Esso Highlands Limited

Papua New Guinea LNG Project

Environmental and Social Management Plan
Appendix 28: Environmental Monitoring Plan

PGGP-EH-SPENV-000018-032

CONTENTS

TABLES

ATTACHMENTS

1.0 INTRODUCTION

1.1 Background

Esso Highlands Limited (EHL) (hereafter referred to as Company) has developed this Environmental Monitoring Plan (EMP) as part of the Environmental and Social Management Plan (ESMP) for the PNG LNG Project (hereafter referred to as the Project).

The objectives of the EMP are to:

- define environmental monitoring requirements
- summarize Company's process for inspection and verification of management and mitigation commitments
- summarize Company's process for periodic assessment and audit to evaluate the implementation and effectiveness of the environmental program
- summarize Company's process for reporting to DEC in relation to monitoring, verification, audit and assessment programs.

The EMP is based on environmental monitoring requirements established in the relevant appendices of the ESMP, as follows:

- Appendix 1: Ecological Management Plan
- Appendix 2: Air Emissions Management Plan
- Appendix 3: Noise and Vibration Management Plan
- Appendix 4: Waste Management Plan
- Appendix 5: Water Management Plan
- Appendix 6: Spill Prevention and Response Plan
- Appendix 8: Weed, Plant Pathogen and Pest Management Plan
- Appendix 9: Erosion and Sediment Control Plan
- Appendix 11: Reinstatement Plan

The EMP should be read in conjunction with the above plans.

The EMP is intended to fulfill conditions of Environment Permit WD-L3 (210) issued by the PNG Department of Environment and Conservation (DEC) for the PNG LNG Project (hereafter referred to as the Environment Permit) as described Table 1.

Table 1: Environment Permit Conditions Met	
Environment Permit Condition	***Details of Condition***
8 l)	*The Project Environmental Management Plan for each phase shall include but not be limited to the following:* *l) environmental monitoring and social impact monitoring strategy, and the process that will be applied to the design, conduct and reporting of these environmental monitoring and social impact monitoring programs*
8 m)	*The Project Environmental Management Plan for each phase shall include but not be limited to the following:* *m) process for notifying the Director of exceedences, unexpected or accidental incidents of material or serious environmental harm, or any other environmental emergencies*
10 k), l), m), n)	*The Project Environment Management Plan shall include, but is not limited to, the following information:* *k) monitoring criteria, sampling and analysis methods and reporting procedures* *l) exceedence responses, notification requirements and remediation strategies* *m) inspections and audits of environmental performance* *n) reporting requirements (including routine compliance monitoring and incident reporting, schedules and responsible authority).*
27	*Regular periodic monitoring of the efficacy of Erosion and Sediment Control structures will be required by the worksite management plans.*
38	*During any submarine construction activities (i.e. dredging, landfall construction, jetty construction, reef breaking) which may involve percussive sources (e.g. blasting, pile driving), visual monitoring for marine mammals and turtles is to be undertaken. Should threatened species enter the area, activities shall cease until the mammals and turtles have left the area.*
92	*In consultation with the Director, the Permit Holder shall develop a detailed Environmental Monitoring Plan for the PNG LNG Project within 120 days of commencement of this Permit for submission to the Director for approval.*
93	*The Environmental Monitoring Plan referred to in Condition 92 should include provisions for the Permit Holder to:* *a) periodically verify predictions in the environment permit application* *b) assess the effects of the project on the environment* *c) measure the effectiveness of management and mitigation measures* *d) assess compliance with this permit and applicable legislation.*
94	*The Monitoring Programs shall be developed in accordance with the approved Pre-Construction Surveys and, Environmental Management Plan. Minimum monitoring requirements should include but not be limited to:* *a) the period and duration of monitoring will be specified by the Director. In some cases monitoring may continue for the duration of the PNG LNG Project and for a period thereafter specified by the Director* *b) the results of the Monitoring Programs shall be provided to the Director by agreed deadlines* *c) the sampling strategies and protocols undertaken for each monitoring program shall include a quality assurance/quality control plan and shall be specified in the relevant environmental management plan;* *d) Wherever practicable, laboratory analyses shall be undertaken by accredited laboratories and / or laboratories approved by the Director. The choice of laboratory should consider the need to analyse collected samples as soon as possible after collection to prevent sample degradation.*
97	*Unless specified elsewhere in this permit, the Permit Holder must submit quarterly and annual Environment Performance Reports to the Director. The performance reports shall include but not be limited to the following information:* *a) results of the monitoring programs under the approved management plans, and comparison against actual performance targets and objectives*

1.2 Scope

This EMP is based on the construction execution plans in place at the time of writing. As the Project progresses and execution plans become further defined, new worksites and activities may be identified and the monitoring activities and locations defined in this EMP will be modified accordingly. Such modifications shall be communicated to DEC as part of Company's quarterly Construction Environmental Report (CER).

This EMP is applicable to all construction and drilling activities associated with Phase I of the Project as described in the ESMP.

The EMP is not applicable to the following:

- Future phases of the Project as described in the ESMP. Company will update, and submit to DEC for approval, an updated EMP at least three months prior to each subsequent development phase (Phases II-VI);
- Hydrostatic testing activities which involve discharge of hydrotest fluids to a surface water body. This will be addressed as part of Company's application for hydrotest discharge permit in due course;
- Operations. Company will, at least six months prior to commencement of production, develop and submit to DEC for approval, an Operations Environmental Monitoring Plan.

Where applicable, monitoring sites and parameters will be carried over into the Operations Environmental Monitoring Plan.

1.3 Structure

The EMP is structured as follows:

1.3.1 Section 2: Monitoring

Describes the field based environmental monitoring (sampling and analysis) program to monitor the effectiveness of management and mitigation measures, assess impacts and demonstrate compliance with applicable legal and other requirements.

1.3.2 Section 3: Verification

Describes the field based inspection and verification programme in place to verify and document the due implementation of, and in some cases the effectiveness of, mitigation measures.

1.3.3 Section 4: Assessment and Audit

Describes the programme of periodic audits and assessments in place to evaluate the implementation and effectiveness of Company's and Contractor's environmental program.

1.3.4 Section 5: Reporting

Describes the process in place for Company reporting to DEC associated with the implementation of the monitoring, verification, audit and assessment programs.

2.0 MONITORING

Company and Contractors implement a field based environmental monitoring (sampling and analysis) program in order to monitor the effectiveness of management and mitigation measures, assess potential impacts and demonstrate compliance with applicable legal and other requirements. The objectives of individual components of the monitoring program are shown in Table 2: Monitoring Objectives.

The monitoring program is detailed in Table 3 Environmental Monitoring. The program includes primarily monitoring to be undertaken by Company however Contractor monitoring is also included where required to demonstrate compliance with conditions of the Environment Permit.

2.1 Monitoring Objectives

Table 2: Monitoring Objectives

Component	Objective
Freshwater and Marine Ecology	Preconstruction: To characterise freshwater ecological conditions prior to construction and provide standard indices of the freshwater ecological conditions against which future conditions can be compared. Construction & Post construction: To characterise freshwater ecological conditions and compare these to preconstruction conditions.
Marine Water Quality Monitoring	Preconstruction: To characterise existing marine water quality prior to construction and provide a background against which future conditions can be compared. Construction & Post construction: To characterise marine water quality conditions and compare these to preconstruction conditions.
Marine Sedimentation Monitoring	Preconstruction: To characterise existing sedimentation in the marine environment prior to construction and provide a background against which future conditions can be compared. Construction: To characterise sedimentation in the marine environment and compare these to preconstruction conditions during construction.
Surface Water Quality Monitoring	Preconstruction: To characterise existing surface water quality prior to construction and provide a background against which future conditions can be compared. Construction & Post construction: To characterise surface water quality conditions and compare these to preconstruction conditions during construction.
Groundwater Monitoring	Preconstruction: To characterise existing groundwater quality prior to construction and provide a background against which future conditions can be compared during preconstruction. Construction and landfill operation: To characterise groundwater quality conditions and compare these to preconstruction conditions.
Stormwater Monitoring	Construction: To characterise stormwater quality and compare against discharge limits applicable to the Project.
Wastewater Monitoring	Construction: To evaluate compliance with the applicable criteria for discharges to sea or freshwater.

Table 3 Environmental Monitoring					
	Location	**Frequency**	**Method**	**Parameters/Criteria**	**Notes**
Freshwater Ecology[1]	See Annex 1.1 TAGA-1 (Tagaria River downstream of Tamalia River Confluence) KOM-2 (Wakuba River upstream of falls) BENA-1 (Benaria River downstream of pipeline) MAND-2 (Mandali River upstream of pipeline) KUTU-1 (Taga Creek upstream of pipeline) MUBI-2 (Mubi River at Kantobo) Viahua 1 & 2 (Viahua River at LNG plant site)	Twice prior to construction, once during construction and once following completion of construction.	See Annex 2.1	Nil	
Marine Ecology[1]	See Annex 1.2	Twice prior to construction and once following completion of the jetty and once following completion of construction.	See Annex 2.2	Nil	Components: Benthos, Mangroves, Seagrass, Coral Reef, Reef fish.
Marine Water Quality (Preconstruction & Construction)[2]	See Annex 1.3	Twice prior to construction and once following completion of the jetty and once following completion of construction.	See Annex 2.3	See Seawater Criteria in Table 4	
Marine Water Quality (Construction)[2]	As Above	Every 6 months (to include once during piling of jetty)		Criteria (Seawater): – No alteration to natural pH – Temperature: No alteration greater than 2^{O}C – Turbidity: No alteration greater than 25 NTU – Dissolved Oxygen: Not less than 5.0mg/L or no change >10% from background levels at any particular time – Oil and Grease: No visible film – Electrical Conductivity	

[1] Further details regarding ecological commitments and the associated monitoring can be found in the ESMP Appendix 1, Ecological Management Plan (PGGP-EH-SPENV-000018-003) and Appendix 5, Water Management Plan (PGGP-EH-SPENV-000018-007). Specific ecological aspects disturbed or affected will be recorded on an ongoing basis across all Project worksites. Detailed rehabilitation monitoring will be outlined in the operations monitoring plan.

[2] Further details regarding ecological commitments and the associated monitoring can be found in the ESMP Appendix 5, Water Management Plan (PGGP-EH-SPENV-000018-007).

Table 3 Environmental Monitoring					
	Location	**Frequency**	**Method**	**Parameters/Criteria**	**Notes**
Marine Sedimentation Monitoring (Preconstruction and Construction)	See Annex 1.4	Twice prior to construction and every 6 months during construction (to include once during piling of jetty)	See Annex 2.4	Criteria (Seawater): – Turbidity: No alteration greater than 25 NTU – Total Suspended Solids: 50mg/L or no change >10% from background levels at any particular time.	
Groundwater Monitoring [3]	LNG Plant & HGCP Landfill sites. One up-gradient, two cross-gradient and two down-gradient wells.	Once prior to construction and annually post landfill construction throughout the life of the construction activities.	See Annex 2.6	pH (pH Units), Dissolved Oxygen, Sulphate as SO_4^{2-}, Ammonia-nitrogen (NH3-N), Nitrates (NO3-+ NO2-), major ions, Chloride, Electrical Conductivity, Arsenic, Barium, Boron, Cadmium dissolved, Chromium (as hexavalent), Cobalt, Copper, Iron (dissolved), Lead, Manganese (dissolved), Mercury, Nickel, Selenium, Silver, Tin, Zinc, Total Petroleum Hydrocarbons, Fecal coliforms, Phenols.	No alteration above natural background. (Up gradient similar to down gradient).
Stormwater Monitoring [4]	Sites where stormwater is collected and discharged from a point source.	As required, upon discharge	Refer to Annex 2.5	Criteria – pH 6.5-9 – Turbidity: No alteration greater than 25 NTU – Electrical Conductivity – Dissolved Oxygen: Not less than 6 mg/L (5 mg/L for seawater) or no change >10% from background levels at any particular time – Oil and Grease: No visible film	Monitoring locations to be defined during execution and communicated to DEC (including maps) as part of Company's quarterly Construction Environmental Report. 'End of pipe' monitoring will be conducted. If end of pipe discharge concentrations exceed the criteria, samples will immediately be taken for the full suite of parameters (Table 4 – relevant freshwater or seawater criteria) in the receiving water body comparing downstream to upstream values. Compliance will be determined by the water body concentrations, not the end of pipe concentrations.
	Sites without stormwater collection systems (sheet runoff).	As required, heavy rainfall events	Visual analysis of sheet flow runoff sites.	Criteria – Oil and Grease: No visible film	Monitoring locations to be defined during execution and communicated to DEC as part of Company's quarterly Construction Environmental Report.

3 Groundwater monitoring will be undertaken at a series of locations prior to construction in order to characterise existing groundwater quality. Further details regarding ecological commitments and the associated monitoring can be found in the ESMP Appendix 5, Water Management Plan (PGGP-EH-SPENV-000018-007).

4 Stormwater quality monitoring will be undertaken at locations where stormwater is running off from potentially contaminated worksite areas. Further details regarding ecological commitments and the associated monitoring can be found in the ESMP Appendix 5, Water Management Plan (PGGP-EH-SPENV-000018-007).

Table 3 Environmental Monitoring					
	Location	**Frequency**	**Method**	**Parameters/Criteria**	**Notes**
Surface Water Quality Monitoring	See Annex 1.5 KOM-2 (Wakuba River upstream of falls/ north of Komo airfield) KOM-4 (East of Komo airfield) TAGA-1 (Tagaria River downstream of Tamalia River Confluence) TAGA-2 (Tagari River near Embetali) BENA-1 (Benaria Rver downstream of pipeline) BENA-2 (Benaria River at Daviravi) MAND-1 (Mandali River upstream of pipeline) MAND-2 (Mandali River downstream of pipeline) AIUR-1 (Aiu River upstream of pipeline) AIUR-2 (Aiu River downstream of pipeline) KUTU-1 (Taga Creek upstream of pipeline) KUTU-2 (Taga Creek downstream of pipeline) KUTU-3 (Wage Creek downstream if pipeline) AIIO-1 (Ai'io River downstream of pipeline) MUBI-1 (Mubi River upstream of Kantobo) MUBI-2 (Mubi River at Kantobo)	Once prior to construction, annually upstream and downstream during construction, once post construction	Refer to Annex 2.5	See Freshwater Criteria in Table 4	Further monitoring locations may be defined during execution and communicated to DEC (including maps) as part of Company's quarterly Construction Environmental Report.
	Upstream and downstream of major river crossings during bridge and road construction and pipeline crossings.	Once immediately prior to crossing and during in water crossing work.	Refer to Annex 2.5	Criteria (Freshwater) – pH 6.5-9 – Turbidity: No alteration greater than 25 NTU – Electrical Conductivity – Dissolved Oxygen: Not less than 6 mg/L (5 mg/L for seawater) or no change >10% from background levels at any particular time – Oil and Grease, No visible film	Monitoring locations to be defined during execution and communicated to DEC (including maps) as part of Company's quarterly Construction Environmental Report.
Wastewater Monitoring [5]	LNG Camps Kobalu Camp	Weekly during plant	Refer to Annex 2.3 & 2.5	Criteria – pH (pH units) 6.5 – 9	Wastewater treatment plants using biological digestion technology require a period of stabilisation in order to achieve steady operations.

[5] Monitoring of wastewater discharges will be undertaken at multiple locations during construction. Monitoring locations will be determined as part of detailed execution planning and communicated to DEC as part of the Quarterly Construction Environmental Reports.

Table 3 Environmental Monitoring					
	Location	**Frequency**	**Method**	**Parameters/Criteria**	**Notes**
	Juni Camp/Training Facility Moro Parker Camp Gobe Camp IDT10 Camp Mubi Camp Kantobo-Mubi Road Camp HGCP Camp (TRB3) Mendi Camp Kopi Camp	stabilization (maximum 90 days) Table 4 water quality criteria will be monitored once following plant stabilization for compliance purposes.		– Residual Chlorine: As close as possible to 1 mg/L – Volume (m3): Cumulative	Therefore, exceedence of these parameters will not constitute a regulatory non-compliance. Monitoring locations to be defined during execution and communicated to DEC (including maps) as part of Company's quarterly Construction Environmental Report. These criteria and the monitoring thereof do not apply to the discharge of wastewater to engineered soakaways/leach fields; or from marine vessels which shall meet MARPOL requirements.
	LNG Camps Kobalu Camp Juni Camp/Training Facility Moro Parker Camp Gobe Camp IDT10 Camp Mubi Camp Kantobo-Mubi Road Camp HGCP Camp (TRB3) Mendi Camp Kopi Camp	Twice monthly (following plant stabilization)	Refer to Annex 2.3 & 2.5	Criteria (Freshwater) – pH (pH units) 6.5 – 9 – BOD 25 mg/L – COD 125 mg/L – Ammonia Nitrogen (See Table 14) – Total Suspended Solids 50 mg/L – Oil & Grease No visible film – Fecal Coliform: Not to exceed 200 colonies **OR** Residual Chlorine: As close as possible to 1 mg/L – Volume (m3): Cumulative	'End of pipe' monitoring will be conducted. If end of pipe discharge concentrations exceed the criteria, samples will immediately be taken for the full suite of parameters (Table 4 – relevant freshwater or seawater criteria) in the receiving water body comparing downstream to upstream values. Compliance will be determined by the water body concentrations, not the end of pipe concentrations. Monitoring locations to be defined during execution and communicated to DEC (including maps) as part of Company's quarterly Construction Environmental Report. These criteria and the monitoring thereof do not apply to the discharge of wastewater to engineered soakaways/leach fields; or from marine vessels which shall meet MARPOL requirements.
Leachate Monitoring	HGCP and LNG Plant Landfills	Upon discharge	Refer to Annex 2.3 and 2.5	See Table 4	Leachate will be sampled for Table 4 parameters only where discharged to surface water or seawater.
Water Abstraction (Volume)[6]	All abstraction points (during construction)	Ongoing frequency	-	Nil	
Raw Materials[7]	All sources utilised for aggregate of timber use.	Ongoing frequency	-	Nil	Sources and volumes of all aggregate and timber utilised for the Project will be documented.
Erosion and Sediment [8]	All erosion control structures will be monitored until adequate slope stabilisation, sediment control and subsidence	Areas of continuing erosion will be identified and assessed every	-	Nil	An annual flyover of the onshore pipeline Right of Way will be undertaken to check for erosion.

6 Further details regarding ecological commitments and the associated monitoring can be found in the ESMP Appendix 5, Water Management Plan (PGGP-EH-SPENV-000018-007).

7 Further details regarding raw materials and the associated monitoring can be found in ESMP Appendix 10, Raw Materials Management Plan (PGGP-EH-SPENV-000018-012).

Table 3 Environmental Monitoring					
	Location	**Frequency**	**Method**	**Parameters/Criteria**	**Notes**
	control has been achieved.	3 months by road and/or foot patrol.			
	Erosion at reclaimed watercourse crossings will be monitored.	Landform stability will be monitored monthly and after significant storm events until stabilization has been achieved.			
Re-instatement	Project-wide	Immediately upon completion of construction	Visual	Nil	Restoration will commence immediately following construction and visual results reported as part of Company's quarterly Construction Environmental Report.
Waste[9]	Waste tracking shall be undertaken across all worksites to provide data from generation through to disposal	Ongoing	-	Data to be recorded includes: -Source -Type -Quantity/Volume -Storage/Containment/Treatment Details -Transportation Details -Disposition Method, Location and Volume	Waste from marine vessels shall be managed in accordance with MARPOL requirements.
Marine Mammals	Offshore	Ongoing	Visual	Nil	Visual monitoring for marine mammals and turtles will be undertaken. Should threatened species enter the area, activities shall cease until the mammals and turtles have left the area.
Spills	Project-wide	Immediately following spill as required	-	To be determined in consultation with DEC	The volume and nature of the spilled material will dictate the frequency and parameters of monitoring, which will be agreed upon by DEC and Company.

8 Further details regarding erosion and the associated monitoring can be found in the ESMP Appendix 9, Erosion and Sediment Control Plan (PGGP-EH-SPENV-000018-011).

9 Further details regarding waste commitments and the associated monitoring can be found in the ESMP Appendix 4, Waste Management Plan (PGGP-EH-SPENV-000018-006). Specific waste management area checklists can be found in Appendix 3.

Table 4: Fresh Water (Surface) and Sea Water Quality Criteria		
Parameter*	**Receiving Water Body**	
	Freshwater	**Seawater**
pH (pH units)	6.5 – 9	No alteration to natural pH
Temperature	No alteration greater than 2°C	No alteration greater than 2°C
Turbidity NTU	No alteration greater than 25 NTU or no change >10% from background levels at any particular time	No alteration greater than 25 NTU or no change >10% from background levels at any particular time
Total Suspended Solids	50 mg/L or no change >10% from background levels at any particular time	50 mg/L or no change >10% from background levels at any particular time
Insoluble residues	No insoluble residues or sludge formation to occur	No insoluble residues or sludge formation to occur
Dissolved oxygen	Not less than 6.0 mg/L or no change >10% from background levels at any particular time	Not less than 5.0 mg/L or no change >10% from background levels at any particular time
Chemical Oxygen Demand (COD)	125 mg/L	125 mg/L
Biological Oxygen Demand (BOD)	25 mg/L	25 mg/L
Sulphate as SO42-	400.0 mg/L	---
Sulphide as HS-	0.002 mg/L	0.002 mg/L
Ammonia-nitrogen (NH3-N)	Dependent on pH and temperature (see Table 5)	---
Nitrate (NO3- + NO2-)	45.0 mg/L	45 mg/L
Potassium	5.0 mg/L	600 mg/L
Barium	1.0 mg/L	1.0 mg/L
Boron	1.0 mg/L	10 mg/L
Cadmium	0.01 mg/L	0.001 mg/L
Chromium (as hexavalent)	0.05 mg/L	0.01 mg/L
Cobalt	Limit of detection	
Copper	1.0 mg/L	0.03 mg/L
Iron	1.0 mg/L	1.0 mg/L
Lead	0.005 mg/L	0.004 mg/L
Manganese	0.5 mg/L	2.0 mg/L
Mercury	0.0002 mg/L	0.0002 mg/L
Nickel	1.0 mg/L	1.0 mg/L
Selenium	0.01 mg/L	0.01 mg/L
Silver	0.05 mg/L	0.05 mg/L
Tin	0.5 mg/L	0.5 mg/L
Zinc	5.0 mg/L	5.0 mg/L
Oil & Grease	No visible film (for construction discharges); and 10 mg/L (for operations discharges)	No visible film (for construction discharges); and 10 mg/L (for operations discharges)
Phenols	0.002 mg/L	0.002 mg/L
Fecal Coliform	Not to exceed 200 colonies or no change >10% from background levels at any particular time	Not to exceed 200 colonies or no change >10% from background levels at any particular time

***** - Units: mg/L unless stated otherwise
- A dash ('—') denotes that no criteria or limit is given in the Regulation and as such does not exist, background levels are in excess of the criterion.
- Metal concentrations are for dissolved substances (passing through a nominal 0.45 um medium)
- NTU = nephelometric turbidity unit
- Cobalt (as 'limit of detectability') uses Graphite furnace atomic absorption spectrometry (GFAAS)
- Limits are subject to detection levels of the appropriate analytical procedure

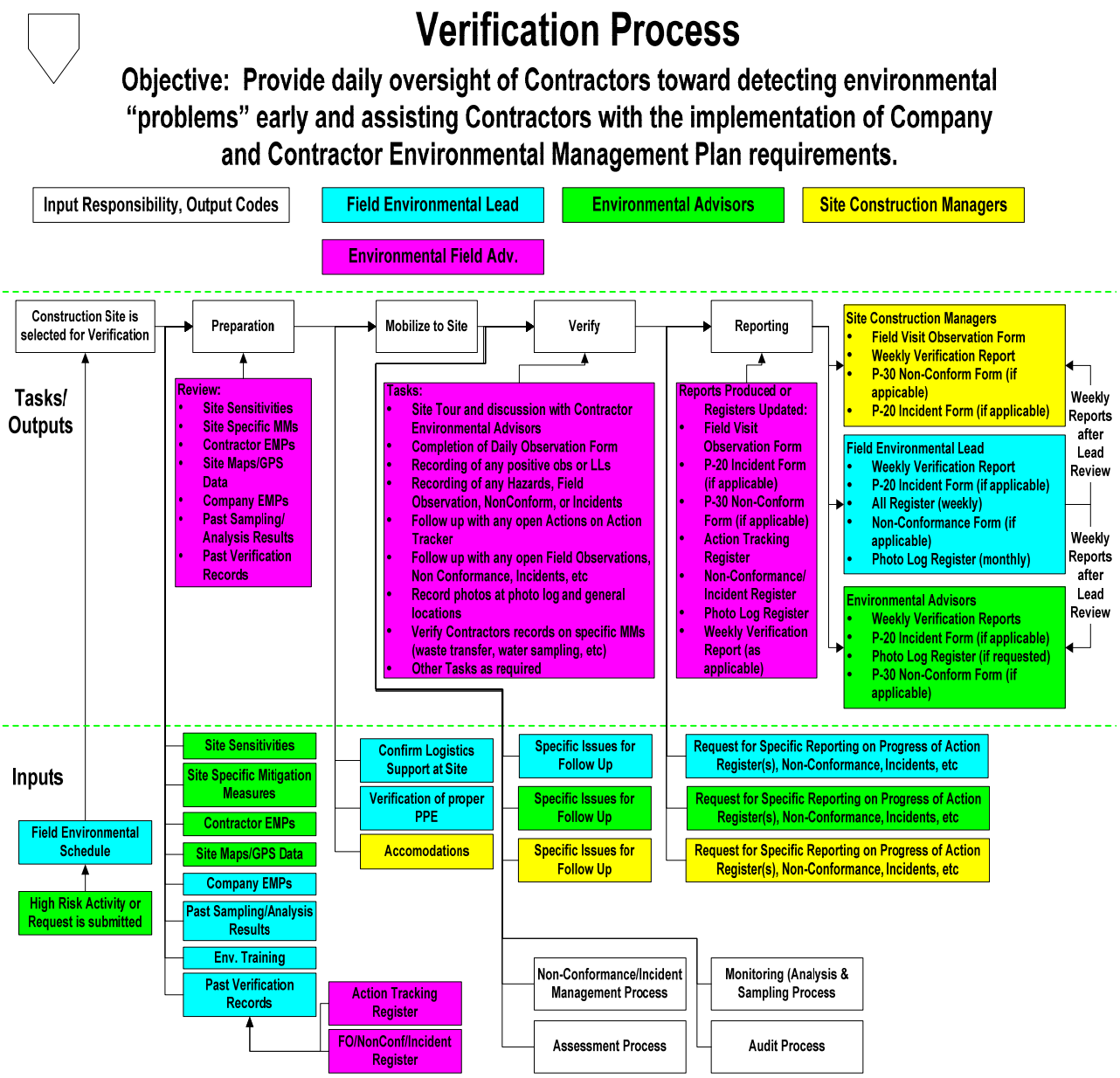
Table 5: Maximum Ammonia-Nitrogen Concentrations for Freshwater (mg/L)			
Temperature ^{o}C	**pH**		
	7.0	**8.0**	**9.0**
5	16.1	1.6	0.2
10	11.0	1.1	0.1
15	7.5	0.8	0.09
20	5.2	0.5	0.07
25	3.6	0.4	0.06
30	2.6	0.3	0.05
35	1.6	0.2	0.04

3.0 VERIFICATION AND INSPECTION

Company and contractors implement a field based inspection programme in order to verify and document the implementation and the effectiveness of mitigation measures identified in Contractor ESMP documents.

As part of Company's oversight of Contractor activities, Company checks and reviews Contractor inspection and verification documentation, which is made available to Company upon request. Figure 1 summarizes the interfaces between the Company's and Contractor's environmental monitors and the actual verification, review and reporting processes.

Figure 1: Field Verification and Inspection Process



Company's verification is executed by Company's Field Environmental Advisors (FEA). The main role of the FEA is to verify Contractor (and Company where applicable) implementation of environmental management and mitigation measures across all Project worksites using predetermined inspection checklists and forms and report results of verification and inspections to the Field Environmental Lead.

The FEA record and report on their activities using a variety of checklists, registers, forms and reports.

These checklists, reports, forms, and registers are summarized below:

Field Action Register: Contains lower severity level actions, comments and measures communicated to Contractor.

The Field Action Register is a lower severity level register of follow up actions, comments, queries that is maintained by the FEA to capture noteworthy items for action by Contractor and requiring FEA stewardship. The FEA populates this register with actions, comments and queries that might carry over multiple weeks or require actions by their back to back.

Field Observation Checklist: Contains higher severity level observations and is utilized as a prompt/guide for inspections.

The Field Observation Checklist is updated on a regular basis. After completion of the Field Observation Checklist, the FEA debriefs the appropriate persons, including Site Manager, Field Superintendent, Project Engineer, and Site Lead. A copy of the checklist is provided to the Contractor and the original retained by the FEA.

Field Observation, Non Conformance, and Incident Register: Contains the current status of all Field Observations, Non Conformances and Incidents with corrective actions, responsible parties and target closure dates

The register contains the observation date recorded, required corrective actions, responsible party, and current closure status.

The FEA populates the Field Observation, Non Conformance and Incident Register on the basis of the findings recorded in the Field Verification Reports. The FEA updates the corrective action status on the register on a monthly basis in consultation with the responsible Site Construction Lead/Manager and Contractor Environmental Lead.

Field Verification Report: Contains observations, suggested corrective actions, and communications from FEA to Contractor and lists Field Observations, Non Conformances and Incidents.

The Field Verification Report is produced by the FEA on a per site visit basis that summarizes the activities, conversations, and action/requests undertaken by the FEA while on site. The Field Verification report contains highlights of the following items: worksite(s) visited, duration of visit, summary of Company and Contractor discussion/interactions, summary of all Field Observations, Non Conformance, and Incidents recorded, including recommendations and follow up/corrective actions and photographs. Actions that the FEA deem important to be stewarded/recorded are registered in the Field Action Register as discussed above. Non Conformances and Incidents contained in the Field Verification Report are the subject of separate Company reporting forms. All pictures taken are registered consistent with the process described below (Photo Log Register).

Photo Log Register: Records the date, location and cardinal direction of photographs taken at worksites.

The Photo Log Register is a register of pictures that are taken by the FEA to chart the progress and status of works at all worksites.

4.0 ASSESSMENT AND AUDIT

4.1 Assessment

Company undertakes periodic assessments to evaluate the implementation and effectiveness of Company and Contractors' environmental program. Such assessments are undertaken in accordance with predetermined protocols agreed with Contractor. Upon completion of the assessments, Company provides Contractor with a draft assessment report. The assessment report is discussed between Company and Contractor at an assessment review meeting, following which Company provides Contractor with a final assessment report.

4.2 Audit

Company undertakes environmental audits, at its discretion, of Contractor activities and work sites, including camps. Such audits are undertaken in accordance with predetermined protocols agreed with Contractor. Upon completion of the audits, Company provides Contractor with a draft audit report. The audit report is discussed between Company and Contractor at an audit review meeting, following which Company provides Contractor with a final audit report.

4.3 Non Conformity Corrective Action

Contractor and Company will steward findings of all assessments and audits. Company maintains an Environmental Action Tracking System which includes all Non-conformances and Field Observations. Company maintains the Environmental Action Tracking System current at all times.

5.0 REPORTING

As detailed in the ESMP, Company shall submit to DEC a quarterly Construction Environmental Report (CER).

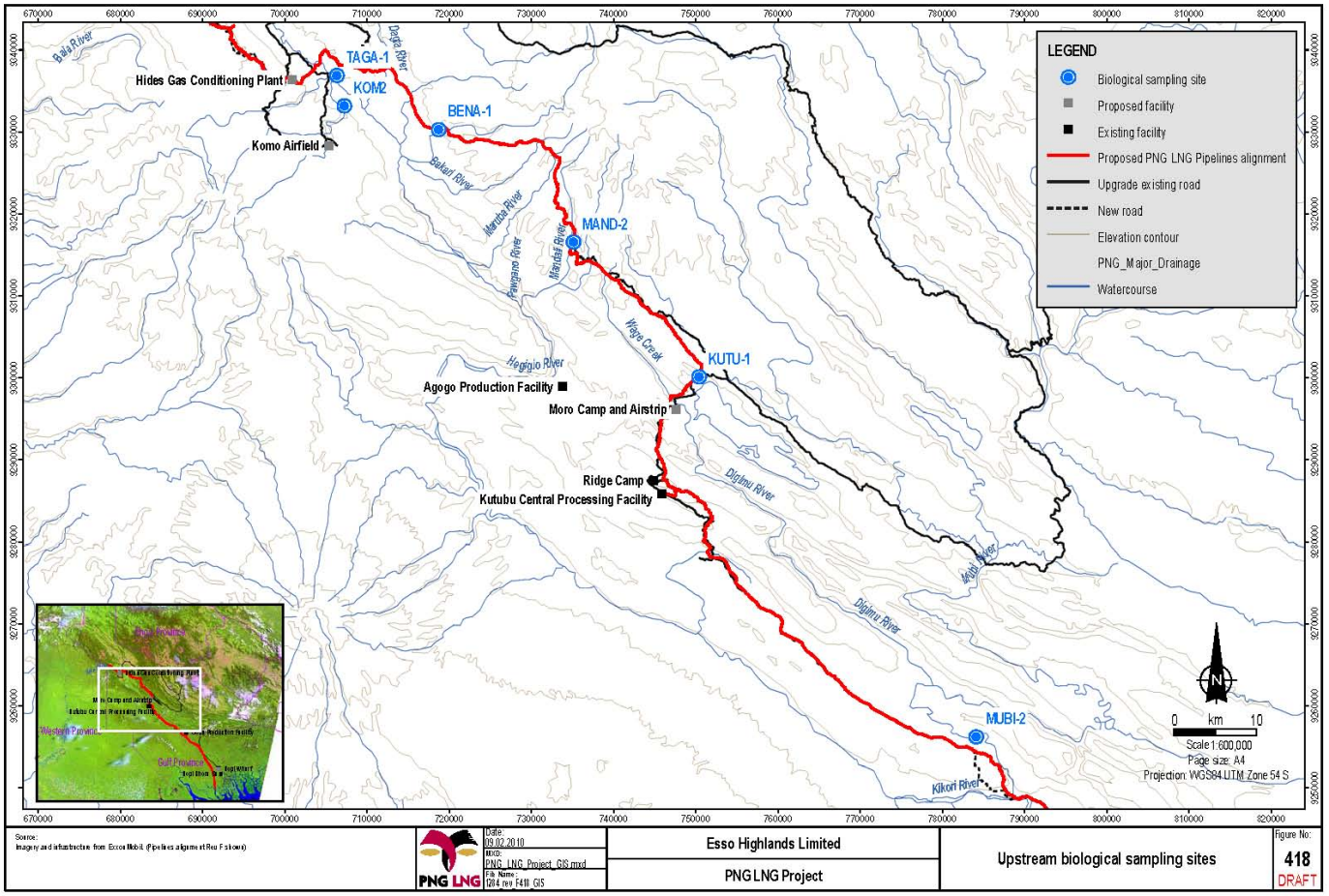
The CER shall include, for the reporting period:

- details and results of all monitoring described in this EMP
- details of additional monitoring locations defined during execution
- details of exceedances of applicable criteria
- summary of inspection and verification undertaken
- summary of assessments and audits undertaken
- summary of non-conformances raised in the reporting period and the status of the associated remedial / corrective action

Annex 1: Monitoring Locations

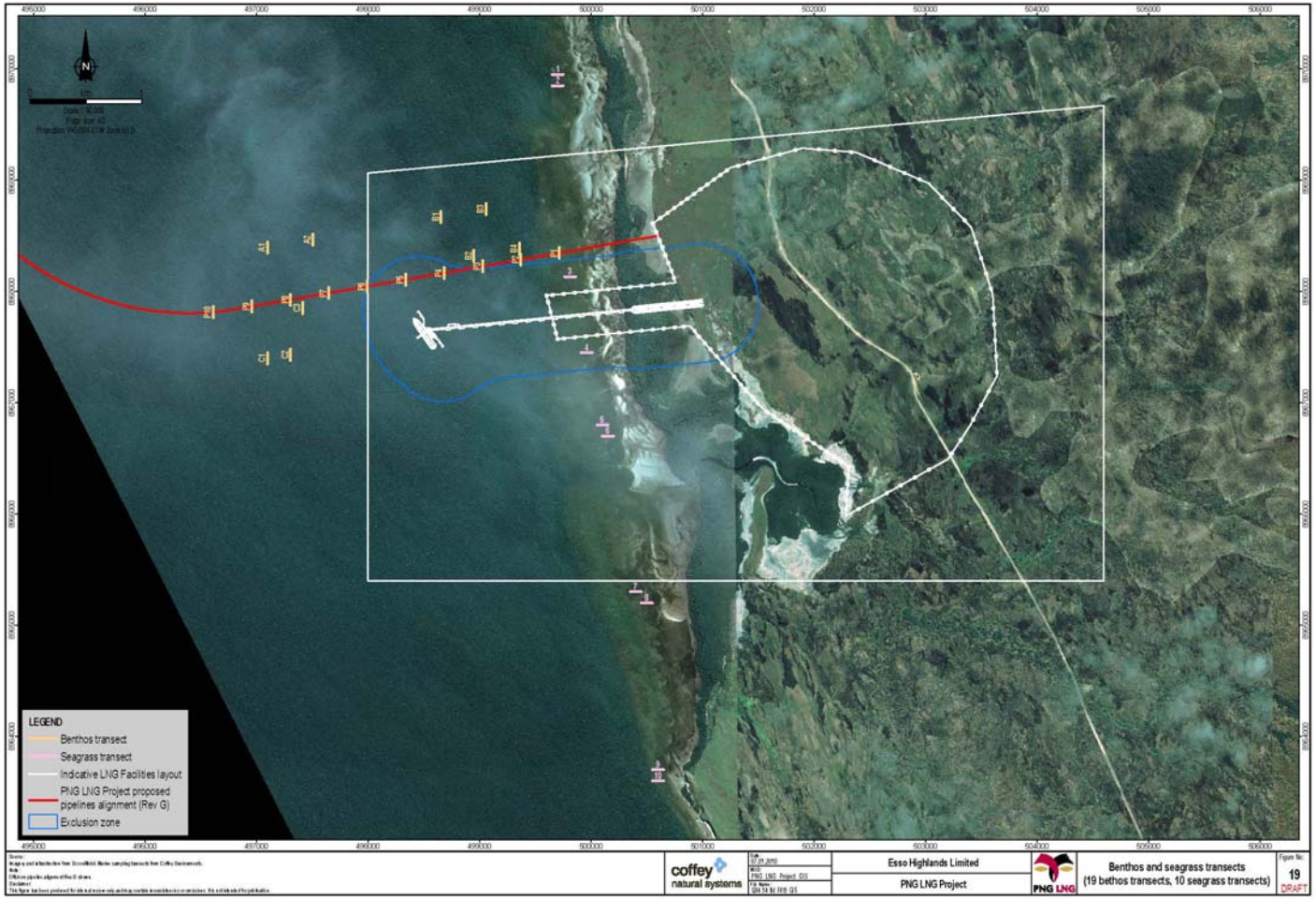
- **A1.1: Freshwater Ecology Monitoring Locations**
- **A1.2: Marine Ecology Monitoring Locations**
- **A1.3: Marine Water Quality Monitoring Locations**
- **A1.4: Sedimentation Monitoring Locations**
- **A1.5 Surface Water Quality Monitoring Locations**

A1.1: Freshwater Ecology Monitoring Locations

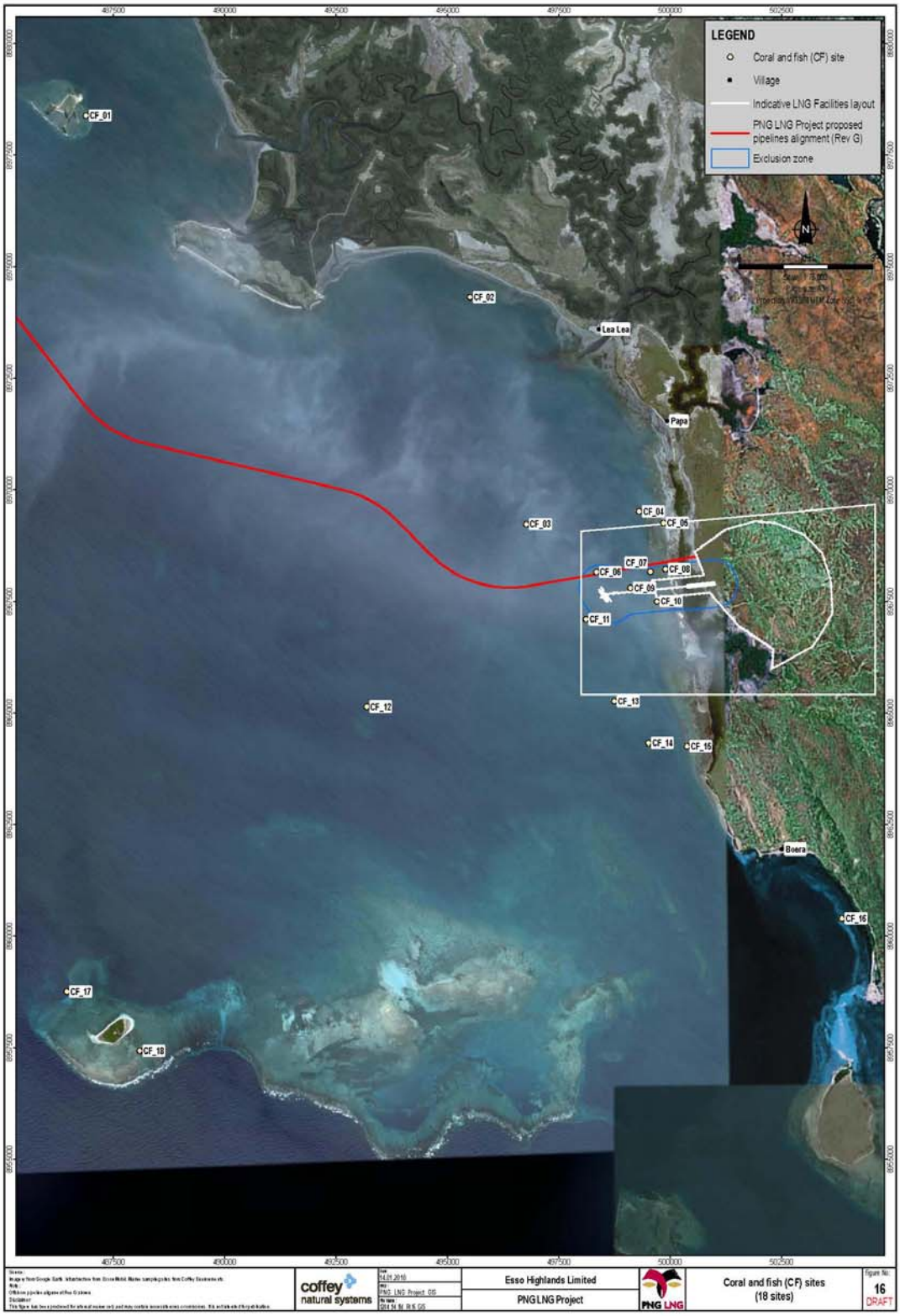


A1.2: Marine Ecology Monitoring Locations

Benthos and Seagrass Monitoring Locations



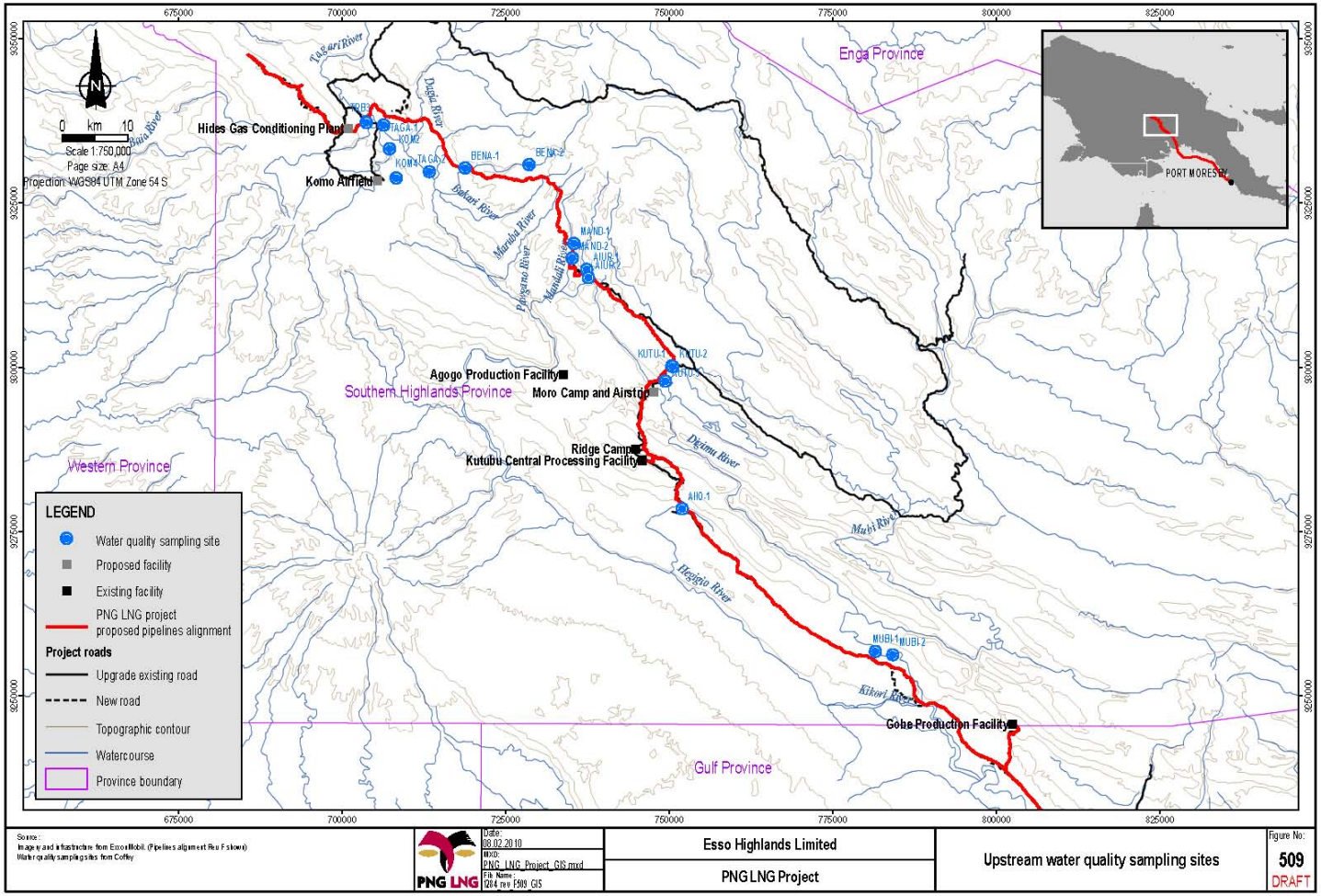
Coral and Reef Fish Monitoring Locations



A1.3: Marine Water Quality Monitoring Locations

A1.4: Sedimentation Monitoring Locations

A1.5 Surface Water Quality Monitoring Locations



Annex 2: Monitoring Methods

- **A2.1: Freshwater Ecology Monitoring Methods**
- **A2.2: Marine Ecology Monitoring Methods**
- **A2.3: Marine Water Quality Monitoring Methods**
- **A2.4: Sedimentation Monitoring Methods**
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- **A2.6: Groundwater Quality Monitoring Methods**

A2.1: Freshwater Ecology Monitoring Methods

Specific sampling methods follow the AusRivAS sampling approach (Department of Natural Resources and Mines, 2001) or similar. Five replicate samples are taken at sites where riffle habitat was available (riffle sites) and composite samples are taken at the remaining sites from edge habitat (edge sites) (Plate 1). For riffle sampling, a 250 µm mesh kick-net is placed in the riffle and an area of approximately 30 cm2 in front of the net is disturbed by hand and foot to dislodge macroinvertebrates. At each site, five replicate samples are obtained, working in an upstream direction. For sites where riffle habitat is not available, sweeps of edge habitat will be conducted in accordance with the AusRivAS protocols or similar, whereby a composite sample is taken by sweeping the net through all available edge habitats that can be reached within five minutes. This sampling technique produces a qualitative sample for the purpose of identifying the presence and absence of taxa and trophic guilds, rather than abundance data. All samples will be preserved in 70% ethanol.

a)

b)

Plate 1 Macroinvertebrate sampling site types a) riffle habitat and b) edge habitat

Macroinvertebrate samples will be delivered to an appropriate facility for identification. The samples are emptied into sorting trays and all macroinvertebrate contents are removed. Specimens are identified to the lowest level of taxonomic classification possible then enumerated.

The freshwater macroinvertebrates of Papua New Guinea are highly diverse, and differ from macroinvertebrate communities in Australia in that many species can fulfil the same ecological role. The high rainfall environment and resulting frequent changes in water levels that occur in the project area create dynamic conditions for aquatic fauna. As a result, the species occupying a particular role can be expected to change considerably over time (Lake 2000). The roles themselves (represented here by the functional feeding guilds) remain relatively constant even though the species may change and, therefore, it can be more informative to monitor the abundance of the functional feeding guilds rather than the individual species present. In particular, it will be helpful to monitor groups that tend to be indicators of environmental change. For example, specialist feeders, such as filter-feeders, shredders and scrapers are more sensitive to perturbation, and generalist feeders, such as predators and collector-gatherers comparatively tolerant to pollution (Rawer-Jost *et al.* 2000).

Where possible, macroinvertebrate taxa are assigned functional feeding guilds based on available literature on their feeding and behavioural mechanisms (Cummins *et al*. 2005). Families are divided into the following categories: predator, filter feeder, scraper, collector, deposit-feeder, collector-scraper, shredder-predator and shredder-scraper.

Plecoptera, Ephemeroptera, Trichoptera (PET) taxa are three orders of macroinvertebrates, which are considered to be among the most sensitive to pollution. Plecopterans, for example, are particularly sensitive to organic pollution, industrial effluent and heated water (Department of Natural Resources and Water, 2007) and are thus useful in monitoring as indicators of ecosystem health.

Data are statistically analysed for the sole purpose of confirming that sites chosen are acceptably similar in community composition and, thus, suitable to be used in comparison with each other and for use in future monitoring. For statistical analysis of overall community and feeding guild data, analyses are performed using PATN v3.12 and S-plus software. Using S-plus, analysis of variance (ANOVA) are performed on the replicated samples to identify any significant differences in abundances at each site, 'Site' being the factor and 'Abundance' being the variable. Chi-squared analysis is also performed to test for significant differences in the proportion of feeding guilds between sites. 'Site' and "Feeding Guild' are grouping variables and 'Abundance' is the count variable. The replicated and composite sampled sites are treated separately as differences may arise from the two different sampling methods.

PATN v3.12 is used to perform multivariate analyses of the taxa abundance data. To visualise the data, an ordination technique, known as semi-strong hybrid multidimensional scaling (SSH) is performed, which maps the distance between samples in terms of the similarity (in this case, Bray-Curtis similarity) of their respective taxa abundance data. Cluster analysis (classification using Agglomerative Hierarchical Fusion and Flexible UPGMA technique) is used to confirm any outliers or groupings visible in the ordination plots.

A2.2: Marine Ecology Monitoring Methods

Benthos

The benthic habitat will be affected by the trenching required for pipeline installation and spoil placement. This disturbance will both remove and smother the benthic communities in and to one side of the trench where material is moved and deposited. Once completed, recolonisation of similar benthic conditions and fauna is expected. The EIS determined that impacts to the benthic environment adjacent to the footprint of the pipeline infrastructure would be low (expected within 1 km and rapid recovery within 2 years) and monitoring will validate this prediction. It has already been determined that the sediment is not contaminated, as defined by Schedule 2 of the draft Marine Pollution (Sea Dumping) Regulations (Coffey Natural Systems, 2009).

Transects will be monitored at replicated locations within 1 km distance of the pipeline in order to observe processes of benthic colonisation and to compare 'before' and 'after' benthic areas.

Once the pipeline is covered, re-establishment of benthic communities in the initially barren sediments will be recorded as visual evidence of biological activity, such as mounds, burrows, casts, tracks and animals themselves. Over the period of post-construction monitoring, it is expected that the extent of observable biological activity will increase until surface features will cease to demarcate presence of the buried pipeline, or of the areas for stockpiling sediment excavated for the trench.

Monitoring will use an underwater towed video camera, taking imagery near the LNG jetty construction location and pipeline trenching and construction locations. A number of 100-m video transects will be undertaken at progressive distances along the pipeline alignment and LNG jetty aligned perpendicularly to impacted areas, extending to a distance just beyond 1 km. The start and finish of transect locations will be marked with a weighted float. Where there is evidence of biological activity (casts, mounds, burrows, holes) still photos will also be captured (including GPS locations, time of capture and a brief description recorded) for description and comparison over time.

Mangroves

The construction of the pipeline and LNG jetty must necessarily pass through and physically remove mangroves in their respective alignments, resulting in new mangrove edges adjacent to the construction routes. While this represents only a very low proportion (estimated 5.3%) of the mangroves within Caution Bay, the ecological and resource value of the mangroves is recognised. Potential changes to hydrodynamic conditions within the mangroves were assessed as low under design of the infrastructure in the EIS and final configuration where no solid MOF is proposed may reduce this risk further. However, validation monitoring of standard indices of the health of mangroves adjacent to and remote from the marine infrastructure is proposed.

The seaward frontal mangroves are monospecific stands of *Rhizophoa stylosa*, with some *Avicennia marina* on the landward edges. Indices of diversity are therefore not a good benchmark however, the most important outcome is that the newly created (and maintained) edges next to the jetty and pipeline route become established and provide natural functions of:

- Protection of coast from erosion
- Trapping of sediment
- Habitat for fish/invertebrates.

Photo-point monitoring (e.g., development of frontal root mass, sapling growth) and periodic fish sampling is proposed to demonstrate these functional values.

Seagrasses

The construction of the pipeline and the LNG jetty must necessarily pass through patches of seagrass that occur between the fringing reef and the mangroves. The footprint of the infrastructure directly affects less than 3% of the seagrass within Caution Bay. The ecological value and importance of seagrass for fisheries is recognised. Sources of impacts are primarily via sedimentation and turbidity during construction; thereafter diminishing. Monitoring of density of seagrasses adjacent to, and up to 2 km remote from the marine infrastructure is proposed to validate effectiveness of the sedimentation mitigation measures and processes of recovery.

Transects / photo points will be established, marked by GPS co-ordinate. A towed video camera will record seagrass cover within each site. A number of 100 m video transects will also be undertaken in addition to the photo points. The start and finish of transect locations will be marked with a weighted float. Further information regarding the methodology can be found in A002. Analysis of the video footage will be used to describe the seagrass condition and determine the percentage cover in each of the photo points and along each of transect.

Coral Reef and Reef Fish

Coral Reef

The habitat and resource value of the fringing reefs and bommies is recognised, the loss (less than 5 %) is compensated in part by the creation of exclusion zone +500 m around the LNG jetty. The condition of the reef (corals) is itself an overall indicator of the existing ambient environmental conditions (sedimentation; fishing use) and currently shows existing evidence of impact from these factors. Monitoring of standard indices (coral life forms, percent cover, abundance and size of fish families) is proposed, in conjunction with sediment / TSS monitoring at locations to validate that impacts from construction are as predicted (within 2 km and recovery within 2-5 yrs) and to determine the longer term positives effects of the exclusion zone.

The fringing reefs within Caution Bay are generally quite degraded through heavy use and sedimentation (EIS, 2009), from which it is difficult to set any quantitative target criteria for typical indices of cover and diversity. However, some post-construction colonisation and succession of coral forms and functional habitats is expected, and the fringing coral reefs adjacent to, and affected by the cuts made for the LNG jetty and pipeline, will, over the 2 to 5 years of post-construction monitoring, show:

- Presence of newly colonising coral colonies and succession of coral forms on any bare rocky surfaces and areas once they cease to be affected by construction-related sedimentation.
- Increased functional complexity of coral life forms (e.g. massive, encrusting, tabulate, soft corals, coralline algae).
- Presence/increasing abundance of reef-dependent fish species.

Over the longer term and during operations, the effect of the exclusion zone around the jetty is expected to result in less human disturbance and gradual improvement of reef condition (coral cover, diversity of coral forms, diversity and abundance of fish) in the exclusion zone.

Monitoring will use an underwater towed video camera, taking imagery over the reef slope (just below the reef crest) and orientated parallel to the reef slope. Two methods will be adopted to quantify coral distribution at the survey sites, including visual census and video transects as described below.

Visual Census

A number of 6 m transects will be positioned over areas containing higher coral cover selected to provide long-term monitoring of coral condition, marked at the start and finish with a weighted float and GPS locations recorded. A weighted measuring tape will be laid over the reef between the two floats. Still photographs will be obtained using a high-definition digital camera in an underwater housing. Photographs will be taken at approximately 0.6 m intervals along the 6 m transect with the camera held at a constant perpendicular distance of 0.5 m above the substrate, with the measuring tape framed in the centre of each photograph. Mosaics of each transect will be constructed by stitching individual photographs together to provide a general overview of the structure of the coral reef community within each survey site.

Analysis of the photographs will record the distance at which key features are intersected (e.g., the start and end of each individual coral type). Records will be made of the following:

- Hard coral families and growth forms (e.g., digitate Acropora, massive Porites, encrusting Faviids).
- Other biota (e.g., soft corals, sponges and Halimeda).
- Abiota (e.g., dead coral, rubble and sand).

Data collected from each site will be used to calculate the percentage coral cover and ecological diversity (coral forms and other groups) from the sampling locations.

Video Transects

Two additional 50 m transects at each survey site will be established to provide a more accurate representation of the overall cover of coral reef assemblages the sites. Each transect will begin at the same weighted float used for the 6 m visual coral transect with a weighted measuring tape laid over the reef to the 50 m length. A video camera orientated across the reef at a constant distance of 0.5 m above the seafloor will be used to record the coral reef assemblage. This method follows the Australian Institute for Marine Science (AIMS) Video Transect Analysis System (AVTAS) method developed by the Australian Institute of Marine Science (AIMS, 2004).

Individual video frames (e.g., approximately 40 frames per 50 m transect) will be assessed to identify the substrate at a number of fixed points per transect (typically 5 points). Live hard coral, live soft coral, algae, invertebrates and other substrata types such as recently dead coral, coral rubble, sand and reef substrate will be recorded along the transects.

Reef Fish

At each of the coral reef survey sites, underwater visual census using a towed video camera will be used to estimate density and abundance of coral reef fish families.

Monitoring will use an underwater towed video camera, taking imagery over the reef slope (just below the reef crest) and orientated parallel to the reef slope. A visual census will be adopted to record diversity and abundance of coral reef fish families at the survey sites.
A number of 50 m transects will be positioned at the reef as per the coral reef video transect, marked at the start and finish with a weighted float and GPS locations recorded. A weighted measuring tape will be laid over the reef between the two floats. A towed video camera rig with two cameras will be towed along the transect 1 to 2 m above the substrate. One camera will be positioned to view vertically and one to view horizontally.

Video footage will be analysed as follows. The numbers of fish will be recorded (identified to families), estimates of fish length will be made using appropriate centimetre size-classes depending on the size of the fish (e.g., 1 cm for fish up to 10 cm, 2 cm for fish between 10 and 30 cm, 5 cm for fish between 30 and 60 cm, and 10 cm for fish over 60 cm). For fish that occur in a school, their number and the distance to the closest and the furthest fish will be estimated.

Video transect footage will also be copied to a DVD and archived as a permanent record.

A2.3: Marine Water Quality Monitoring Methods

Sources of impact to marine water quality include surface runoff and disposal of waste waters including treated domestic waste water, surface runoff, hydrotest water and reject brine from desalination processes. Of these, only hydrotest is a once-off discharge resulting from tank integrity testing; the other sources will extend through construction and during operation. The EIS describes appropriate mitigation measures to ensure that discharges meet the appropriate water quality criteria in the receiving water body.

Water samples will be taken by means of a Niskin oceanographical sampling bottle lowered to 1 m below surface. Sampling will be undertaken from the bow of the vessel, which is pointed up-wind and up-current to minimise sample contamination. Prior to transferring the sample from the Niskin bottle into a sample bottle, the sample bottle will be rinsed with site water to ensure it is free of contaminants. During transfer the sampler will wear powder-free latex gloves.

A2.4: Sedimentation Monitoring Method

During construction the main agent of impact to marine water quality and the habitats within Caution Bay will be increased suspended sediments and sedimentation arising either from erosion and subsequent runoff from land disturbed during construction or from direct disturbance of the seabed during construction of the offshore facilities, including any associated dredging and trenching. Habitats such as coral reefs and seagrass beds are particularly vulnerable to smothering and reduction of ambient light. Loss of habitat directly in the footprint of the facilities is unavoidable; however, mitigation measures are incorporated into the construction EMPs to limit as far as practicable, the spread of any suspended sediments to within the immediate vicinity of the physical structures or source of impact.

The selection of locations and frequency of monitoring is guided by the impact prediction in the EIS. For most assessments of construction-related impacts from sedimentation on sensitive habitats such as the reefs and seagrass areas, the magnitude of impact was considered as 'medium,' where it affected less than 10% of the available habitat and / or was expected to occur within 2 km from source with recovery within 2 to 5 years. For the pipeline installation, the impact was considered 'low', where impacts were expected to be confined within 1 km with recovery within 2 years.

Sedimentation is typically measured with the use of sediment traps, placed and recovered by divers. However, most of the fringing reef areas and seagrass areas are shallow, where material settling in traps is not necessarily a true indication of natural settlement (material may be temporarily resuspended by wave activity), and baseline results in the EIS were variable, probably as a result of these factors. Although programmable sediment trap carousels are available, they are designed for deep water and activity of animals and colonising organisms in shallow waters also inhibits the effectiveness of these or integrated turbidity sensors. Hence sediment will be directly measured as total suspended solids (TSS) and turbidity.

Physical parameters will be recorded in situ at each site with a CTD (conductivity, temperature, density) instrument fitted with appropriate probes, and lowered/raised from surface to near-bottom. The CTD will record in 1-second intervals for each cast undertaken. The CTD will be lowered from the boat at a rate of around 1 m per second.

Simultaneously, water samples will be collected for analysis of TSS. Surface and within the water column samples will be taken by means of a Niskin oceanographical sampling bottle lowered from the bow of the vessel. Samples will be taken from 1 m below the surface and at approximately mid-water column. The use of a Niskin bottle minimises sample contamination and allows for the water sample to be collected and transported to the surface without mixing with water from different depths.

A2.5: Surface Water Quality Monitoring Methods

This document describes generic procedures to be implemented to undertake the surface water sampling throughout the PNG LNG project area. This document is subject to change.

Equipment Required

The following equipment is required to undertake water sampling:

- Laboratory-supplied sample bottles.
- Sampling pole.
- Latex gloves (powder free).
- Chain of custody log sheet, waterproof notebook, permanent markers and pencils.
- Water quality meter (pH, temperature, conductivity, turbidity and dissolved oxygen).
- Calibration solutions for water quality meter (pH buffers, conductivity and turbidity standards).
- Syringes and filters (0.45 µm) for filtration of samples requiring dissolved metal analysis.
- Plastic bags and rubber bands (for bagging up samples).
- Deionised distilled water (rinsate water for blanks).
- Eskies and freezer blocks.

Sample bottles, syringes and filters (0.45 µm), rinsate water, eskies and freezer blocks and chain of custody log sheets are provided by the analytical laboratory.

Sampling Locations and Access

Site selection considered the following factors:

- Potential for impact due to project activities.
- Appropriate location upstream/downstream of project activities.
- Site accessibility, safety and security.
- Use as a water resource by local communities.
- Representativeness of stream section.

In Situ Measurements

The following water quality parameters are to be measured in situ using an appropriate water quality meter:

- pH.
- Temperature.
- Dissolved oxygen.
- Conductivity.
- Turbidity.

This instrument is to be calibrated prior to use in accordance with instrument supplier's instructions using appropriate calibration solutions.

Laboratory Analyses

For the baseline sampling events, analyses are to be undertaken for the complete suite of parameters described in the Environmental Monitoring Plan.

Analyses should be undertaken by a laboratory approved by Company and the DEC.

Sample Bottles and Sample Preservation

Water samples are to be collected into suitably prepared bottles, containing sample preservatives as appropriate, that have been supplied by the analytical laboratory responsible for conducting the analyses. Advice is to be sought from the laboratory regarding the bottles and volumes required to undertake required analyses, whether preservatives have been added to bottles and if rinsing of the bottles should be undertaken before sample collection (rinsing should not be undertaken if the samples have been pre-dosed with preservative). Note that due to international air safety regulations, sample containers freighted by air may not be able to be pre-dosed with preservative. For some parameters recommended sample holding times or preservation requirements may therefore not be able to be met prior to sample analysis.

Samples for analysis of dissolved metals may be filtered in the field. Nitric acid will be added to these samples (and samples for total metal analysis) when received in the laboratory.

All samples should be chilled as soon as practicable to 4ºC after collection and transported to the analytical laboratory. Coolers and ice bricks should be used to assist keeping samples cool.

Water Sample Collection

Water samples are to be collected using as per the following:

- Sample bottles are to be clearly labelled with a permanent waterproof marker to show:
  - Project identification.
  - Sample site identification.
  - Date and time of sampling.
  - Name of sampler.

The lid as well as the bottle should be labelled with the sample site identification.

- Samples are to be collected directly into the bottles provided, where this can be safely undertaken. An exception is crocodile-infested waters where sampling is to be undertaken from a boat using a sampling pole with fitted bottle.
- The sampler must wear powder-free latex gloves and take care not to touch the internal surfaces of the bottles or tops.
- Sample bottles should be rinsed with the water to be sampled before collecting the actual sample, unless sample bottles have been pre-dosed with preservative in which case no rinsing should occur. Bottles for bacteriological analyses (i.e., faecal coliforms) should not be rinsed.
- Ideally, water samples should be taken mid-stream with the bottle facing upstream and placed about 10 cm under the water. However, this is not possible at many sites and sampling from a riverbank is often the only practical and safe option[10].
- Remove the bottle cap once the bottle is submerged below the water's surface, both when rinsing the bottle and taking the sample. If there is negligible current, create one by moving the bottle forward horizontally in a direction away from the body. If possible, the sample site should be approached from downstream.
- If a boat is used for sampling, it should be moving slowly upstream with the sample taken at the front of the boat from water uncontaminated by the vessel.
- All sample bottles should be filled to the top.
- Place samples into coolers as soon as possible after sampling. The use of wet ice instead of freezer blocks is not recommended.
- Samples requiring filtration should be filtered as soon as possible after collection. Filtering should preferably be undertaken at the time of sampling using 0.45 µm membrane filters fitted to syringes. If water is particularly turbid, a 1.2 µm filter should

[10] When sampling from a riverbank, samples should be taken as far out in the channel and away from the sampler as possible without compromising safety of the sampler.

be attached to the syringe as a pre-filter (or alternatively several 0.45 µm filters may be required due to clogging). Filtering may be undertaken on return from the field or in the laboratory if necessary.

Stream Discharge Estimation

An estimate should be made of stream velocity at the time of sampling. This can be done with the use of a propeller current meter and a wading rod or, more simply, by recording the time it takes for a float[11] tossed into the centre of the stream to travel a given distance (e.g., 10 m) and multiplying the resultant velocity by a factor of 0.7 to allow for vertical velocity variations across the river profile. If using this method, several measurements should be undertaken and the average velocity calculated.

River discharge at the time of each sampling run can is then calculated based on the estimated velocity and estimated depth and width of the stream (average velocity x cross-sectional area).

Documentation

Site Description

A description of each sampling location is to be recorded in a waterproof log book. These observations should include:

- Details about site access, including coordinates of landing location if accessed by helicopter and trekking time to site.
- Description of stream (e.g., water clarity, velocity, streambed and bank composition, channel characteristics, i.e., slope, width, depth).
- Name of stream.
- Sampling location identification.
- Coordinates of sampling location.
- Date and time of sampling.
- Weather conditions.
- Estimation of stream width, depth and velocity, and stream discharge.
- Information concerning water use by local villagers.
- Safety observations.

This information should be transferred to a field log sheet. Photographs (and sometimes video) are also to be taken at each site.

In Situ Measurements

Results from in situ stream measurements are to be recorded in the waterproof log book. These measurements are to include:

- pH.
- Temperature.
- Conductivity.
- Dissolved oxygen.
- Turbidity.

This information should be transferred to a field log sheet.

[11] A suitable float can be something as simple as a piece of orange peel.

Collected Samples

Sample bottles should be clearly labelled with a permanent waterproof marker. Details of samples collected (and analytical parameters required) should be recorded in the waterproof log book. This should include sample identification codes given to quality assurance samples, i.e., blank and duplicate samples (these samples should not be obviously identifiable by the analytical laboratory).

This information is to be transferred to the Chain of Custody form for submission to the laboratory with the samples (except information identifying blanks and duplicates). A copy of the Chain of Custody form is also to be retained by the samplers.

Quality Assurance and Quality Control

Blanks

Each sampling campaign should include preparation of at least one set of sampling blanks. This involves filling of empty bottles from a bulk sample of distilled deionised water in a manner as close as possible to that used for the actual sample bottles. The blanks should then be preserved and handled in the same way as the sample bottles.

Duplicates

Duplicates are two samples collected from the same sample site at the same time (or in immediate succession) for analysis at the laboratory. A set of duplicate samples should be collected on each sampling campaign.

Laboratory Quality Assurance Program

Analyses should be undertaken by a Company and DEC approved laboratory. A laboratory quality assurance program is to be that includes analysis and reporting of the following quality control samples:

- Method blank.
- Sample duplicates.
- Laboratory control samples.
- Matrix spikes.

Analytical results should be assessed to determine that they are within acceptable limits, such as those described in APHA (1995)[12].

Sample Transportation

Storage

Samples should be kept refrigerated (<4ºC where practical) until transported to the analytical laboratory. Should suitable refrigeration space not be available at camps, use freezer bricks to keep samples cool in eskies. (Note that empty drink bottles filled with water and frozen can be used for this purpose).

Packing for Transport

Samples should be packed for export to the analytical laboratory as follows:

- Samples should be packed standing upright in eskies so as to minimise the risk of breakage or spillage. Ensure that all sample lids are tightly on and glass bottles are packed away from each other. Also check that sample labels have not rubbed off bottles. It is prudent to place all samples from individual sites in one plastic bag so that they can be easily identified should sample labels become unreadable.
- Pack adequate numbers of freezer blocks in with the samples to keep them cool.

[12] American Public Health Association. 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edition. Greenberg, A.E., Clesceri, L.S. and Eaton, A.D. (eds).

- The chain of custody form should also be placed into a plastic bag and placed into one of the eskies. A copy of this form is also to be retained by the sampler.
- The lids of eskies should be tightly taped with packing tape to prevent movement.
- Mark the number of the consignment piece, e.g., 1 of 3, 2 of 3 and 3 of 3.
- Place the 'fragile' stickers and 'keep chilled' stickers (supplied with bottles) prominently on each consignment piece.
- Measure the weight and volume of the total consignment.

Consignment Documentation

Transport of samples will need to be arranged from the field to the analytical Laboratory. Transport of Company samples (i.e. from Moro to Australia) can be arranged through the EHL Logistics Office at Moro.

The following documentation will need to be provided for the consignment if sent outside of PNG.

- Laboratory **AQIS Permit** to Import Quarantine Material. A copy of this permit should be placed in a plastic bag and taped to the outside of each piece of the consignment. A copy should also be included with the Customs Declaration and air waybill forms for the consignment.
- **Customs Declaration** stating that the samples have a declared Value for Customs of about US$20 and that they are environmental samples being shipped to Australia for laboratory analysis and disposal. The declaration must be on company letterhead.
- **Air waybill** supplied by the courier. For Company samples this will be arranged by Moro EHL Logistics Office who will organise transport of the samples to Port Moresby on an OSL charter flight and then organise for a courier company (TNT Express) to transport samples to Australia, see them through customs and quarantine and deliver them to the laboratory.

Dispatch Checklist

- Samples packaged well.
- Chain of Custody form included with consignment.
- 'Fragile' and 'Keep Chilled' stickers affixed to eskies.
- Address labels affixed to each consignment piece.
- AQIS Permit on outside of each consignment piece.
- Customs Declaration completed and AQIS Permit attached to Customs Declaration.
- Air Waybill documentation completed.

A2.6: Groundwater Quality Monitoring Methods

Sampling Equipment

Equipment used for the sampling of the newly installed monitoring wells includes:

- Hand tools.
- Cut proof gloves (AS4343).
- Nitrile Gloves.
- 100 m Water Level Dipper.
- Down hole “Whale” pump.
- 1 litre “Clearview” plastic bailer.
- Water Quality Meter YSI 556 MPS
- Buckets.
- Sampling bottles containing appropriate preservatives (as supplied by laboratory).
- Esky and ice packs.
- Packing material.

Borehole Gauging

The purpose of borehole gauging is to establish static water levels within the boreholes. Gauging data from the wells are obtained from the top of casing (TOC) and are measured with a 100 m Water Level Dipper. Upon completion of the installation of the groundwater monitoring network, wells are surveyed to determine the elevation (in metres above mean sea level mMSL) of the ground surface in each drilling location, and the top of each well casing.

Purging

Once the pump has been installed, boreholes are purged of either three well volumes or until purged dry using a down hole pump (Whale) in order to remove the stagnant groundwater and allow for the infiltration of fresh groundwater into the well. The objective of purging the wells is to facilitate the collection of the samples representative of the formation waters.

Purging continues until three consecutive measurements of groundwater quality parameters (dissolved oxygen, pH, temperature and conductivity), taken at five-minute intervals, are seen to stabilise**.** Measurements are considered to have stabilised once readings fall within the following limits:

- pH ± 0.05.
- Temperature° – ± 10%.
- Electrical conductivity (µs/cm) – ± 3%.
- Dissolved oxygen – ± 10%.
- Redox potential (mV) – ± 10%.

The water quality meter is calibrated in accordance with the manufacturer’s specification prior to the commencement of the survey.

Water quality measurements are taken by positioning the probe within the middle of the sample collection bucket, turning it on and recording readings once they had stabilised.

Sampling

Samples are collected upon stabilisation of groundwater quality parameters. Wells purged dry are considered to be sufficiently purged, and groundwater samples are collected from these wells.

Samples are collected with the use of a disposable plastic bailer, and transferred into the laboratory supplied bottles, which are all labelled appropriately prior to sample collection.
Each label includes:

- Sample ID- borehole ID (lid labeled as well).
- Project number.
- Date and time of collection.
- Sampler's initials.

Once samples are collected they are immediately stored in esky's filled with ice packs. Care is taken to pack esky's neatly and keep samples upright.

QA/QC
Quality control samples are collected to determine variations caused by the analytical methods and sample integrity during transport and storage.

At the same time as the original sample, one field (intra laboratory) duplicate is collected for every 10 samples and submitted to the laboratory for analysis. A single trip blank (sample container filled with distilled water) is placed in each esky and analysed for total petroleum hydrocarbon (C6-C9), benzene, toluene, ethylbenzene and xylene contamination.

Sample Analysis
Analysis of groundwater samples is undertaken using Company and DEC approved laboratories.