baia River	BAI1	6	1.228	142	32.844	Large turbid river (Baia River)	Electrofishing, trapping	Yes
Baia River	BAI2	6	1.329	142	32.823	Swamp	Gillnetting, trapping	
Baia River	BAI4	6	1.171	142	33.041	Large turbid river (Tikawe Ck)	Electrofishing	Yes
Baia River	BAI5	6	1.12	142	33.037	Large turbid river (Baia River)	Water and Sediment Quality site only	No
Baia River	BAI6	6	1.69	142	32.289	Large turbid river (Baia River)	Water and Sediment Quality site only	No
Baia River	BAI7	6	1.593	142	32.535	Clear-water stream	Electrofishing	Yes
Baia River	BAI8	6	1.532	142	32.642	Clear-water stream	Electrofishing	Yes
South Karius	KAR1	5	59.321	142	40.283	Clear-water stream (Baia headwaters)	Electrofishing	Yes – not analysed
South Karius	KAR2	5	59.454	142	40.216	Clear-water stream (Baia headwaters)	Electrofishing	No
Tagari River	TAG1	5	57.29	142	48.313	Large turbid river (Tagari R US HGCP)	Electrofishing	Yes
Tagari River	TAG3	5	59.702	142	51.743	Large turbid river (Tagari R DS HGCP)	Electrofishing	Yes
Tagari River	TAG4	5	58.393	142	49.372	Clear-water stream	Electrofishing	Yes
Tagari River	TAG5	5	59.528	142	50.39	Clear-water stream	Electrofishing	No
Tagari River	TAG6	5	59.862	142	51.215	Clear-water stream (Timalia River)	Electrofishing	No
Tagari River	TAG7	5	56.506	142	47.144	Clear-water stream	Electrofishing	Yes
Hegigio River	HEG1	6	4.938	142	56.166	Large turbid river (Hegigio River)	Water and Sediment Quality site only	No
Hegigio River	HEG2	6	12.329	143	0.808	Large turbid river (Hegigio River)	Electrofishing	Yes – not analysed
Hegigio River	H16	6	5.025	142	58.395	Clear-water stream (Bocari River)	Water and Sediment Quality site only	
Hegigio River	H17	6	7.167	143	0.882	Clear-water stream (Moruba River)	Electrofishing	Yes
Hegigio River	H18	6	9.887	143	3.284	Clear-water stream	Electrofishing	Yes

Footnotes: Habitat type is further described in Table 3-1. Samples were taken at as many sites as possible to make the most of the opportunity. However, the number of samples that were chosen for analysis was rationalised to select the most useful samples only. Therefore, a subset of the macroinvertebrate samples was analysed and some samples were not analysed.

2.2 Fish

2.2.1 Electrofishing

Electrofishing is the most effective method of sampling fish and crustaceans from shallow streams (see Plate 2-1). The instrument used for this study was a Smith-Root Model 12-B backpack-mounted electrofisher, able to output pulsed DC current over a range of voltages up to 1100 V and a wide variety of pulse frequencies and waveforms. Voltages used were adjusted according to conductivity measured at each site and generally ranged between 500V and 800V.

Plate 2-1 Electrofishing in a tributary of the Baia River (Camp 3)

Electrofishing was performed in a number of ways. In wide streams, the operator worked in an upstream direction, sampling all available aquatic habitats that could be accessed safely. Plastic waders, insulating gloves and a life-jacket were worn at all times to protect the operator. The electrofisher had a net sewn into the anode pole and thus animals were netted as they became stunned. An assistant, also wearing waders and gloves and a life-jacket, followed behind with a dip-net to collect animals that the operator missed.

Alternatively, in narrower streams that were fast-flowing, the assistant secured a fine-meshed net behind the operator to block-off the stream and collect animals that may be washed downstream. In this case, where capture of animals by the operator was difficult, the electrofisher was instead used to stun and 'herd' animals in a downstream direction to be collected in the net.

The instrument logs 'on-time' and this figure was recorded at each site as a measure of sampling 'effort'. In this study, the emphasis was on biodiversity assessment and thus the instrument was used to collect as many species as possible, rather than to perform quantitative sub-sampling of the population.

2.2.2 Netting and Trapping

The majority of aquatic habitats encountered in the upstream study were not suitable for gill-netting, seine netting, cast netting and trapping due to lack of areas with suitable water depth or high river flow velocities. The exceptions were the swamp habitat (site BAI2) located near the Baia River at Camp 3, which was suitable for gill-netting and trapping. At this site, one of each of three sizes of gill net (1.5 cm mesh, 2.5 cm mesh and 3.5 cm mesh) each 10 m long and 2 m deep, were set overnight. In addition, a single panel net, which was

15 m long, consisting of three 5 m long panels of different mesh size (75 mm, 100 mm and 175 mm), was set overnight. Fine-meshed baited traps were also set at this location.

Plate 2-2 Perched swamp at Baia River (BAI2)

Bait traps were able to be set at a swamp in the Juha South (Camp 2) area and a pool in a stream in Juha South (Camp 2) area.

2.2.3 Sample Processing

Fish and crustacean specimens were identified to species in the field where possible. Where the species name could not be determined, representative specimens were fixed in 10% formalin for 2-4 days, then transferred to 70% ethanol. Prior to shipping, preserved samples were drained, rinsed in freshwater, dried and repackaged. Samples were shipped to the office of Hydrobiology in Brisbane for identification. In addition, 'voucher' specimens were retained to provide a reference collection of each species recorded. Detailed specimen photographs were also taken of each species.

Specimens were measured (fork length or total length for fish and carapace length for crustaceans) and weighed using electronic scales (to the nearest 0.1 g up to 500 g and the nearest 1 g between 500 and 5000 g).

2.3 Macroinvertebrates

A 250 µm mesh kick-net was used to sample macroinvertebrates from riffle habitat. With the kick-net placed in the riffle, an area of approximately 30 cm^2 in front of the net was disturbed by hand and foot to dislodge macroinvertebrates (Plate 2-3). At each site, 5 replicate samples were obtained, working in an upstream direction. Samples were immediately preserved in 70% ethanol.

Plate 2-3 Macroinvertebrate sampling

Macroinvertebrate samples were delivered to Ecowise Environmental (Brisbane) for processing. The samples were emptied into sorting trays and all macroinvertebrate contents were removed. Specimens were identified to the family level of taxonomic classification and then enumerated.

The statistical package PRIMER v.6 was used to perform multivariate analyses of the family abundance data. To visualise the data, an ordination technique, known as non-metric MDS (nMDS), was performed which maps the distance between samples in terms of the similarity (in this case, Bray-Curtis similarity) of their respective family abundance data. Abundance data were 4^{th}-root transformed prior to analysis to normalise for the high number of zeros that is typical for macroinvertebrate abundance datasets. The ANOSIM statistical procedure was used to test for significance of groupings.

Where it was possible, macroinvertebrate families were assigned to a feeding guild. Families were divided into the following categories; predator, filter feeder, scraper, collector, deposit-feeder, collector-scraper, shredder-predator, shredder-scraper. The analysis and monitoring of feeding guilds has been demonstrated as being a useful tool for the assessment of sediment impacts. Feeding guilds that rely on very delicate feeding structures (such as filter feeders) and those that rely on algal resources (such as scrapers) are known to be particularly sensitive to sediment. Sediment impacts, therefore, can often be seen as a shift in trophic structure of macroinvertebrate communities, rather than significant changes in abundance alone. As such, baseline trophic guild proportions are given here.

2.4 Previous Studies

The proposed PNG LNG Project builds on the previously proposed PNG Gas Project, a joint venture between Chevron and South Pacific Pipeline Co. (NSR 1998; Enesar 2005). Environment impact studies for the PNG Gas Project covered the majority of the proposed pipeline route and infrastructure.

The present study represents some work done in totally new project areas (namely the Hides to Juha pipeline route and the Hides Gas Conditioning Plant) and some work to provide extra data for areas that were not covered in detail in the PNG Gas Project EIS (namely the Tagari River and the Homa to Idauwi area). Therefore, this impact assessment will be made with due consideration to the following existing bodies of work:

- DBA (2005). Supporting Study 12: Onshore Aquatic Environmental Impacts. Supporting study to Enesar (2005) Environmental Impact Assessment. David Balloch and Associates.

- Enesar (2005). PNG Gas Project EIS. Report to Esso Highlands Limited.

- NSR (1998). PNG Gas Project Environmental Plan. Existing Environment and Impact Assessment Sections. Report to Chevron Niugini Limited.

- Vui, R. (2003). A preliminary freshwater fish inventory report from Libano, proposed wildlife management area (WMA), Southern Highlands Province. A report submitted to World Wildlife Fund for Nature, Kikori Integrated Conservation Development Project.

- Various WWF reports and papers on Kikori Basin and Lake Kutubu fish fauna and resource use.

3 DESCRIPTION OF AQUATIC COMMUNITIES

3.1 Aquatic Habitats

The aquatic environment in the region from Moro to the Kikori delta, including Lake Kutubu, was studied during the EIS for the previously proposed PNG Gas Project (Enesar 2005) and will not be covered in this report. The upstream components of the PNG LNG Project are located in an area that is generally not well studied. Table 3-1 summarises the aquatic habitats present in PNG LNG Project upstream segment.

In this report the following terms are used to describe the existing habitats of the project area:

- Clear-water streams – small surface-water streams with low suspended sediment. In some places, these streams have a ground-water source;
- Sinkhole streams – small streams with low suspended sediment that terminate in, natural depressions or holes in the ground;
- Swamps and other standing waterbodies – some of these believed to have surface-water origins (i.e., depressions that collected surface runoff or receive over-bank flows from a neighbouring stream) and some believed to have groundwater origins; and
- Large turbid rivers – rivers with high discharge and visibly containing substantial levels of suspended sediment.

Examples of these habitats are provided in Table 3-1.

Table 3-1 Aquatic habitats of the upstream project area (from furthest 'upstream' to 'downstream' in the project layout

Project Segment	Approx. Altitude	Study Base	Catchment	Habitats Present	Habitat Features	Example Photographs	
Juha	900 m	Camp 2 (Juha South)	Carrington River, Strickland River Catchment	• Clear-water streams. • Sinkhole streams.	• Small (1-2 m wide) clear-water rainforest streams. • Streams that terminate in 'sinkholes'. • High canopy shading. • Substrate consisting of concreted limestone or cobble-boulders dispersed in sediment/leaf litter.	 *a) Shaded rainforest stream*	 *b) Concreted limestone stream ending in sinkhole in depressions northeast of Camp 2*
Baia River Crossing and surrounds	400 m	Camp 3 (Baia)	Baia River, Strickland River Catchment	• Large turbid river. • Clear-water streams. • Swamp.	• High velocity, turbulent, turbid Baia River mainstream, flowing over cobble-boulder substrate. Numerous rapids and eroded banks. • Small (1-2 m wide) clear-water rainforest stream tributaries. • Perched off-river water bodies with silt-mud substrate.	 *Baia River mainstream at Camp 3*	 *Baia River clear-water tributary*
						 *Perched swamp*	

Karius Ridge	1,400 m	Camp 4 (Karius)	Baia River headwaters, Strickland River Catchment	• Clear-water streams. • Sinkhole stream/swamp.	• Shallow, braided, clear-water, high-velocity stream flowing over cobble-boulder substrate. • Standing groundwater/sinkholes	 *Baia River at Camp 4*	 *Standing groundwater/sinkholes*
Hides Conditioning Plant and surrounds	1,200 m	Nogoli	Tagari River	• Large turbid river. • Clear-water streams.	• High velocity, turbulent, turbid Tagari River mainstream, flowing over cobble-boulder substrate. Numerous rapids and eroded banks. • Major clear-water tributary river – Timalia River, flowing over boulder-cobble substrate with sand beaches. • Small (2-4 m wide) turbid or clear-water surface water streams. • Small, mainly clear-water, ground water-fed streams.	 *Tagari River mainstream*	 *Timalia River*
						 *Tagari River surface water tributary*	 *Tagari River ground water tributary at source*

Homa to Idauwi Deviation region	800 m – 1,300 m	Moro	Hegigio River	• Large turbid river. • Clear-water stream.	• High velocity, turbulent, turbid Hegigio River mainstream, flowing over cobble-boulder substrate. Numerous rapids and eroded banks. • Clear-water tributary streams, flowing over boulder-cobble substrate.	 *Hegigio River mainstream*	 *Hegigio River tributary*

3.2 Fish and Macrocrustaceans

3.2.1 Juha Area

The fish fauna of the Juha area (JUH1-9) consisted of only one species; *Oxyeleotris fimbriata* (see Table 3-2). This species is common and widespread in surface water streams of the Juha area and also in those streams that terminate in sinkholes. The species is also widespread throughout other project areas and is common throughout Papua New Guinea.

Table 3-2 Fishes of the Juha area

Common Name	Species Name	Family Name	Status	Habitat		
FISH						
Fimbriate gudgeon	*Oxyeleotris fimbriata*	Eleotridae	Common/widespread	Surface water streams and sinkhole streams		
	Turbid waters					
	Clear-water tributaries					
	Swamps					

The occurrence of fish populations in watercourses upstream of deep sinkholes, into which the watercourse plunges, is an interesting observation. Many gudgeons in the family Eleotridae are known to be amphidromous, that is, eggs deposited in freshwater and are washed downstream into estuarine waters, with juveniles migrating back into freshwater. The occurrence of populations of *O. fimbriata* upstream of significant migration barriers (sinkhole waterfalls) suggests either that individuals migrating upstream are able to traverse these barriers (certainly not out of the question given observations of the climbing abilities of other related gudgeons) or that populations are reproducing in other ways, constrained to the habitat upstream of sinkholes.

It is also interesting to note that *O. fimbriata* is phylogenetically related to the blind cave gudgeon, *Oxyeleotris caeca* (Allen 1996; Romero and Paulson 2001). The blind cave gudgeon was not recorded during the present study, but was identified from locations near the Mubi River in the previous PNG Gas Project EIS (Enesar 2005). It is tempting to hypothesise that *O. caeca* may have evolved from sub-populations of *O. fimbriata* that became genetically isolated or 'stranded' in subterranean habitats due to the formation of sinkholes, such as the situation in the Juha area.

Sinkholes are located in deep gullies in the Juha area and the difficulties of such terrain may preclude pipelining. In this case, potentially sensitive fauna in sinkholes would not be exposed to direct impacts.

3.2.2 Baia River Area

The fishes recorded from the Baia River sampling sites (BAI1-8) in the region of Camp 3 are shown in Table 3-3. There was a clear differentiation between the fauna associated with the Baia River mainstream, and that associated with the clear-water tributaries and the swamp habitat. The Baia River, at the Camp 3 location, is a fast-flowing, dynamic, turbid river and, not surprisingly, the fish fauna was dominated by species that are generally believed to be among the more sediment-tolerant species.

Table 3-3 Fishes and other aquatic fauna of the Baia River (Camp 3) area

Common Name	Species Name	Family Name	Status	Habitat		
FISH						
Concave goby	*Glossogobius concavifrons*	Gobiidae	Common/widespread	Baia River mainstream riffles		
Adamson's grunter	*Hephastus adamsoni*	Terapontidae	Common/widespread	Baia River mainstream riffles		
Taylor's catfish	*Arius taylori*	Ariidae	Common/widespread	Baia River mainstream pools and riffles		
Southern tandan	*Neosilurus equinus*	Plotosidae	Common/widespread	Baia River mainstream pools and riffles		
Pale yellow tandan	*Oloplotosus luteus*	Plotosidae	Common/widespread	Baia River mainstream riffles		
Goldie River rainbowfish	*Melanotaenia goldei*	Melanotaeniidae	Common/widespread	Baia River mainstream backwaters		
Banded mogurnda	*Mogurnda cingulata*	Eleotridae	Common/widespread	Baia River clear-water tributaries and off-river swamp		
Fimbriate gudgeon	*Oxyeleotris fimbriata*	Eleotridae	Common/widespread	Baia River clear-water tributaries		
CRUSTACEANS						
Freshwater prawn	*Macrobrachium handschini*	Palaemonidae	Common/widespread	Baia River large tributary (Tikawe Creek)		
Unidentified crab	?			Baia River mainstream backwaters		
MOLLUSCS						
Unidentified shell	?			Baia River mainstream backwaters		
REPTILES						
PNG freshwater crocodile	*Crocodilus novaeguineae*	Crocodylidae	Common/widespread	Off-river swamp		
	Turbid waters					
	Clear-water tributaries					
	Swamps					

Conditions in the Baia River at the time of sampling prevented sampling in the mid-stream habitats of the river. Species recorded from this site were collected from near-edge riffles and pools. All species collected were common and widespread throughout the region.

Gobies were the most common species encountered. Fork-tailed (Taylor's catfish) and eel-tailed catfish (southern tandan) represented the main large-bodied species at this site.

Only two species of fish were recorded from the clear-water tributaries of the Baia River; banded mogurnda (*Mogurnda cingulata*) and fimbriate gudgeon (*Oxyeleotris fimbriata*). *M. cingulata* was the only species recorded from the off-river swamp.

In the Baia River, a single species of prawn, *Macrobrachium handschini*, was recorded in low numbers. A single species of crab was also recorded. Molluscs (screw-shells) were also recorded from the swamp, again in low numbers. This was the only record of prawns from the entire aquatic fauna study.

The swamp (site BAI2) located near Camp 3 was a notable habitat-type that was not observed at any of the other sampling locations (but likely to be present in other places along the pipeline alignment). A juvenile freshwater crocodile (*Crocodilus novaeguineae*) was captured in the swamp. Local labourers also reported the presence of a crocodile nest on the banks of the swamp that was found during camp construction. The swamp is small (~150 m long and ~15 m wide) and supports only small-bodied fish (*Mogurnda cingulata*) and thus is not considered to be a permanent crocodile habitat able to support a large number of adults. Rather, it is believed that the swamp may be used as a juvenile nursery habitat.

3.2.3 Karius Ridge Area

The Karius Ridge area (sites KAR1&2) lies in the headwaters of the Baia River. At this location, the Baia River is a shallow, braided, fast-flowing, clear-water river and a single species, the fimbriate gudgeon, which is found throughout the project area, and throughout PNG, was recorded here (Table 3-4).

Table 3-4 Fishes of the Karius Ridge area

Common Name	Species Name	Family Name	Status	Habitat		
FISH						
Fimbriate gudgeon	*Oxyeleotris fimbriata*	Eleotridae	Common/widespread	Baia River headwaters		
	Turbid waters					
	Clear-water tributaries					
	Swamps					

3.2.4 Tagari River Area

Sampling in the Tagari River area (TAG1-7) targeted the Tagari River mainstream, the major tributary stream, Timalia River, and smaller tributaries draining the proposed HGCP area. Sampling in the Tagari River mainstream was hampered by the high flow conditions experienced at the time of this study. Sampling was limited to near-edge habitats that were able to be accessed near suitable helicopter landing sites within the river. Usually, these were near-edge riffles. Mid-stream deeper pool habitats were not able to be sampled. The fishes recorded from the Tagari River are listed in Table 3-5.

Table 3-5 Fishes of the Tagari River area

Common Name	Species Name	Family Name	Status	Habitat		
FISH						
Concave goby	*Glossogobius concavifrons*	Gobiidae	Common/widespread	Tagari River mainstream and tributaries		
Snow trout[1]	*Schizothorax richardsoni*	Cyprinidae	Introduced	Tagari River mainstream and tributaries		
Narrow-fronted tandan	*Neosilurus ater*	Plotosidae	Common/widespread	Tagari River tributaries		
Mountain hardyhead	*Craterocephalus nouhuysi*	Atherinidae	Common/widespread	Tagari River tributaries		
Banded mogurnda	*Mogurnda cingulata*	Eleotridae	Common/widespread	Tagari River tributaries		
Fimbriate gudgeon	*Oxyeleotris fimbriata*	Eleotridae	Common/widespread	Tagari River tributaries		
	Turbid waters					
	Clear-water tributaries					
	Swamps					

Only two species were recorded from the mainstream; the concave goby and snow trout. It is expected that fork-tailed and eel-tailed catfish, and possibly other species, would be present in the Tagari River mainstream but were not able to be effectively sampled given the high flow conditions. The other species were caught from the tributary streams that were able to be more effectively sampled. All species recorded are common and widespread.

Of all the areas sampled in the upstream component of the PNG LNG Project, the sites sampled in the Tagari River area were the most densely populated by humans. This was most evident at road crossings of tributary streams, where there were numerous settlements and some vehicular traffic. Indeed, water quality analysis at these sites (TAG 4, TAG 5, and TAG 6) showed there to be higher concentrations of nitrate than other locations (see Hydrobiology 2008c). Some fishing was reported to be undertaken, but this activity is generally limited to off-channel swamp habitats that are inundated during flood conditions, or sites at the confluences to the Tagari River and clear-water tributaries (A. Flynn, pers. obs.).

3.2.5 Hegigio River Area

Fishes and crustaceans sampled from the Hegigio River area (HEG1&2 and H16-H18) are listed in
Table 3-6. Sampling in the Hegigio River mainstream was hampered by the high flow conditions experienced at the time of sampling. The Hegigio River, at the areas sampled for this study, is a very turbid and dynamic river, with numerous landslips and gorges. During this study, sampling of the Hegigio River itself was only possible at the confluence of the Hegigio River and tributaries, where helicopters were able to land and where water

[1] The snow trout is an exotic species, intentionally introduced to highland streams of Papua New Guinea by the PNG Government as part of various fisheries enhancement initiatives.

velocities were safe to work in. The upstream reaches of the tributaries were able to be sampled effectively.

Table 3-6 Fishes and crustaceans of the Hegigio River area

Common Name	Species Name	Family Name	Status	Habitat		
FISH						
Concave goby	*Glossogobius concavifrons*	Gobiidae	Common/widespread	Hegigio River mainstream and tributaries riffles		
Southern tandan	*Neosilurus equinus*	Plotosidae	Common/widespread	Hegigio River mainstream and tributaries pools and riffles		
Banded mogurnda	*Mogurnda cingulata*	Eleotridae	Common/widespread	Hegigio River clear-water tributaries		
Fimbriate gudgeon	*Oxyeleotris fimbriata*	Eleotridae	Common/widespread	Hegigio River clear-water tributaries		
CRUSTACEANS						
Freshwater crayfish	*Cherax cf. albertisii*	Parastacidae	Common/widespread	Hegigio River clear-water tributaries		
	Turbid waters					
	Clear-water tributaries					
	Swamps					

Two fish species were recorded from the Hegigio River near tributary confluences; the concave goby and the southern tandan. Both of these species are common and widespread and occur both in the Hegigio River mainstream and in the clear-water tributaries. Two additional species, *Mogurnda cingulata* and *Oxyeleotris fimbriata*, occurred in the higher-altitude reaches of the tributary streams. At the highest upstream reaches of the tributaries sampled (~1,280 m), the only fish species recorded was *O. fimbriata*. The freshwater crayfish record represented one single specimen.

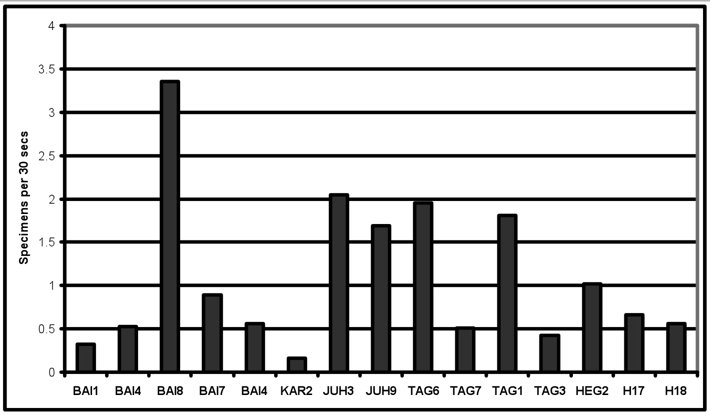
A previous study in another area of the Hegigio River catchment, which focussed on clear-water tributaries, recorded the occurrence of several other fish species and these are listed in Table 3-7.

Table 3-7 Additional species recorded from the Hegigio River area (Vui 2003)

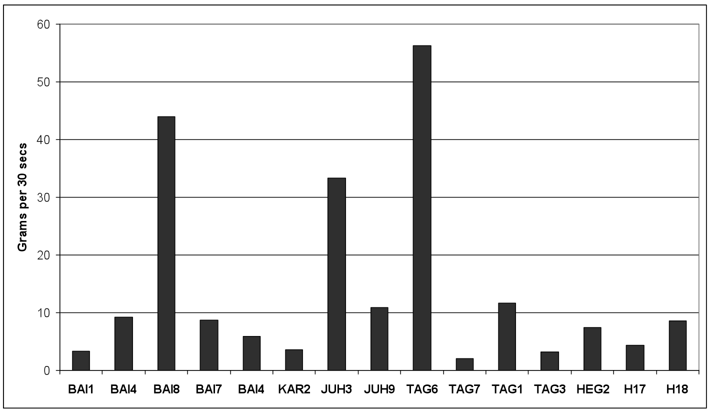
Common Name	Species Name	Family Name	Notes		
FISH					
Common carp	*Cyprinus carpio*	Cyprinidae			
Northern rivers catfish	*Arius utarus*	Ariidae	Possible misidentification – not expected to be present in this area		
Broad-snouted catfish	*Arius latirostris*	Ariidae			
Fly River garfish	*Zenarchopterus kampeni*	Hemiramphidae			
Mountain hardyhead	*Craterocephalus nouhuysi*	Atherinidae			
Kutubu hardyhead	*Craterocephalus lacustris*	Atherinidae	Considered to only occur in Lake Kutubu		
Pima hardyhead	*Craterocephalus pimatuae*	Atherinidae			
Diamond mullet	*Liza alata*	Mugilidae			
Greenback mullet	*Liza subviridis*	Mugilidae			
Strickland rainbowfish	*Melanotaenia iris*	Melanotaeniidae			
Waigeo rainbowfish	*Melanotaenia catherinae*	Melanotaeniidae	Possible misidentification – not expected to be present in this area		
Sorong rainbowfish	*Melanotaenia fredericki*	Melanotaeniidae	Possible misidentification – not expected to be present in this area		
Unidentified rainbowfish		Melanotaeniidae			
Sande's mouth almighty	*Glossamia sandei*	Apogonidae			
Lined grunter	*Hephastus lineatus*	Terapontidae	Possible misidentification – not expected to be present in this area		
Sooty grunter	*Hephastus fuliginosus*	Terapontidae			
Adamson's grunter	*Hephastus adamsoni*	Terapontidae			
Paniai gudgeon	*Oxyeleotris wisselensis*	Eleotridae			
Mountain goby	*Glossogobius sp. 3*	Gobiidae			
Twinspot goby	*Glossogobius sp. 6*	Gobiidae			
Fly River goby	*Glossogobius sp. 11*	Gobiidae			
Kutubu goby	*Glossogobius sp. 12*	Gobiidae			
Bighead goby	*Glossogobius sp. 13*	Gobiidae			
	Turbid waters				
	Clear-water tributaries				
	Swamps				

3.2.6 Abundance and Biomass

The sampling carried out for this study was necessarily a blend of exploratory and quantitative sampling. Quantitative, but un-replicated measures of abundance and biomass were able to be made at most sites where electrofishing was carried out. Figure 3-1 shows relative abundance and biomass for electrofisher catches, normalised to a 'per 30 secs' catch rate, at sites where suitable data were collected.



a). Abundance



b). Biomass

Figure 3-1 Relative abundance and biomass for electrofisher catches

These data reflect the depauperate fish and crustacean communities in the mainstream Baia River (BAI1). One of the Baia River clear-water tributaries (BAI8) was relatively productive, having high fish abundance and biomass. The habitat at this site was characterised by a reach of the tributary that descended through a rocky cascade, to then flow through a flat swampy area, creating a braided stream with numerous shallow pools (see Plate 3-1). This area had particularly high densities of *Mogurnda cingulata*.

Plate 3-1 Productive habitat at BAI8

Figure 3-1 clearly illustrates the very low abundance and biomass of fish in the high-altitude headwaters of the Baia River at site KAR2, with only one species recorded here.

The only species of fish recorded from the Juha area sites was *O. fimbriata*, but there was a greater abundance of this one species than all fish species recorded at KAR2 and most of the Baia River tributary sites.

Fish abundances at Tagari River mainstream and tributary sites were variable, but catches were highest in the Timalia River (TAG6), the major tributary to the south of Nogoli and the HGCP project area. This large catch was comprised of a number of relatively large eel-tailed catfish at this site, resulting in the catch with the highest biomass of all sites.

Catches from the Hegigio River sites were generally low, with abundance (but not biomass) being highest at the site HEG2, which was located at the junction of the Hegigio River mainstream and the Maruba River, one of the clear-water tributaries.

3.3 Macroinvertebrates

Raw data obtained from macroinvertebrate analysis[2] are given in Appendix 1. Identified organisms that were counted from each sample have been retained, preserved in ethanol and are stored at Hydrobiology's office in Brisbane.

There was considerable variability in the macroinvertebrate communities across the sampling sites, with no clear distinction between different 'catchments' (or, more correctly, study areas). Figure 3-2 shows an nMDS plot of macroinvertebrate samples, colour-coded by study area, showing that there is as much variability within each study area as there is between the study areas.

Figure 3-3 shows the same data colour-coded by river type, with the categories being 'turbid' large rivers or 'clear' smaller tributaries. This factor separates the data into more distinct groups and these groups were found to be significantly different (ANOSIM Global $R = 0.3$, $p<0.001$). This suggests that the macroinvertebrate assemblages associated with large turbid rivers are significantly different from that of small clear-water tributaries.

[2] Note that samples collected from sites JUH2, KAR1 and HEG2 were not analysed. Samples from these sites remained preserved at Hydrobiology's office in Brisbane.

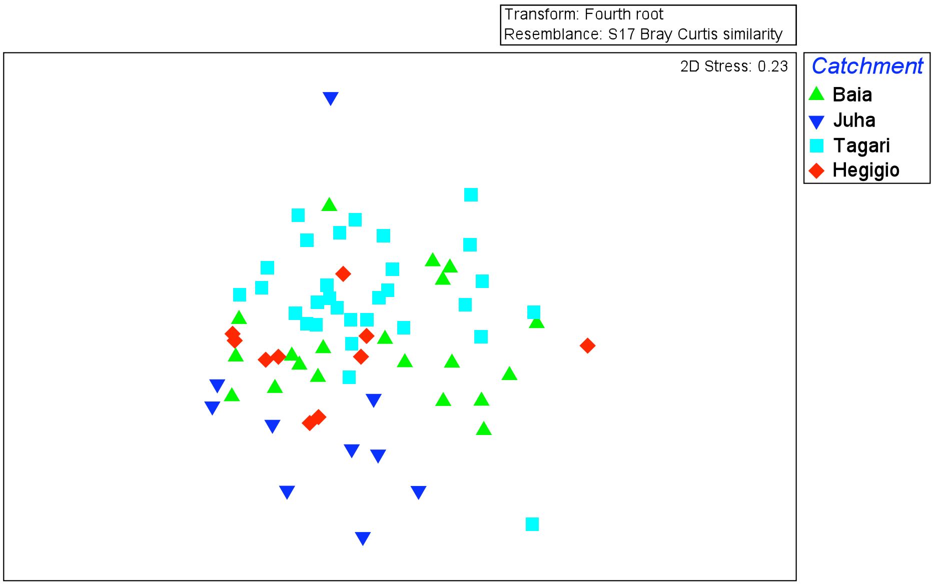


Figure 3-2 nMDS of macroinvertebrate communities based on study area

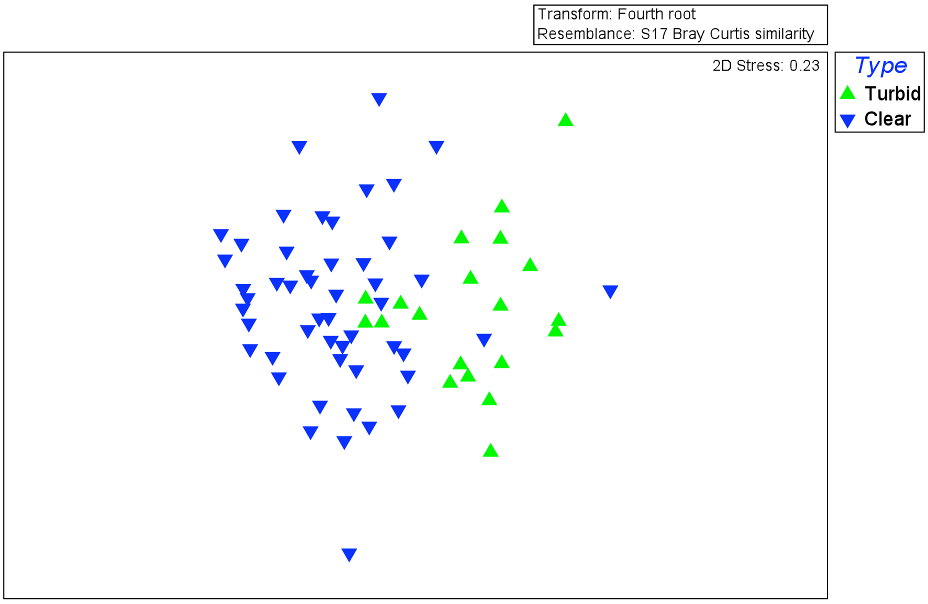


Figure 3-3 nMDS plot of macroinvertebrate communities based on river type

Absolute abundance of macroinvertebrate feeding guilds at each site, averaged across the five replicate samples, is given in Table 3-8. As some families were not able to be assigned to a feeding guild, and were thus removed from this particular data analysis, these numbers do not represent total abundance (see Appendix 1). However, these data demonstrate the low abundance of macroinvertebrates in large turbid rivers compared to clear-water tributaries (although the site TAG1 recorded a relatively high abundance).

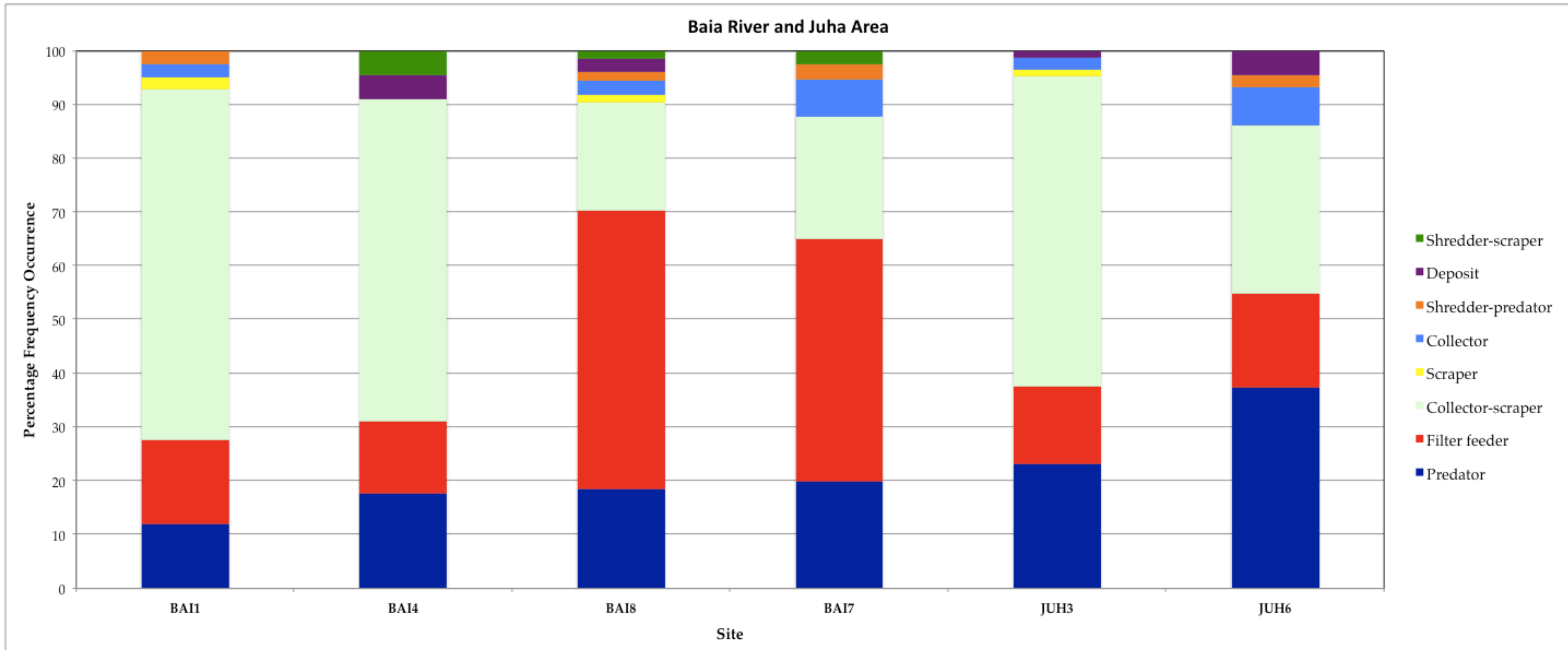
Table 3-8 Mean abundance of macroinvertebrate feeding guilds

Feeding Guild	BAI1	BAI4	BAI8	BAI7	JUH3	JUH6	TAG6	TAG5	TAG4	TAG7	TAG1	TAG3	H17	H18
Predator	5	4	38	14	20	48	11	23	7	8	6	3	22	53
Filter feeder	7	3	105	32	12	23	38	231	10	7	10	4	41	33
Collector-scraper	27	14	41	16	49	41	71	75	33	91	42	6	80	47
Scraper	1	0	3	0	1	0	2	0	1	0	1	0	25	3
Collector	1	0	6	5	2	9	1	0	0	0	1	1	7	0
Shredder-predator	1	0	3	2	0	3	3	4	0	2	0	1	2	0
Deposit	0	1	5	0	1	6	2	21	19	2	2	1	6	2
Shredder-scraper	0	1	3	2	0	0	1	1	1	0	0	1	5	2
MEAN ABUNDANCE	**42**	**23**	**203**	**72**	**85**	**129**	**129**	**356**	**72**	**109**	**62**	**17**	**188**	**139**

Turbid sites

Clear water sites

Figure 3-4shows mean proportional abundance of macroinvertebrate feeding guilds. Data from the Baia River sites most clearly demonstrates the differences in the proportion of filter feeders (generally believed to be the feeding type most sensitive to sediment) in turbid rivers compared to clear-water tributaries. Filter feeders comprise a significant proportion of the macroinvertebrate communities in clear-water streams, indicating that the ecological processes of these receiving environments are potentially more sensitive to potential sediment impacts. The collector-scraper feeding guild is also represents a high proportion of the macroinvertebrate community in clear-water streams and large rivers. This suggests that benthic algal processes or cycling of terrestrial vegetative material through the aquatic system may represent an important basis to ecological functioning in clear-water streams.



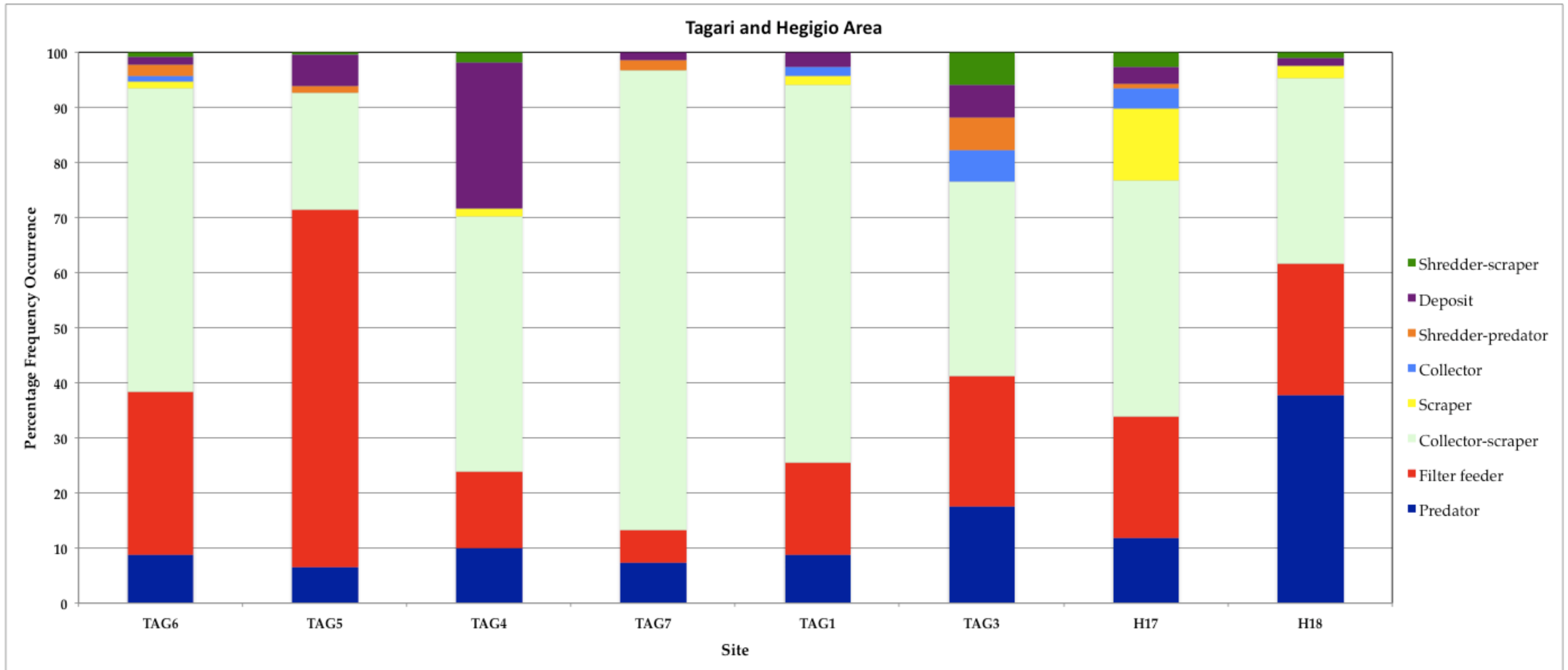


Figure 3-4 Mean proportion of macroinvertebrate feeding guilds

4 IMPACT ASSESSMENT

4.1 Impact Categorisation

Potential impacts associated with the Project will differ between the construction phase and the operation phase. The potential impacts operate on varying spatial and temporal scales and some affect aquatic ecosystems directly, while others do so indirectly. In addition, the receiving environments of the Project area have different conservation values, sensitivities and resilience. Mitigation measures may ameliorate some of the potential impacts and impacts that still remain possible after mitigation are termed 'residual impacts'. The following impact assessment considers possible impacts without mitigation, outlines possible mitigations measures, and potential residual impacts. While this assessment is based on field data collection in the receiving environment, the assessment of potential impacts necessarily involves professional judgement, based on our understanding of the project development and many years of collective experience assessing such projects in Papua New Guinea and other high rainfall tropical environments.

The following impact assessment has been carried out on the basis of watercourse type. As mentioned above, the field programs were unable to sample every watercourse crossing along the proposed route, but rather sampled representative watercourses likely to be encountered along the route.

Impact assessment involved five steps:

1. Characterisation of the range of aquatic habitat types, fauna and flora likely to occur in the Project area, the conservation significance of these and their sensitivities;

2. Identification of construction and operation activities to be carried out and assessment of how these may interact with aquatic ecosystems;

3. Identification of potential impact mechanisms associated with these activities;

4. Implementation of a procedure for rating risk that provides a consistent and transparent way of assessing the stresses associated with development activities and their potential effects on receptors; and

5. Recommendation of mitigation measures to address the potential impacts and predict the extent to which they are expected to reduce the impacts.

The results of step one are outlined in the Section 3. This section outlines the remaining steps.

4.1.1 Construction Phase

The general activities of the construction phase that could potentially impact aquatic ecosystems are:

- Pipeline and road construction (RoW clearing, trenching, bridging, pipe laying and covering), in particular, where the pipe crosses, or lies adjacent to, a watercourse;

- The construction of the Juha Production Facility (JPF); and

- The construction of the Hides Gas Conditioning Plant (HGCP).

Specific activities associated with each of these, which are relevant to this impact assessment, are outlined below.

4.1.1.1 RoW Construction

Pipeline and road construction will involve the clearing of a Right of Way (RoW). The RoW will be of varying widths, depending on the limitations of the environment, but will average approximately 22 m along most of the route within the study area dealt with in this report (i.e. Hides to Juha). At watercourse crossings, the RoW will be 10 m wide for minor crossings and up to 30 m wide for crossings of larger rivers. While the details of RoW construction and pipe-laying will evolve further leading up to construction of this segment (scheduled for approximately 2017), bulk earthworks required for the RoW construction is expected to take approximately six months. Once the RoW is cleared, trenching will advance in lengths in the order of a few hundred meters, with pipe-laying following at a suitable distance behind. Sediments dug from the trench will be stockpiled and, depending on the grade of the extracted material, will either be used to back-fill the trench or will be used as road-base. Once the pipe is laid, the RoW will be allowed to naturally revegetate back to a narrower corridor of approximately 8 m, which will be maintained as a 2-lane access road.

The RoW will intersect a number of watercourses of various types and will potentially lie adjacent to a number of watercourses or water bodies. The method used for crossing watercourses will be determined by a range of engineering and environmental constraints and this is not known for all crossings. Again, this assessment aims to categories the sensitivities and potential impacts of the watercourse types likely to be intersected along the pipeline corridor, which can then feed into a construction management plan that can inform environmental management decisions on a crossing-by-crossing basis as watercourses are encountered.

Additional earthworks will be required for supporting pipeline construction facilities; namely the construction of a small number of helipads between Hides and Juha and the construction of three wellpads in the Juha area. There will be no mid-route construction camps required for the Juha to Hides segment as personnel will be based either at the HGCP plant construction site or the JPF construction site, working out from those locations. The pipeline route will traverse a range of topographies and soil type combinations, each with a different erodibility potential.

4.1.1.2 Juha Production Facility Construction

The region where the Juha Production Facility (JPF) is to be built is bound by the Karius Range to the north and east and by the Carrington River to the south. The site is approximately 45 km northwest of the Hides Gas Conditioning Plant (HGCP) site and is in a sparsely populated area.

The construction phase will involve the building of a construction camp and access roads to support construction labourers and the construction of the operations camp, new wells and well heads. Wells and wellpads will be located to the west and northwest of the JPF site, with a steep gorge separating the southern from the northern wellpad sites. The wellpads will placed at intervals of hundreds of metres along this ridge line. Each wellpad will only require an area of the scale of tens of square metres to be cleared and this area will fall within the RoW corridor, such that no clearing will be required over and above that carried out as part of pipeline construction. Drilling new wells may or may not require the use of very limited quantities of foam drilling fluids depending on the need for drilling fractured upper limestone in the Juha region.

The operations camp will encompass the construction of residential areas, the industrial area, a helipad, a sewage treatment facility and a telecommunications tower. Given that the JPF will be maintained by a small number of staff on an intermittent basis and, given the constraints of the topography on development, the required footprint area for the JPF will be relatively small.

4.1.1.3 Hides Gas Conditioning Plant Construction

The construction of the Hides Gas Conditioning Plant (HGCP) will involve the building of a construction camp and access roads to support construction labourers and the construction of the operations camp, new wells and wellpads. The HGCP and associated facilities are to be constructed at the southeast base of the Hides Ridge approximately 2 km north-northeast of the existing village of Laite. Wellpads will be located along the crest of the Hides Ridge, which rises to the northwest of the HGCP site and the construction of these wellpads and connecting RoW is not covered in this report.

The footprint for the operations camp for the HGCP and associated infrastructure will be somewhat larger than that for the JPF.

The construction of the HGCP will involve the following activities:

- Transport to and onsite construction of the various facility compounds;
- Transport and storage of a range of materials and compounds (mainly fuel);
- Handling and treatment of waste;
- Use of vehicles for transporting staff and goods;
- Construction of holding ponds, drains and bunds; and
- Stockpiling and management of topsoil, spoil and road base material.

4.1.2 Operation Phase

The general activities of the operation phase that could potentially impact aquatic ecosystems are:

- Management of waste collection facilities (e.g. separation pits, sumps and retention ponds draining industrial facilities);
- Use and maintenance of road infrastructure;
- Transport and storage of a range of chemical compounds (mainly hydrocarbons); and
- Movement of support staff (and potentially non-support staff) into and out of the Project area.

4.1.3 Potential Impacts

A number of potential impacts have been identified and these fall into three broad categories:

- Potential impacts to physical aquatic habitat (direct impacts to habitats and indirect impact to fauna and flora);

- Potential impacts to water quality (indirect impact to fauna and flora); and

- Potential impacts to biological communities (direct impact to fauna and flora).

Table 4-1 shows which potential impacts are associated with each activity and project phase. This table shows that there are more potential impacts associated with construction than operation.

Table 4-1 Potential impacts
C = Construction Phase, O = Operation Phase

Activity / Impact mechanism		Pipeline construction	Well and well pad construction	Road construction	Stockpiling materials	Camp infrastructure construction	Hydrotesting	Storage and transport of chemicals	Waste management	Use and maintenance of roads	Pipeline operation
Impacts to Physical Habitat	Reduction / modification to riparian habitat	C		C							
	Sediment	C	C	C	C	C				C, O	
Impacts to Water Quality	Metals mobilisation	C	C	C	C	C				C, O	
	Release of hydrotesting water into waterways						C				
	Release of drilling fluids into waterways		C						O		
	Accidental chemical (fuel) or wastewater spills	C	C	C		C		C, O	O	C, O	O
Impacts to Biological Communities	Sediment	C	C	C	C	C				C, O	
	Introduction of exotic species	C	C	C		C,O		C,O		C, O	

4.1.3.1 Impacts to Physical Habitat

The mechanisms that could lead to impacts to physical habitats are:

- Direct physical damaged/reduction/modification to riparian habitat; and
- Sediment mobilisation.

Riparian Habitat Modification

Riparian habitat is a key component of aquatic ecosystems, providing stream shading, structural habitat (e.g. tree root habitat, snag habitat and aquatic insect emergence habitat), stream bank stabilisation (erosion protection) and detrital food sources. Some riparian vegetation will need to be cleared at RoW watercourse crossings. This activity will be restricted to the construction phase.

Sediment Mobilisation

Sediment is mobilised through natural erosion processes, and aquatic ecosystems in the study area are likely to be exposed to periodically elevated turbidity (particularly in the larger river systems). Sediment impacts are expected to be potentially more severe in habitats characterised by lower turbidity, such as tributary, sink hole or off-channel wetlands. Fauna and flora in these habitats are generally adapted to clear-water conditions and are therefore considered less tolerant of sediment impacts.

Watercourse crossing construction could increase sediment mobilisation through a combination of heavy equipment use and trampling effects in the vicinity of banks and the removal of riparian vegetation in the RoW corridor. Sediment from side-cast materials from pipeline trenches that are positioned near waterways may be mobilised if heavy rainfall occurs during construction. Other construction-related activities will involve the clearing of terrestrial vegetation and some of this work will be carried out on steep terrain. Heavy rainfall during the construction phase may erode exposed sediments on these slopes into waterways, a process that would be exacerbated where highly erodible soil types exist.

During both the construction and operation phases, use of access roads could also result in sediment inputs to watercourses, mainly via road runoff.

The generalised effects of sediment on aquatic habitats and organisms were outlined in previous EIS documents produced for the previous gas project (NSR 1998, DBA 2005) and these will not be repeated in total here. In summary, the effects of sediment to habitats can be described as:

- Increased sedimentation, causing smothering or in-filling of fine-scale habitat, such as interstitial spaces. This may also alter detrital carbon cycling processes; and
- Increased suspended solids concentration, causing scouring of fine-scale habitat structure, such as egg-laying surfaces, and diminishing light penetration for primary production by plants.

4.1.3.2 Impacts to Water Quality

The mechanisms that could lead to changes in water quality are:

- Mobilisation of sediments (described above);

- Mobilisation of metals associated with sediments;
- Release of hydrotesting water;
- Release of drilling fluids into waterways; and
- Accidental chemical or wastewater spills.

Mobilisation of metals associated with sediments

Activities that could potentially lead to increased sediment mobilisation could also result in increased metal mobilisation through erosion of metals-enriched sediment. The types and quantities of metals released will depend on the geology in construction areas. Sediment sampling undertaken for this study (see Hydrobiology 2008c) showed that river bed and bank sediments are naturally very low in metals, although geologically active, metal-enriched sediment may be encountered at some areas in the Project area. The bioavailability of sediment-related metals depends on a number of factors. Metals often bind to fine suspended particles or form biologically inert compounds (e.g. metal ligands) and these forms are not bioavailable. Water pH can affect the extent to which metals are represented in their dissolved form and, hence, the bioavailability of metals. Generally, greater metal bioavailability occurs in waters of lower pH. The toxicity of released metals to aquatic biota will depend on pH and water hardness with toxicity generally increasing in 'soft' water and pH affecting the chemical speciation of metals (some of which are more toxic than others). In general, the waters sampled in baseline studies (see Hydrobiology 2008c) do not have properties that would be expected to increase the bioavailability of sediment-bound metals and therefore this potential impact is deemed to have a very low likelihood.

Release of hydrotesting water

Corrosion inhibitor, oxygen scavenger and biocide compounds may be added to hydrotesting water to reduce rusting and biofouling of the pipeline. These compounds may enter watercourses, possibly resulting in toxicity to fauna.

Release of drilling fluids

Small quantities of untreated foaming agents, corrosion inhibitors, and possibly bentonite clay and polymers may be released during drilling in some areas. These agents may enter groundwater and, subsequently escape into surface waters, potentially resulting in toxicity to fauna.

Accidental chemical or wastewater spills

Accidental chemical and wastewater spills associated with the Project are likely to primarily involve hydrocarbons such as oils, petrol and grease or sewage wastewater. Obviously, the potential impacts depend on the size of spillages, but with good environmental management, with special consideration to the risks associated with construction vehicles working in or near streams, the potential impacts should be very minor.

4.1.3.3 Impacts to Biological Communities

The impact mechanisms that could result in potential impacts to biological communities are:

- Sediment; and

- The introduction of exotic species.

Sediment

In addition to the potential effects of sediment to physical habitat outlined above, sediment can have direct and indirect effects to fauna and flora itself. The generalised effects of sediment to fauna and flora have been described in EIS documentation for the previous gas project and will not be repeated in total here (NSR 1998, DBA 2005). In summary, the potential effects can be summarised as follows:

- Impacts to food resources:
  - Scouring or smothering of fine benthic structure and food resources; and
  - Reduced primary production due to decreased light penetration.
- Impacts to fauna:
  - Abrasion of fine body integuments;
  - Scouring or smothering of egg masses or larvae; and
  - Reduced success of visual-based predatory or reproductive behaviours.

Sediment is considered to be the primary stressor associated with this project and potential impacts are expected to be highest during the construction phase. RoW earthworks adjacent to watercourses and stream crossings are likely to be the most important causes of sediment mobilisation. Again, communities associated with clear-water tributaries are generally considered to be more sensitive to those inhabiting turbid rivers.

Introduction of exotic species

Introductions of noxious weeds and/or exotic fish species could have impacts on the region's indigenous fauna. Introductions could be accidental (e.g. washing down machinery covered with noxious weed plant debris or seed stock) or intentional (e.g. release of fish into waterways for fishing). It is pertinent to note that the baseline surveys recorded the occurrence of an introduced fish species, the snow tout (*Schizothorax richardsoni*) in the Tagari catchment. This species was intentionally introduced in a number of highland rivers by the PNG Government in a program to increase fisheries resources. The impacts of this, and other introductions, on local fauna have not been assessed. This, or other species, may come to populate other highland catchments through natural dispersal, but the Project should aim to not accelerate this process.

4.1.3.4 Assumptions and Exclusions

Hydrotest Water

Hydrotesting will be required prior to pipeline commissioning. Hydrotesting will involve the abstraction of water from one part of the study area and the transfer of that water to another part of the study area (and potentially another catchment). Anti-corrosion and biocide compounds may be added to water used for hydrotesting to prevent pipeline corrosion or biofouling. Hydrotest water may be recycled for use in other areas of the project, or some proportion of the water may be discharged into watercourses. Hydrotest water will be treated to meet environmental guidelines prior to discharging into watercourses. For the purposes of this assessment, it has been assumed that, the volumes of hydrotest water that may be discharged to watercourses will be small compared to the flow of the system from which water is abstracted or discharged. Potential water quality impacts are assessed here, but it is assumed that the extraction or discharge of hydrotest water will not cause significant alterations to the hydrology of watercourses and so hydrological impacts are not included here.

Fishing Pressure

It is assumed that the fishing in the waterways around the JPF and HGCP will be controlled by on-site hunting/fishing rules. Therefore, it is assumed that there will be no increases in fishing pressure in the project area, at least not directly attributable to the development of the project, and potential impacts of increased fishing pressure are not assessed here.

4.2 Sediment Transport and Suspended Solids Calculations

Through a separate study, Hydrobiology assessed hydrology and sediment transport aspects of the upstream project and this study generated calculations of sediment delivery and suspended solids concentrations at the Baia River and Tagari River (Hydrobiology 2008e). Potential impacts to aquatic fauna related to sediment mobilisation into watercourses are the most important potential impacts to be considered for the upstream project. The key findings of the hydrology and sediment transport study (Hydrobiology 2008e), summarised in this section, form the basis of the assessment of potential sediment-related aquatic fauna impacts.

4.2.1 Sediment Delivery from RoW Construction

The sediment transport capacity and resultant TSS capacity for the Baia and Tagari rivers was modelled to understand the baseline sediment characteristics of these rivers (Table 4-2).

Table 4-2 Upper and lower potential sediment transport rates for the Baia and Tagari rivers for 10%, 50% and 90% exceedence flows.

	Baia River			Tagari River		
Flow Scenario	Q_{10}	Q_{50}	Q_{90}	Q_{10}	Q_{50}	Q_{90}
Discharge (m^3 / s)	365	93	44	389	99	49
Sediment Transport (t / day)	150681 -166731	22513 -24839	7619 -8398	72277 -81453	9368 -10575	3064 - 3454
TSS (mg / L)	4256 -4709	2491 -2749	1788 -1971	1921 -2164	971 -1095	653 - 736

NB. "Q_x" refers to the percent of the time that this discharge is exceeded. For example, Q_{10} indicates river flow exceeds this discharge only 10 % of the time.

Secondly, rules were applied to define the ratio of disturbed sediment entering a watercourse, depending on its distance between the construction site and a watercourse. Zones were defined according to distance from the nearest watercourse, with delivery ratios set for both coarse and fine sediment for each zone. The size of these zones was set arbitrarily according to Hydrobiology (2008e). The adopted values are presented in Table 4-3.

Table 4-3 Delivery ratios for coarse and fine sediment for the three delivery zones.

Zone	Distance from River	Delivery ratio (<125 µm)	Delivery ratio (>125 µm)
1	< 0.5 km	0.5	0.3
2	0.5 km – 2.0 km	0.3	0.2
3	> 2.0 km	0.2	0.1

Finally, calculations were made as to the construction-related input of sediment and the result this has on suspended solids concentration. This calculation was made for both the <125 µm sediment fraction and the total sediment fraction and the calculations were made for the Tagari River (Table 4-4) and the Baia River (Table 4-6). The <125 µm fraction is generally believed to contribute more to the suspended load (and thus influence TSS more), while heavier fractions are believed to be generally more associated with bed loads. Again, the detailed methods and assumptions associated with these calculations (which are made for a worst-case scenario month of worst impact) are described in Hydrobiology (2008e).

Table 4-4 Potential impacts to the Tagari River TSS (highlighted in green) resulting from RoW clearance during the month of maximum impact.

Exceedence value		10%	50%	90%
Discharge (m3 / s)		389	99	49
Potential Transport Rate (t / day)	Upper	81,453	10,575	3,454
	Lower	72,277	9,368	3,065
Potential TSS (mg / L)	Upper	2,164	1,095	736
	Lower	1,921	971	653
250 m Progress Rate				
Added Total Load (t / day)		8,396	2,799	933
Added < 125 µm Load (t / day)		5,254	1,751	584
Added Total TSS (mg / L)		250	326	219
Added < 125 µm TSS (mg / L)		156	204	137
Added <125 µm (% of Potential TSS)		7%	19%	19%
500 m Progress Rate				
Added Total Load (t / day)		17,621	5,874	1,958
Added < 125 µm Load (t / day)		11,080	3,693	1,231
Added Total TSS (mg / L)		525	685	460
Added < 125 µm TSS (mg / L)		330	431	289
Added <125 µm (% of Potential TSS)		15%	40%	40%

NB. Exceedence values refer to the percent of the time that this discharge is exceeded. For example, 10 % indicates river flow exceeds this discharge only 10 % of the time.

If the assumption is made that the conditions experienced in the Tagari River at the time of aquatic fauna and water quality sampling represented 'median' flow conditions, the calculated results for total TSS during construction, in terms of elevation above background, are summarised in Table 4-5.

Table 4-5 Calculated percentage increase in total TSS in the Tagari River above instantaneous background measurement in median conditions.

	Mean Total TSS measured in field (mg/L)	Added Total TSS (mg/L) at 50% Flow	Total TSS (mg/L) During Construction at 50% Flow	Percentage increase above background
Tagari River (250 m Progress)	154	326	480	312%
Tagari River (500 m Progress)	154	685	839	545%

Sediment calculations for the Baia River are given in Table 4-6. The Baia River has a similar modelled discharge to the Tagari River, but has a higher modelled background sediment transport rate and thus higher modelled background potential TSS.

Table 4-6 Impacts to the Baia River TSS resulting from RoW clearance during the month of maximum impact. Impacts to TSS are highlighted in green.

Exceedence value		**10%**	**50%**	**90%**
Discharge (m3 / s)		365	93	44
Potential Transport Rate (t / day)	Upper	166,731	24,839	8,936
	Lower	150,681	22,513	8,106
Potential TSS (mg / L)	Upper	4,709	2,749	2,020
	Lower	4,256	2,491	1,832
250 m Progress Rate				
Added Total Load (t / day)		11,644	3,881	1,294
Added < 125 µm Load (t / day)		7,241	2,414	805
Added Total TSS (mg / L)		369	482	323
Added < 125 µm TSS (mg / L)		229	300	201
Added <125 µm (% of Potential TSS)		5%	11%	10%
500 m Progress Rate				
Added Total Load (t / day)		24,174	8,058	2,686
Added < 125 µm Load (t / day)		14,984	4,995	1,665
Added Total TSS (mg / L)		766	1000	670
Added < 125 µm TSS (mg / L)		475	620	415
Added <125 µm (% of Potential TSS)		10%	23%	21%

NB. Exceedence values refer to the percent of the time that this discharge is exceeded. For example, 10 % indicates river flow exceeds this discharge only 10 % of the time.

Assuming conditions in the Baia River encountered during the field sampling program represented 'median' conditions, the impact to TSS can be summarised as in Table 4-7.

Table 4-7 Calculated percentage increase in total TSS in the Baia River above instantaneous background measurement in median conditions

	Mean Total TSS measured in field (mg/L)	Added Total TSS (mg/L) at 50% Flow	Total TSS (mg/L) During Construction at 50% Flow	Percentage increase above background
Baia River (250 m Progress)	195	482	677	347%
Baia River (500 m Progress)	195	1000	1195	612%

4.2.2 Sediment Delivery from HGCP Construction

Sediment transport and TSS calculations were also made for the Tagari River with respect to disturbance related to the construction of the HGCP. The incremental increase in sediment contributed to the system from construction of the HGCP is relatively minor compared to that of the RoW construction (Table 4-8).

Table 4-8 Tagari River TSS impacts within the month of maximum impact (Month 2) resulting from the construction of the HGCP.

Flow Scenario	Discharge (m^3 / s)	Current Transport Rate (t / day)		Current TSS (mg / L)		Added Load (t / day)	Added TSS (mg / L)
		Upper	Lower	Upper	Lower		
10%	388.59	81453	72277	2164	1921	3,264	97
50%	99.22	10575	9368	1095	971	1,088	127
90%	49.22	3454	3065	736	653	363	85

With this additional sediment input, which will occur over a short time frame, the total incremental increase in TSS in the Tagari River, again, assuming median conditions were experienced in the field, is given in Table 4-9.

Table 4-9 Calculated cumulative percentage increase in total TSS in the Tagari River above instantaneous background measurement in median conditions.

	Mean Total TSS measured in field (mg/L)	Added Total TSS (mg/L) from RoW at 50% Flow	Added Total TSS (mg/L) from HGCP at 50% Flow	Total TSS (mg/L) During Construction at 50% Flow	Percentage increase above background
Tagari River (250 m Progress)	154	326	127	607	394%
Tagari River (500 m Progress)	154	685	127	966	627%

Like many of Papua New Guinea's highland rivers, both the Tagari and Baia rivers are highly dynamic systems that experience large fluctuations in natural sediment loads. High rainfall episodes and landslides (which do appear to be frequent in both catchments) contribute sediment to the river systems. The single 'snap-shot' sampling survey undertaken for this study is not able to define the natural range of sediment conditions in the rivers.

Modelling of the rivers has derived *potential* TSS loads and these are significantly higher than the values measured in the field, indicating that the rivers are carrying a lower sediment load than what they could *potentially* carry (in the absence of natural sediment-delivery controls such as vegetation). Therefore, for the purposes of this impact assessment the figures presented above should not be viewed as absolute numbers against which some guideline or threshold values of tolerance of aquatic organisms can be compared. Rather, the sediment delivery and TSS figures are built into the assessment framework (Section 4.3), along with information about likely organism sensitivities, to develop the impact assessment.

4.2.3 A Note on Clear-water Tributaries

As described above, clear-water tributaries, sinkhole streams and off-channel water bodies generally have a higher sensitivity to sediment input compared to large, turbid rivers. The sediment delivery and TSS calculations presented above are for the Baia River and Tagari River main stems. While the sediment conditions in clear-water streams themselves were not modelled, implicit in the modelling is that sediment is transported to these main stems in tributaries that drain the construction areas or is transported as overland runoff. Table 4-3 shows that, if a disturbance site is, for example, >2 km from a main stem, about 20% of the fine sediment fraction, and about 10% of the coarse sediment fraction will be transported to the main stem. It follows that if the disturbance site is close to a stream, then the majority of this sediment will be transported within the tributary stream, potentially creating high-sediment conditions in the stream. This suggests that sediment from construction activity near clear-water tributaries needs to be managed appropriately.

Perhaps the clearest example of this is the proposed HGCP site, where several tributary streams drain the construction site and connect to the Tagari River (Figure 4-1). Modelling results (see Table 4-8 and Table 4-9) are available only for the Tagari River but it is reasonable to expect that the tributary streams would be the primary conduit for sediments to be transported from the construction site to the Tagari River main stem and thus, for a short time, may be exposed to approximately the same TSS increases as those modelled for the Tagari River.

Figure 4-1 Location of proposed HGCP site

4.3 Impact Assessment Method

4.3.1 Method Description

A risk-ranking method was applied to evaluate the risks to aquatic biota associated with the various potential impacts identified in Section 4.1. Definitions of consequence and likelihood have been tailored to the aquatic environment and the nature of potential impacts likely to be associated with this Project. Definitions of scale and duration used to define consequence have been made consistent with those used in the previous EIS (Enesar 2005). This will help make risk predictions derived for the newly studied upstream reaches comparable with those made in the previous EIS. The impact assessment method documents the decisions taken to arrive at an impact rating, while also taking into consideration the elements of confidence surrounding each prediction.

The risk assessment method used in Enesar (2005) outlined whether the severity of potential impacts would be expected to stay the same, increase or diminish over time. This information has been incorporated into the method adopted for this study.

The full details of the steps involved in the impact assessment are outlined in Appendix 2.

4.3.2 Data Confidence and Assumptions

The following points are made in relation to the assumptions of the impact assessment and confidence in predictions:

- The baseline survey was a snap shot assessment in a poorly-studied area and this limits the ability to extrapolate results to other times of the year / flow conditions.
- The presence of rare or endemic species cannot be discounted, particularly species associated with sinkholes that were not targeted for sampling;
- Sampling in the Hegigio River and Tagari River was hampered by flood conditions and fish community data are under-representative;
- The responses of PNG fauna to various project-related stressors are not well known or published in scientific literature. However, Hydrobiology has considerable experience in assessing impacts, with a particular emphasis on sediment-related impacts, on PNG freshwater fauna and experience with fixed and linear infrastructure projects; and
- The rating of confidence in the impact assessment tables below take into consideration the experience gained by Hydrobiology in first-hand observations of accidental spills/releases and routine monitoring biological impacts of various project in Papua New Guinea and other sites in the tropics.

4.4 Mitigation Measures

Mitigation measures to be adopted to ameliorate the potential impacts of the project on the aquatic ecosystem were developed in workshops involving specialists and the proponent. Table 4-10 outlines the mitigation measures that the proponent has committed to, and the following impact assessment rates the potential impacts with and without mitigation, to highlight the effect of the mitigation.

Table 4-10 Mitigation measures relevant to aquatic ecosystems

Mitigation Measure	Relevant Period	
	Construction	Operations
Prohibit transportation of live animals, plants or seeds to the Juha or Hides Ridge areas.	X	X
At Hides Ridge, hydrotest water sourced off the Ridge will be discharged into the same watershed as its source to prevent cross-contamination with live organisms from another catchment.	X	
Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROW/access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses.	X	
On Hides Ridge and between Hides Ridge and Juha, align the route to bypass potentially high-value conservation swamps or swamps in sinkholes <50 m deep where practicable. At sites where this is impractical reduce side-cast into these high value habitats.	X	
Provide protection for stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m, to reduce entry of erosion material.	X	
Prohibit disposal of any waste into forest, streams or sinkholes.	X	X
Dispose of drilling fluids, drilling cuttings and other drilling materials in an appropriate manner away from Hides Ridge.	X	
Dispose of wastes from ROW/access way construction activities (not spoil) and camps (including the drilling camp) away from Hides Ridge.	X	X
Waste management procedures will be established to control and appropriately manage all non-biodegradable materials.	X	X
Manage sewage in an appropriate manner to limit environmental contamination.	X	X
Prohibit washdown or fuel handling near or in streams.	X	X
Establish appropriate fuel handling transport and storage procedures in EMPs.		
Where practicable, trees felled into watercourses will be removed and used for revegetation works.	X	
Where practical, stabilise cleared banks to provide a suitable habitat for recolonisation.	X	X
Where practicable, the pipeline ROW/access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses.	X	
Conduct fine-scale routing of the ROW/access ways to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable.	X	
At some watercourse crossings, where the watercourse is considered too large and fast-flowing for the use of conventional open-cut trenching methods, horizontal directional drilling may be used to install the pipeline.	X	
Implement good industry-practice management of in-stream activities where practicable to limit the downstream extent of turbid water created by trenching (e.g., the use of sediment-trapping devices such as silt curtains), particularly for watercourses that have either beneficial uses or flow on to sensitive habitat downstream of project works.	X	
For watercourse crossings at which horizontal directional drilling techniques are used, a drilling fluids and cuttings management system, including drill cuttings settlement and slurry containment pits, will be implemented.	X	
Develop hydrotest disposal management plan that includes adherance to guidelines and measures as follows:	X	

– Disposal of hydrotest waters in accordance with good industry-practice engineering codes for system gauging, hydrotesting and disposal. – Measures to hold and treat hydrotest waste water where necessary prior to release so the quality meets the requirements of the relevant water discharge permit. – Pre-discharge sampling and analysis of hydrotest water to check that quality complies with the conditions attached to the relevant water discharge permit. – If the waste water is to be discharged to land for infiltration, the outflow energies will be dissipated (e.g., via sprinkler or T-bar arrangements) to prevent problematic soil erosion.		
Fuel, lubricating oils and chemicals will be stored in appropriately-sized designated areas that have impervious liners and bunds, or are in double-hulled tanks. This includes temporary fuel stores along the ROW and access roads.	X	X
Procedures for vehicle/equipment refueling will be implemented to prevent spillages, and appropriate spill containment equipment will be available at refuelling sites and construction sites. All drivers will be appropriately trained in emergency spill response procedures.	X	X
Vehicles and machinery maintained to a high level of safety with respect to leaks. Drivers will be appropriately trained and have the required driving licence.	X	X
Operations sites will be designed to intercept potentially contaminated water.	X	X
The washing of equipment, vehicles or machinery near or within watercourses will be prohibited.	X	X
An appropriate number of staff will be trained in the handling of emergency response and spill scenarios.	X	X
The duration of construction activities at watercourse crossings will be as short as practicable.	X	
The construction of bridges, abutments and in-river bridge supports (where needed) will take into account the hydraulics of the watercourse in their design to provide long term stability and to limit flow disruptions.	X	
Develop an erosion and sediment control plan for all construction-related activities to: – Implement good industry practice erosion and sediment control measures at watercourse crossings, as necessary. – Prohibit stockpiling spoil and topsoil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline). – Control sediment runoff from stockpiles and cleared areas around watercourses. – Implement sediment control measures downstream of sidecast material where safe and practicable. – Limit erosion and sediment delivery to streams from new quarries. – Prohibit side-casting material directly into waterways where practicable. – Grade pipeline ROW/roadway alignments adjacent to streams away from watercourses. – Monitor and maintain erosion and sediment control measures until adequate soil stabilisation has been achieved. – Install diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas. – Install sediment control structures to intercept sediment-laden surface runoff to reduce sediment delivery to watercourses. – Monitor for and rectify areas of problematic erosion at reclaimed watercourse crossings.	X	
Reduce construction activities in areas prone to mass failures by fine-scale route selection during detailed design.	X	
River / stream crossings will be limited in areas of high, unstable banks.	X	
Develop a watercourse crossing construction management plan that addresses the	X	

sensitivities of crossings on an individual watercourse basis. Plans are to consider, where relevant: – Watercourse diversions requirements. – Disturbance limits. – Equipment limitations. – Erosion control measures. – Fine-scale routing at crossing sites to limit disturbance of particularly large and established riparian vegetation and complex bank habitat structure. – Delay the clearing of banks of watercourses for temporary vehicle crossing until the need for the crossing is imminent, where practicable.		
Where practical, restrict public access to watercourses on new access roads and those near the Juha Production Facility and Hides Gas Conditioning Plant.	X	X
Develop and implement water quality management plans to protect and monitor water quality downstream of the Hides Gas Conditioning Plant and the Juha Production Facility.	X	X

4.5 Clear-water Streams, Sinkhole Streams and Off-channel Water Bodies

4.5.1 Existing Conditions

Much of the upstream Project area is in pristine rainforest where there are no existing anthropogenic impacts. The area of the proposed HCGP is the most densely-populated part of the study area. A number of settlements are located adjacent to watercourses draining the proposed HGCP area and water quality sampling (see Hydrobiology 2008c) recorded elevated nitrate concentrations in some streams, probably related to human waste, animal waste and domestic washing activities. Existing impacts to riparian vegetation (and thus bank stabilisation) were also observed in this area.

There are some abandoned exploration wells in the Juha area and currently unused wells in the Hides area (Plate 4-1). These structures are small in area (tens of meters squared) and, if commissioned and decommissioned appropriately, these structures should represent a very low level of existing impact with negligible persistent releases of hydrocarbons.

Permanently filled off-channel wetlands and sinkholes are regarded as high value habitat given that they represent a unique habitat in karst country. Tracer experiments reported in the previous gas project EIS (Enesar 2005) confirmed that there are hydrological linkages between groundwater and surface water streams. However, existing impacts to sinkholes or other groundwater bodies from previous exploration and other activities are expected to be negligible.

a). Abandoned exploration well at Juha camp

b). Unused Hides 4 well

Plate 4-1 Currently unused wells in the Juha and Hides area

4.5.2 Sensitivities

Fish species encountered during the baseline survey represent those that are widely distributed in the region and PNG. No rare or endemic species were recorded. This finding corroborates with fish data presented in the previous gas project EIS (Enesar 2005).

It is assumed that fish and invertebrates inhabiting clear-water streams, sinkholes and off-channel water-bodies are generally more sensitive to sediment-related impacts than those inhabiting turbid rivers. The fish fauna of clear-water streams, sinkholes and off-channel waterbodies includes species that have life-history traits that are sensitive to sediment, such as nest-building and active egg guarding and egg-laying on delicate structure. In addition, clear-water streams and off-channel wetlands hosted one of the few colourful fish species in the study area (the banded mogurnda – *Mogurnda cingulata*). This species may rely on its colour for mating displays (i.e. visual mating cues). In general, communities associated with high-altitude streams are also considered to have slower recovery/recolonisation processes than those associated with the mainstream communities of large rivers. This is due in part to the geographic isolation of the high-altitude streams and thus the longer time frame for recruitment back into an affected area, should impacts occur.

Permanently filled swamps in sinkhole habitat, such as that occurring in the Hides Ridge area (identified in Enesar 2005) and the upper Baia River catchment and the perched off-channel water body in the Hegigio River catchment are regarded as having high environmental values (see Plate 4-2). Such standing bodies are theoretically more susceptible to project-related impacts as they may contain sensitive fauna and generally less resilient habitats, because they lack the dilution and dispersion capacity of flowing streams.

a). Inundated sinkhole habitat near the South Karius fly camp (4)

b). Perched lake and surrounding wetlands near the Homa-Idauwi section of the Hegigio River

Plate 4-2 Examples of potentially sensitive standing water bodies in the project area

4.5.3 Impact Assessment

4.5.3.1 Impacts to physical habitat

Table 4-11 provides a summary of the impact assessment for potential impacts to physical habitat in clear-water environments. In this table, risk ratings are provided for circumstances with and without the recommended mitigation measures in place. While the predicted risk ratings are generally low even with no mitigations in place, proposed mitigation are expected to reduce the risk impacts to physical habitats to a very low to negligible level.

4.5.3.2 Impacts to water quality

Table 4-12 provides a summary of the impact assessment for potential impacts to water quality in clear-water environments.

4.5.3.3 Impacts to biological communities

Table 4-13 provides a summary of the impact assessment for potential impacts to biological communities in clear-water environments.

Table 4-11 Impact assessment - physical habitat impacts – clear-water habitats

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Removal Riparian Vegetation and Modification of Bank Structure	Without	Site (1)	Low (1)	Long (3)	Low	Definite	Low	Negative (S)	High
	With	Site (1)	Low(1)	Long (3)	Low	Probable	Low	Negative (S)	High
Increased Sediment Mobilisation	Without	Local (2)	Moderate (2)	Short (1)	Low	Probable	Low	Negative (D)	High
	With	Site (1)	Low (1)	Short (1)	Very low	Probable	Very Low	Negative (D)	High

Table 4-12 Impact assessment - water quality – clear-water habitats

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Increased metal mobilisation and bioavailability	Without	Local (2)	Low (1)	Medium (2)	Low	Possible	Very Low	Negative (D)	Medium
	With	Site (1)	Low (1)	Short (1)	Very Low	Improbable	Insignificant	Negative (D)	Medium
Release of hydrotest water/drilling fluids	Without	Site (1)	Moderate (2)	Medium (2)	Low	Possible	Very Low	Negative (D)	High
	With	Site (1)	None (0)	None	Not significant	Improbable	Insignificant	N/A	Medium
Accidental spills	Without	Local (2)	Moderate (2)	Medium (2)	Medium	Possible	Low	Negative (D)	High
	With	Site (1)	Low (1)	Short (1)	Very Low	Possible	Insignificant	Negative (D)	High

Table 4-13 Impact assessment –impacts to biological communities – clear-water habitats

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Increased sediment mobilisation	Without	Local (2)	Low (2)	Medium (2)	Medium	Definite	High	Negative (D)	High
	With	Site (1)	Low (1)	Medium (2)	Very low	Probable	Very Low	Negative (D)	High
Introduction of exotic species	Without	Regional (3)	Moderate (2)	Long (3)	Very High	Possible	High	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Negative (I)	Low

4.6 Large Turbid Rivers

4.6.1 Existing Conditions

The Baia River is in an isolated and sparsely populated region of the Project area and has been subject to very little anthropogenic influence. The Tagari and Hegigio rivers are closer to population centres within the Project area, but have also had low exposure to anthropogenic influence. These rivers are subject to natural disturbances resulting in elevated turbidity, primarily bank slumping and bed scouring due to heavy rainfall and high flow velocities (Plate 4-3).

	
a) Significant slumping in the middle Hegigio River	*b) Garden near Tagari River*

Plate 4-3 Existing disturbances in the Hegigio and Tagari catchments

At a finer spatial scale, and of relevance to pipeline crossings of watercourses, field surveys identified the existence of unstable river banks at locations sampled on the Baia River (Plate 4-4). Such features represent significant sediment input and sources of natural impact to aquatic habitat structure. Indeed, field studies indicated that the geomorphic processes observed in the upper reaches of the Baia River may not only be causing high suspended solids concentrations, thus precluding the existence of some species, but also be limiting the creation of stable aquatic habitats, due to periodic scouring and sedimentation, thus further precluding the occurrence of some species. Importantly, such unstable soils are also likely to present engineering constraints and so engineering solutions at such locations (i.e. bridging over the river) may preclude project-related impacts to habitats.

	
a) Large river bank slumping (Camp 3)	*b) Smaller, localised river bank slumping (upstream of Camp 3)*

Plate 4-4 Examples to bank slumping, Baia River

4.6.2 Sensitivities

The potential impacts to large turbid rivers are:

- Increased sediment input;
- Riparian vegetation clearing and modification to riparian habitat structure;
- Altered water chemistry through the potential enhanced mobilisation of metals, the release of anti-corrosion and anti-biofouling agents contained within hydrotest waters and possible accidental chemical (hydrocarbon) spills; and
- Introduction or proliferation of exotic species.

The large rivers of the project area are generally turbid, with large discharge. These characteristics engender these watercourses with a lower sensitivity to project-related stressors than smaller clear-water streams. Organisms inhabiting these rivers are exposed to high sediment conditions and are tolerant of these conditions. For example, ariid catfish are mouth-brooding, protecting eggs and larvae from sediment impacts. Ariid and plotisid catfishes also possess barbels for sensing prey in high sediment conditions. The implication of this is that such species are likely to be less sensitive to increased sediment mobilisation that may result from various activities associated with the Project.

The field sampling conducted in these rivers indicates that most fishes inhabit lower-current backwaters, ledges and riffles. It is expected that tributaries of these large rivers provide clear-water refugia if conditions of flow velocity and/or in the mainstream become intolerable. Observations made in the field indicate that the fishes present in these reaches are tolerant of changes to aquatic habitat structure, such as sedimentation, bank slumping and shifting benthic environment.

In terms of pipeline crossing of watercourses, the engineering constraints imposed by the size of these rivers and instability of banks will likely dictate that these water courses are bridged, thus removing the potential impacts associated with activities such as in-stream trenching and fine-scale modification of bank habitat. However, for the purposes of this impact assessment, it is assumed that the RoW corridor will extend to the river bank.

The Baia, Tagari and Hegigio rivers host fish species that are widespread throughout the Project area and PNG. The communities associated with these mainstream habitats generally have a high potential for recovery/recolonisation should project-related impacts occur.

The Baia, Tagari and Hegigio rivers have a high capacity for dilution in the case of potential metals mobilisation and spills and a high capacity for buffering against altered hydrology. Again, in this respect, large turbid rivers are deemed to be a less sensitive receiving environment than small tributary streams.

One species of introduced fish (the snow trout, *Schizothorax richardsoni*) was recorded in the Tagari River mainstream and tributaries. This species is one of several that were intentionally introduced into highland streams by the PNG Government. The ecological effects of this introduction have not been studied. However, data collected in this field program indicate that the species is co-occurring with a number of native species. The collection of small individuals in the Tagari River mainstream indicates that the species is successfully breeding and has established populations in the Tagari River mainstream and is thus free to disperse to other large rivers. The potential for the project to further spread this species among other large turbid rivers, above and beyond the natural spread of this species, is considered negligible.

4.6.3 Impact Assessment

4.6.3.1 Impacts to Physical Habitat

An assessment of potential impacts to physical habitats in large rivers is given in Table 4-14.

4.6.3.2 Impacts to Water Quality

An assessment of potential impacts to water quality in large rivers is given in Table 4-15.

4.6.3.3 Impacts to Biological Communities

An assessment of potential impacts to physical habitats in large rivers is given in Table 4-16.

Table 4-14 Impact assessment –impacts to physical habitat - large rivers

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Reduced riparian vegetation, modified habitat structure	Without	Site (1)	Low (1)	Medium (2)	Low	Definite	Low	Negative (S)	High
	With	Site (1)	Low (1)	Medium (2)	Very Low	Definite	Very Low	Negative (S)	High
Increased sediment	Without	Site (1)	Low (1)	Short (1)	Very Low	Probable	Very Low	Negative (D)	High
	With	Site (1)	None (0)	Short (1)	Not Significant	Probable	Insignificant	Neutral	High

Table 4-15 Impact assessment –impacts to water quality - large rivers

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Increase metal mobilisation	Without	Local (2)	Low (1)	Short (1)	Very Low	Possible	Very Low	Negative (D)	Medium
	With	Local (2)	None (0)	Short (1)	Very Low	Improbable	Insignificant	-	Medium
Release of hydrotest water/drilling fluids	Without	Local (2)	Low (1)	Short (1)	Very Low	Possible	Insignificant	-	High
	With	Local (2)	None (0)	Short (1)	Insignificant	Improbable	Insignificant	-	High
Accidental spills	Without	Local (2)	Low (1)	Short (1)	Very Low	Possible	Insignificant	-	High
	With	Site (1)	None (0)	Short (1)	Insignificant	Improbable	Insignificant	-	High

Table 4-16 Impact assessment –impacts to biological communities - large rivers

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Increased sediment	Without	Site (1)	Low (1)	Short (1)	Very Low	Probable	Very Low	Negative (D)	High
	With	Site (1)	None (0)	Short (1)	Not Significant	Probable	Insignificant	Neutral	High
Introduction of exotic species	Without	Regional (3)	Moderate (2)	Long (3)	Very High	Improbable	High	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Neutral	Low

5 CONCLUSIONS

Aquatic habitats encountered during this study can be categorised as follows:

- Clear-water streams;
- Sink hole streams;
- Swamps and other standing waterbodies; and
- Large turbid rivers.

No rare, endemic or endangered aquatic species were identified at the sites sampled. All species recorded are common and widespread throughout southern PNG. Sinkholes and some standing waterbodies were not sampled. While these habitats have been identified as potentially sensitive, both from the point of view of the potential occurrence of rare species or the low resilience of the habitat itself, the project is not expected to intersect or interact with such habitats.

It is hypothesised that altitude, habitat type and sediment regime are the primary factors controlling the diversity and abundance of fishes and other aquatic fauna in the project area. Many of the upstream areas sampled were at high altitude and at the highest altitudes in, for example, the Juha area and the Karius area (up to 1,300 m in elevation), only one fish species was identified. In lower-altitude areas, the fish communities were generally more diverse.

Aquatic resources in the far-upstream segment of the project area, with the possible exception of the area of the proposed Hides Gas Conditioning Plant (HGCP), do not appear to be utilised significantly by local people. This is believed to be because there are very few settlements in this segment (again, with the exception of the area around Nogoli), the small streams are inhabited by small-bodied species, and the large rivers are difficult to fish in given the high flows and high sediment regime.

Generally, this study has concluded that clear-water aquatic habitats are more sensitive than large rivers and the potential project-related impacts of most significance is sediment. In particular, increased mobilisation of sediment to watercourses in the construction phase has the most potential to cause aquatic impacts. The construction phase is a concentrated, relatively short phase of the project, and while the potential impacts of this phase are considered to be greater than that of the operations phase, they should be short-lived.

The primary sources of sediment mobilisation to watercourses are likely to be:

- Runoff from the cleared right of way (RoW), exacerbated during intense rainfall periods;
- Runoff from any sediment stockpiles, exacerbated during intense rainfall periods;
- Side-casting of soils associated with the construction of the right of way (RoW), exacerbated in areas with particularly steep slopes;
- Construction of RoW watercourse crossings, including trenching of the pipeline; and
- Construction of bridges to span large rivers.

The potential effects of sediment to habitats and organisms are summarised in Section 3 and were also outlined in a previous EIS (DBA 2005).The potential impacts of this project on aquatic habitats and fauna are considered to be minor. The main factors mitigating the severity of the potential impacts are:

- The limited area of disturbance to aquatic habitats;
- The absence of rare, endemic or endangered species;

- The low sensitivity (high resilience) of large turbid rivers;
- The opportunity to fine-tune the RoW alignment to avoid obscure or potentially sensitive habitats (e.g. sinkholes).

The additional mitigation measures identified in this report, if successful, will further reduce the aquatic impacts associated with the construction and operation of the project.

6 REFERENCES

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Appendix 1 Macroinvertebrate Raw Data

Order	Family	BAI1-1	BAI1-2	BAI1-3	BAI1-4	BAI1-5	BAI4-1	BAI4-2	BAI4-3	BAI4-4	BAI4-5	BAI8-1	BAI8-2	BAI8-3	BAI8-4	BAI8-5	BAI7-1	BAI7-2	BAI7-3	BAI7-4	BAI7-5	JUH3-1	JUH3-2	JUH3-3	JUH3-4	JUH3-5	JUH6-1	JUH6-2	JUH6-3	JUH6-4	JUH6-5	TAG6-1	TAG6-2	TAG6-3	TAG6-4	TAG6-5	TAG5-1	TAG5-2	TAG5-3	TAG5-4	TAG5-5	TAG4-1	TAG4-2	TAG4-3	TAG4-4	TAG4-5	TAG7-1	TAG7-2	TAG7-3	TAG7-4	TAG7-5	TAG1-1	TAG1-2	TAG1-3	TAG1-4	TAG1-5	TAG3-1	TAG3-2	TAG3-3	TAG3-4	TAG3-5	H17-1	H17-2	H17-3	H17-4	H17-5	H18-1
Acarina	Acarina		1		1									1	4	2				1	1	2	5	9	2	7	3		1	1	1			1	1							1										1		1									1		1	1	
Amphipoda	Unidentified														4																																																				
Bivalvia	Corbiculidae																																																												1						
Bivalvia	Sphaeriidae																																									1					1																				
Bivalvia	Bivalve unident																												1	1																																					
Coleoptera	Coleoptera unident															1											1		1														3																								
Coleoptera	Dytiscidae														1																																																				
Coleoptera	Elmidae			2			1	1				3	13	15	10	8	3	2	2	3	2	29	14	15	4	7	19		5	3	1		1		1							1				1							1					1	1				3	5	10	7	1
Coleoptera	Gyrinidae																												1																																						
Coleoptera	Hydraenidae											3			4	1		1		1		1					10	2	2							2							5			1															1		2				
Coleoptera	Hydrophilidae																																																															3			
Coleoptera	Limnichidae																																																																		
Coleoptera	Psephenidae														1																																																				
Coleoptera	Ptilodactylidae														2		1									1	4	2	25																																						
Coleoptera	Scirtidae			1								3		1	5				1	3	8	1					8	5	11	1		1	1		1	2																1							1						7		
Coleoptera	Staphylinidae																																																										1								1
Crustacea	Ostracoda																													1																																				1	
Crustacea	Crustacea unident																													1																																					
Diptera	Athericidae																2					1		2	1																																										
Diptera	Blephariceridae																																																													1					
Diptera	Ceratopogonidae	1											1	1	4	11					1	3				2	7		43	4			1				1	3	3	2	2	2															2	2					2	2	2	2	
Diptera	Chironomidae															13						3							31	9																																					
Diptera	Empididae								1		1	2	3	2		2				1	2					1	2		5	1			5	5			1	5			1	5	4	2	2	3	2							2	1								3	1	2	2	
Diptera	Ephydridae														1																																																				
Diptera	Psychodidae											4		1							1	1	1		1	1	5		1																																						
Diptera	cf Chironominae	10	1	1	13	2	2	1	7	13	8	26	11	12	29	34	3	3	9	3	5	14	1	12	5	2	14		13	2	2	4	50	32	2	7	9	37	65	11	118	10	4	2	1	3	15	1	8	2	14	7	5	11	3	2	4	10	4	4	5	7	24	32	35	46	13
Diptera	cf Orthocladiinae	1	1	1	4			2	11	2	4	12	6	20	17	7	6	1	1	6	2	20	3	4		4	37	6	18	8	6	9	51	65	39	52	13	78	56	16	96	35	30	18	22	15	140	21	103	14	105	10		45	3	6		1	2	2	2	15	14	32	14	20	19
Diptera	cf Tanypodinae					1					1	4	3	8	43	10	2				1	1	1	1	2	2	12		34	3	1		1	2		2	1		17		11	1					3		2		1	1				1						1	2	9	14	7	1
Diptera	Simuliidae	1			7	1			3	2	1	117	64	72	114	7	27	5	3	9	12	13	7			8	8		9			20	14	4		12	9	359	258	65	135	11	3	4	5	4	1		3	2	1	21	3	3	4	5	1			5	3	16	45	3	12	29	3
Diptera	Tabanidae																										2																								1	1												1			
Diptera	Tanyderidae																										2		1																																						
Diptera	Tipulidae				1											3	3	2		1								2							2	3		1	5	3	4						2											1		1				2	1		
Diptera	Diptera unident								1														2						1												2																										
Ephemeroptera	Baetidae	10	15	1	33	4	11	1	6	7	9	1	1	4	18		4			4		15	5	13		10	1		2			10	81	12	4	13	10	25	10	1	42	2		2			21	5	5	1	8	20	5	42	20	11	2		1	1	5	35	36	44	24	69	10
Ephemeroptera	Caenidae		3	1	7	2						9		2	6	9	4	2	3	1	3	9	1	4			2		8	1		1	4	1	2	2	1	1	2		8	7	11	4	1	1	6		2	3	9	1		3	1	2								1	9	1	
Ephemeroptera	Leptophlebiidae	15	5	7	9	2	1			1					1		2					18	1	13	1	13	3		1	3	1								1		1											2	1	3	1	8		1			1				1	3	
Ephemeroptera	Prosopistomatidae																																																				1														
Ephemeroptera	Ephemeroptera unident	6		3	13		3	3	5	6	1	70	12	45	58	31	32	5	16	17	10	39	12	10	14	3	7	5	31	11	6	18	42	36	6	22	21	71	20	3	30	17	12	6	2	1	18	10	17	7	25	37	10	45	36	19	3		6	7	5	1		21	9	19	7
Gastropoda	Hydrobiidae																									1																					1				1																
Gastropoda	Lymnaeidae																																																								1										
Hemiptera	Mesoveliidae																										1												1																												
Hemiptera	Naucoridae	1		1									3	3	6	10	1		1	1	2	1			1	1			1		1			1	2	2												1			1	1			1							2	2	8	7	9	6
Hemiptera	Veliidae																													2	1																																	7			
Lepidoptera	Pyralidae		1											1																												1	1	1	1																	2	2				
Nematoda	Nematoda unident																										2																																								
Odonata	Anisoptera unident				1		1					3		1			4		1	5	1	1			2				3					1			1				4																										
Odonata	Libellulidae									1		1	3			1		2				1									1							1	2		1										1													1		2	
Odonata	Macromiidae																																						2	1	4																										
Odonata	Zygoptera unident											5			5	2	2	1		1	1	4							1												3																										
Oligochaeta	Oligochaeta						1			1						5						1	1		1		9	1	12	1				2			5	17	14	1	67	32	21	25	3	14	2			2	1	3		1	1		1					1	3	6	5	13	
Trichoptera	Calamoceratidae									1		5			1		3	2		1	1														1		1	1		1	2	1			1	2											1								5		1
Trichoptera	Calocidae														1																																																				
Trichoptera	Ecnomidae																						1	1			6	1	1	1																		1																			
Trichoptera	Glossosomatidae																																																													10	23	38	9	13	
Trichoptera	Hydrobiosidae																					7	1				1		2																																						
Trichoptera	Hydropsychidae		3	1	8	2	1					6	11	12	71	35	23	13	2	24	31		3				2	3	4			22	31	10	29	37	12	109	68	42	99	8	2		1	3	4	2	7	1	5	4	1	3	5	2						4	26	7	18	11	12
Trichoptera	Hydroptilidae																					1											3	1	1	2																												2		4	
Trichoptera	Leptoceridae											2		2	2		1							2			1		1					1	1			3	2		1	2				1				1	2			1	1							1	1	8	3	11	1
Trichoptera	Odontoceridae																																																																		3
Trichoptera	Philopotamidae											3								3	2								10																																			2	12		21
Trichoptera	Polycentropodidae											1																																																			1	3		1	
Trichoptera	Trichoptera unident	2	1	2	2	3		1	4			4		2	13	6	5		1	5		3							21	3			4				2				2				1		1							1	2		1					3	1	3	2	4	
Turbellaria	Dugesiidae														2					4		1		1		1																																					1	1			

Appendix 2 Risk Assessment Rating Method

The significance of risk associated with all potential impacts that could result from the Project is determined in order to assist decision makers involved in the EIS process. For this study the inference behind each of the risk rating categories for decision makers is given below:

- **Insignificant:** the risk associated with a potential impact is negligible and **will not** have an influence on any decision regarding the proposed activity / impact mechanism;

- **Very Low**: the risk associated with the potential impact is very small and **should not** have any influence on any decision regarding the proposed activity / impact mechanism;

- **Low**: the risk associated with the potential impact is small and **may not** have any influence on any decision regarding the proposed activity / impact mechanism;

- **Medium**: the risk associated with the potential impact is moderate and **should** influence decisions regarding the proposed activity / impact mechanism;

- **High**: the risk associated with the potential impact **will be** high and **will** influence decisions regarding the proposed activity / impact mechanism;

- **Very High**: the risk associated with the potential impact is **very** high and **will** influence decisions regarding the proposed activity / impact mechanism. Alternatives should be sought to the proposed activity or additional mitigation measures applied.

The risk associated with a given impact is a product of both the consequences of that impact and the likelihood of that impact occurring. There are several key components that underpin the consequences associated with a given impact. These are spatial extent, temporal extent and the severity of that impact. Step 1 of the risk assessment decision framework used for this study is to rate the consequence of a given impact based on the explicit definitions provided in the consequence table below. The consequence rating for a given impact is determined by adding the scores for extent, severity and duration in Consequence Rating Table #1 below and cross-referencing that score with consequence ratings in Consequence Rating Table #2.

Consequence Rating Table #1

Rating	Definition of Rating	Score
A. Extent – ***the area in which the impact will be experienced***		
None		0
Site	Immediate watercourse within 2 km downstream of an impact location	1
Local	2 km – 10 km downstream from site-scale waters (reach / tributary scale)	2
Regional	Greater than 10 km downstream from site scale waters (river system / catchment) scale	3
B. Severity – ***the magnitude of the impact in relation to the sensitivities of the receiving environment***		
None	Unlikely to be detectable	0
Low	Detectable but small not ecologically significant	1
Moderate	Abundance and distribution altered, but no major impacts on population survival or ecosystem function	2
High	Significant impacts on populations, communities and ecosystem functioning, possibly resulting in population extinctions or irreversible changes to ecosystem health and functioning	3
C. Duration – ***the timeframe over which the impact will be experienced***		
None		0
Short-term	Residual impacts lasting < 1 year	1
Medium-term	Residual impacts lasting between 1 and 5 years	2
Long-term	Residual impacts lasting longer than 5 years	3
Combined Score		
Consequence Rating	**From Consequence Rating Table #2**	

Consequence Rating Table #2

Combined Score (A+B+C)	**0-2**	**3-4**	**5**	**6**	**7**	**8-9**
Consequence Rating	Not significant	Very Low	Low	Medium	High	Very

The next step is to outline the likelihood of that impact occurring based on clear definitions of probability provided in the Likelihood Rating Table below.

Likelihood Rating Table

Probability – *the likelihood of an impact occurring*	
Improbable	< 10% chance of occurring
Possible	11-50% chance of occurring
Probable	51-90% chance of occurring
Definite	> 90% chance of occurring

To determine the significance rating for risk associated with that impact, cross reference results for consequence and likelihood against rankings given in the Risk Assessment Table below.

Significance Rating Table

Significance Rating	Consequence		Probability
Insignificant	Very Low	&	Improbable
	Very Low	&	Possible
Very Low	Very Low	&	Probable
	Very Low	&	Definite
	Low	&	Improbable
	Low	&	Possible
Low	Low	&	Probable
	Low	&	Definite
	Medium	&	Improbable
	Medium	&	Possible
High	High	&	Probable
	High	&	Definite
	Very High	&	Improbable
	Very High	&	Possible
Very High	Very High	&	Probable
	Very High	&	Definite

Step 4 is to define the status of the impact (i.e. whether the impact is deleterious or beneficial)

Step 5 is to outline whether impacts are expected to increase (I), diminish (D) or stay the same (S) over time. For this step, a D in the status column of the impact assessment table denotes an impact that is expected to decrease over time (for example, decreases in the severity of an impact as remediation measures start taking affect), while an I in this column denotes an impact that is expected to increase over time (for example, increased impacts of introduced exotic species as that species spreads and multiplies). Alternatively, an impact may remain at a stable level over time, which is denoted by (S).

Step 6 is to define the confidence surrounding predictions made in terms of the risk rating produced from steps 1-3. For this step, assign confidence to one of the following categories: high, medium or low.

The above information can then be summarised into an impact assessment table where risk ratings can be carried out for a given impact under scenarios with and without mitigation in place (see the example below).

Example impact assessment table

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
	Without	Local (2)	Mod (2)	Short (1)	Low	Probable	Low	Negative (D)	High
	With	Site (1)	Low (1)	Short (1)	Very Low	Possible	Insignificant	Negative (D)	High