DRAFT ENVIRONMENTAL IMPACT STATEMENT

BLACKTIP PROJECT

VOLUME 2 TECHNICAL APPENDICES OCTOBER 2004






WOODSIDE

Contents

Appendix A **Blacktip Project – Environmental Noise Assessment prepared by Air Noise Environment**

Appendix B **Blacktip Project Offshore and Intertidal Environmental Surveys prepared by Sinclair Knight Merz**

Appendix C **Technical Report Sea Turtles, Dugongs and Seagrasses in the Region of the Blacktip Project prepared by Dr Michael Guinea, Charles Darwin University**

Appendix D **Blacktip Development Onshore Plant Site and Gas Pipeline Route, Wadeye/Port Keats, Northern Territory: Desktop Assessment of Acid Sulfate Soils prepared by Sinclair Knight Merz**

Appendix E **Blacktip Project EIS: Hydrology and Water Quality prepared by EWL Sciences**

Appendix F **Environmental Impact Statement for the Proposed Blacktip Project Vegetation and Flora Study prepared by EcOz Environmental Services**

Appendix G **Biting Insect Survey and Assessment Blacktip Project June 2004 prepared by Northern Territory Medical Entomology**

Appendix H **Environmental Impact Statement for Proposed Blacktip Terrestrial Fauna Study prepared by EcOz Environmental Services**

Appendix I **Environmental Impact Statement for the Proposed Blacktip Gas Project Archaeology and Historic Heritage prepared by Begnaze**

Appendix J **Blacktip Produced Formation Water Assessment prepared by International Risk Consultants Environment**

Appendix K **Blacktip Oil Spill Risk Assessment Modelling prepared by International Risk Consultants Environment**

Appendix L **Assessment of species with Indigenous conservation values and related environmental cultural values in the vicinity of the proposed Blacktip gas pipeline and processing plant near Wadeye in the Northern Territory prepared by Smyth and Bahrdt Consultants**

Appendix M **Social Impact Assessment of the Proposed Blacktip Project, Wadeye, Northern Territory prepared by IMpaxSIA Consulting**

Appendix N Blacktip Project – EIS Health Programme Project Health Review prepared by Worley

Appendix O Framework Offshore Environmental Management Plan prepared by Sinclair Knight Merz

Appendix P Framework Marine and Intertidal Monitoring Programme prepared by Sinclair Knight Merz

Appendix A

Blacktip Project – Environmental Noise Assessment prepared by Air Noise Environment






This page has been left intentionally blank

BLACKTIP PROJECT – ENVIRONMENTAL NOISE ASSESSMENT

October 2004

Prepared by:

AIR NOISE ENVIRONMENT PTY LTD
5/26 Brandl Street, Brisbane Technology Park
Eight Mile Plains, Queensland 4113
07 3341 1811 (ph) 07 3341 2822 (fax)
ane@ane.com.au

Project Reference:	930
Document Title:	Blacktip Project - Environmental Noise Assessment
Client:	Sinclair Knight Merz
Document Reference:	N:\Completed\930 SKM\Report\930Final03.doc
Date Issued:	13 October 2004
Prepared by:	Caroline Heathcote
Approved by:	

Copyright:

Air Noise Environment retains ownership of the copyright to all reports, drawings, designs, plans, figures and other work produced by Air Noise Environment Pty Ltd during the course of fulfilling a commission. The client named on the cover of this document shall have a licence to use such documents and materials for the purpose of the subject commission provided they are reproduced in full or, alternatively, in part with due acknowledgment to Air Noise Environment.

Third parties must not reproduce this document, in part or in full, without obtaining the prior permission of Air Noise Environment Pty Ltd.

Disclaimer:

This document has been prepared with all due care and attention by professional scientists and engineers according to accepted practices and techniques. This document is issued in confidence and is relevant only to the issues pertinent to the subject matter contained herein. Air Noise Environment Pty Ltd holds no responsibility for misapplication or misinterpretation by third parties of the contents of this document. If this document does not contain an original signature, it is not an authorised copy. Unauthorised versions should not be relied upon for any purpose by the client, regulatory agencies or other interested parties.

Where site inspections, testing or fieldwork have taken place, the report is based on the information made available by the client or their nominees during the visit, visual observations and any subsequent discussions with regulatory authorities. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Air Noise Environment Pty Ltd is both complete and accurate. It is further assumed that normal activities were being undertaken at the site on the day of the site visit(s).

EXECUTIVE SUMMARY

The Project

Woodside Energy Limited (Woodside), in association with its joint venture partner ENI Australia (ENI), proposes to develop the Blacktip gas field in permit WA-279-P of the Joseph Bonaparte Gulf, approximately 245 km south west of Darwin. It is proposed that gas and associated reservoir liquids are exported from the Blacktip field via a subsea pipeline to an onshore processing plant. The pipeline required will be approximately 110 km in length and will travel in a south-easterly direction to a suitable shore landing site. The shore landing for the export pipeline will be approximately 20 km west of the township of Wadeye.

Air Noise Environment Pty Ltd were commissioned by Sinclair Knight Merz on behalf of the joint venture to undertake a noise assessment for inclusion in the Environmental Impact Assessment being completed for the project. The assessment considered the potential impacts of noise associated with the following project activities:

- construction and operation of the onshore processing plant; and
- construction and operation of the onshore pipeline.

Methodology

Receptor Locations

A desktop review of surrounding landuses was undertaken to identify landuses and receptor locations nearby to the proposed development site. The report has identified two groups of sensitive receptors: Wadeye Township, which has approximately 2,500 residents located 12 km from the Blacktip Project; and Tchindi Aboriginal Camping Ground, which is used on an ad hoc basis, located 2.5 km away.

Existing Noise Levels

Background noise monitoring has been completed at Wadeye Township, and at the proposed Blacktip processing plant for a 24 hour period at each site. The results of the ambient noise monitoring has identified that the areas are generally quiet as would be expected in a rural/rural residential environment.

Noise Emissions – Construction Phase

Potential sources of noise emissions during the construction phase of the project considered by the assessment include:

- Shore crossing construction:
  - Trenching and dredging;
  - Blasting;
  - Beach and dune excavation;
  - Pipeline installation;

- Padding, shading and backfilling;
- Restoration and rehabilitation.

- Onshore pipeline construction:
  - Clear and grade;
  - Blasting;
  - Trenching and stringing;
  - Welding and joint coating;
  - Hydrotesting and dewatering;
  - Padding, shading and backfilling;
  - String and pit tie-ins;
  - Restoration and rehabilitation;
  - Commissioning.

- Gas processing plant construction:
  - Clearing of vegetation;
  - Blasting;
  - Laying foundations and erecting facilities;
  - Installing equipment and systems;
  - Installing ancillaries;
  - Testing and commissioning;
  - Clean-up and removal of construction related equipment;
  - Road traffic through Wadeye Township.

The most significant noise emission is from blasting due to the associated vibration impacts. However, it is unlikely that blasting will be required, and if necessary may only occur for a limited period where large rocks are encountered at the shoreline edge, and along the pipeline route depending on the ground encountered.

Noise Emissions – Operational Phase

Noise emissions associated with the operational phase of the project considered in the assessment include the emissions from the following activities and equipment:

1. Operational equipment:
   - Power generation equipment
   - Process pumps
   - Air coolers
   - Control valves
   - Slugcatchers
   - HP / LP Flare tips
   - Export Compressor
   - Relief / flaring from blow down
   - Condensate offloading pumps
   - Fire water pumps
   - Instrument Air Compressor
   - Standby Diesel Power Generation

2. Plant maintenance operations;

3. Flaring from blow down; and
4. Traffic movements.

Noise Predictions

Predictions of noise levels at nearby receptors have been undertaken for noise emissions from both the construction and operational phases of the project utilising preliminary plant and equipment information. The predictive modelling utilised a methodology that considered worst-case meteorological conditions combined with no shielding by surrounding terrain features.

Impacts and Recommendations

Construction Noise

The results of the predictive modelling have been compared with the legislative requirements of the Northern Territory Government Draft Waste Management and Pollution Control (Environmental Noise) Regulation. In addition predicted noise levels are compared with noise criteria levels designed to preserve acoustic amenity at nearby receptors.

Overall, the assessment has concluded that there is a limited potential for noise impacts from the day-time construction of the proposed onshore pipeline and processing plant due to the significant buffer distances to potentially sensitive receptors at Wadeye Township and the Tchindi Aboriginal Camping Ground.

However, if night-time construction works are proposed for the clear and grade, blasting and trench dredging stages it is recommended that validation monitoring is carried out to assess the actual noise levels during the works. If the noise levels are found to be above the recommended noise criteria outlined in Table 3.2, a noise management plan will need to be implemented.

In order to minimise the potential for noise impacts on surrounding landuses such as the Tchindi Aboriginal Training Ground, and Wadeye Township it is recommended that the following best practice measures be undertaken during the construction phase of the project.

1. Blasting: If blasting is required it is recommended that a noise management plan is submitted to the Northern Territory Office of Environment and Heritage where blasting is undertaken. This noise management procedure should include the following:

    - ✍ potentially sensitive receptors within a 2 km radius should be notified of the proposed works a minimum of 24 hours in advance;

    - ✍ where receptors occur at or within 1 km of the proposed blast site, prediction of potential air overblast pressure and vibration should be undertaken based on the proposed blast size and type;

    - ✍ the results of the predictions should be provided to the regulatory authority prior to commencement of blasting for approval along with any proposed mitigation measures

including the possibility to increase cover material depth, increase spacings between charges and reduce the size of charges detonated per event.

2. Road Traffic Noise: Woodside has confirmed that a noise management plan and traffic management plan will be implemented to ensure appropriate management of construction road traffic through Wadeye Township. The noise management plan should as a minimum identify suitable transport routes through the town to minimise impact. Where possible, heavy vehicle movements are to be restricted to normal day-time periods (ie, 7 am to 6 pm Monday to Saturday).

Operational Noise

Overall, the assessment has concluded that there is a limited potential for noise impacts from the operation of the proposed onshore pipeline and gas processing plant due to the significant buffer distances to potentially sensitive receptors.

It is recommended that prior to any planned maintenance or flaring from blow down at the processing plant, representatives of the Tchindi Aboriginal Camping Ground and any dwellings within a 5 km radius of the site should be notified at least 24 hours before the event.

CONTENTS

1 INTRODUCTION 1

1.1 THE PROJECT 1

1.2 SCOPE OF THE ASSESSMENT 1

1.3 LIMITATIONS OF THE ASSESSMENT 2

2 NOISE GOALS AND CRITERIA 3

2.1 OVERVIEW 3

2.2 CONSTRUCTION NOISE 3
2.1.1 Draft Environmental Noise Regulation 3
2.1.2 Existing Noise Levels and Intrusive Noise Criteria 4

2.2 OPERATIONAL NOISE 5

3 THE EXISTING ENVIRONMENT 8

3.1 SURROUNDING LANDUSE AND RECEPTOR LOCATIONS 8

3.2 EXISTING NOISE LEVELS 8
3.2.1 Introduction 8
3.2.2 Monitoring Locations 8
3.2.3 Noise Monitoring Methodology 9
3.2.4 Results of Continuous Noise Monitoring 9

4 NOISE EMISSIONS 11

4.1 CONSTRUCTION PHASE 11

4.2 OPERATIONAL PHASE 11
4.2.1 Introduction 11
4.2.2 Gas Processing Plant - Normal Operations 11
4.2.3 Gas Processing Plant – Maintenance 12
4.2.4 Gas Processing Plant – Unplanned Releases 13
4.2.5 Traffic Movements 13

5 ASSESSMENT OF POTENTIAL IMPACTS 14

5.1 CONSTRUCTION NOISE **14**
5.1.1 Modelling Methodology 14
5.1.2 Results of Noise Modelling 14

5.2 OPERATIONAL NOISE **17**
5.2.1 Onshore Pipeline 17
5.2.2 Gas Processing Plant – Normal Operations 18
5.2.3 Gas Processing Plant – Maintenance Operations 19

6 SUMMARY AND CONCLUSIONS **20**

6.1 OVERVIEW **20**

6.2 CONSTRUCTION NOISE IMPACTS **20**

6.3 OPERATIONAL NOISE IMPACTS **21**

APPENDIX A: FIGURES AND PLATES

APPENDIX B: ACOUSTIC GLOSSARY

APPENDIC C: BACKGROUND NOISE LEVELS

APPENDIX D: CONSTRUCTION PLANT

1 INTRODUCTION

1.1 THE PROJECT

Woodside Energy Limited (Woodside), in association with its joint venture partner ENI Australia (ENI), proposes to develop the Blacktip gas field in permit WA-279-P of the Joseph Bonaparte Gulf, approximately 245 km south west of Darwin. Investigations indicate that the Blacktip gas field, located in approximately 50 m of water, comprises gas condensate reserves of approximately 1 trillion cubic feet (tcf). It is proposed that gas and associated reservoir liquids are exported from the Blacktip field via subsea pipeline to an onshore processing plant. The pipeline required will be approximately 110 km in length and will travel in a south-east direction to a suitable shore landing site. The shore landing for the export pipeline will be approximately 20 km west of Wadeye. The onshore facilities will be located close to the beach landing and will be connected to the landfall by a 2.5 km underground pipeline

Air Noise Environment Pty Ltd were commissioned by Sinclair Knight Merz on behalf of the joint venture to undertake a noise assessment for inclusion in the Environmental Impact Assessment being completed for the project. The assessment considered the potential impacts of noise associated with the processing plant and pipeline construction and operation on nearby receptors.

1.2 SCOPE OF THE ASSESSMENT

The requirements for the noise assessment element of the EIS are defined in Section 7.9 of the Draft Guidelines for the Preparation of a Draft Environmental Impact Statement on the Blacktip Project[1].

The key noise issues identified in Section 7.9 of the guidelines are as follows:

- Identification of sensitive noise receptors adjacent to the pipeline route, and at the offshore and onshore facilities.
- Identification of typical background noise levels.
- Assess the impacts of noise generated during construction along the pipeline route, and at the offshore and onshore facilities, against current typical background levels, and the sensitivity of the receptor, and describe measures to mitigate it.
- Anticipate noise levels, their timings and duration should be considered in conjunction with the sensitivity of the receptor.
- Assess the potential impact of noise generation from the operation of the pipeline, offshore and onshore facilities, including noise from venting, flaring from blow down, and compressor stations.

[1] *Woodside Energy Ltd, Draft EIS Guidelines – Part B Blacktip Gas Project, March 2003*

- Identify mitigation measures as appropriate.

This report has carried out a detailed risk assessment for human impacts, however, the report does not consider potential impacts on the marine and terrestrial environments, or cultural heritage sites. A detailed assessment of the risks to these particular environments are discussed in the main draft EIS report (Sinclair Knight Merz 2004) and in the accompanying Technical Appendices:

- *EcOz Environmental Impact Statement for the proposed Blacktip Gas Project Terrestrial Fauna Study;* and

- *Begnaze Pty Ltd Environmental Impact Statement for proposed Blacktip Gas Development Archaeology and Historic Heritage Report.*

1.3 LIMITATIONS OF THE ASSESSMENT

This report has been carried out based on the information available at the time of preparing the noise assessment. If, at the detail design stage of the project, there are significant changes to the design of the project the noise implications may need to be reassessed and incorporated into the Noise Management Plan. Matters that could affect the conclusions of this report include changes to the pipeline route, the processing plant location, construction/operational equipment to be used, and changes in the proximity to sensitive human receptors of noise generating activities.

2 NOISE GOALS AND CRITERIA

2.1 OVERVIEW

At present the Northern Territory Government does not define specific environmental noise criteria that can be adopted for the environmental noise assessment. However, previous discussions with the Northern Territory Office of Environment and Heritage have indicated that the Draft Waste Management and Pollution Control (Environmental Noise) Regulation is considered to be the most appropriate approach for the purposes of this assessment.

Reference is made to this draft legislation in the assessment, and further criteria are determined on the basis of commonly adopted standards as appropriate.

2.2 CONSTRUCTION NOISE

2.2.1 Draft Environmental Noise Regulation

The draft Environmental Noise Regulation specifies requirements in relation to construction noise. For construction undertaken between 7 am and 7 pm on a day that is not a Sunday or a public holiday, noise levels are deemed acceptable subject to the following:

- the work is undertaken in accordance with AS 2436 – 1981 Guide to Noise Control on Construction, Maintenance and Demolition Sites;
- the equipment used is the quietest reasonably available;
- if the occupier is required to prepare a construction noise management plan, the plan was approved and complied with.

For construction undertaken outside of the above hours the occupier of the construction site must demonstrate the following:

- the work is undertaken in accordance with AS 2436 – 1981 Guide to Noise Control on Construction, Maintenance and Demolition Sites;
- the equipment used is the quietest reasonably available;
- the construction work is being completed in accordance with an approved construction noise management plan;
- a minimum of 24-hours before the construction work notify in writing relevant premises that could be affected;
- it is reasonably necessary for the construction work to be carried out.

2.2.2 Existing Noise Levels and Intrusive Noise Criteria

In addition to the consideration of the recommended noise criteria in place in the Northern Territory the terms of reference for the project also specifically requires that the assessment:

"Assess the impacts of noise generated during construction along the pipeline route, and at the offshore and onshore facilities, against current typical background levels, and the sensitivity of the receptor, and describe measures to mitigate it."

The intent of this clause is to assess potential impacts against existing noise levels to determine the potential for noise intrusion and annoyance at nearby landuses. The level of annoyance caused by noise intrusion is generally related to the audibility of the noise at the receiver's location, along with characteristics of the noise including tonality, impulsiveness and duration.

Audibility of noise sources at a receptor location is a function of both the magnitude and character of the noise source in comparison with pre-existing ambient noise levels. Typically, if the introduced noise source is limited to being at or below the background noise level, acoustic amenity for the existing landuse will be largely maintained. At these levels the introduced noise source would be barely audible at a typical receiver.

Similarly introduced noise levels of less the 5 dB(A) above existing background noise levels are generally assumed to be of marginal significance with respect to annoyance. For night time periods, a lesser allowable increase of 3 dB(A) is generally adopted due to the greater risk of noise impacts at night. Criteria based on allowable increases relative to background noise levels are consistent with criteria adopted in a number of states in Australia (eg, for environmental licences for industry in Queensland, by the Environmental Protection Agency) and by some overseas agencies. For construction noise the duration of the construction period is also commonly taken into consideration. In this instance, the construction duration is expected to be in excess of 6 months. For this reason, the criteria adopted would be consistent with those for a permanent facility.

It should be noted, however, that if the noise source being considered has significant tonal or impulsive characteristics it is typically more intrusive at the same noise level in comparison with a source without these characteristics. As such a correction needs to be applied to source noise levels likely to exhibit significant tonal or impulsive characteristics to account for this variable impact. These adjustments are discussed further in Section 5.

Using this approach for comparing source noise influences to background, Table 2.1 presents the recommended criteria for construction activities at surrounding receptors.

TABLE 2.1: RECOMMENDED NOISE CRITERIA FOR CONSTRUCTION ACTIVITIES

Period	Receptor Component Recommended Criteria (Average $L_{Amax,T}$)[1]
Day (7 am – 6 pm)	Background plus 5 dB(A)
Evening (6 pm – 10 pm)	Background plus 5 dB(A)
Night (10 pm – 7 am)	Background plus 3 dB(A)

[1] *Usually, the L_{A10} parameter measured over a minimum period of 15 minutes is generally adopted to represent the average $L_{Amax,T}$.*

2.3 OPERATIONAL NOISE

For general noise sources, which include industrial and operational noise, acceptable maximum noise levels are presented in Schedule 2 of the Regulations. The maximum acceptable noise levels are defined according to the nature of the noise receiving area and are presented in Table 2.2 below.

It should be noted that the Regulations do not take into consideration existing background noise levels, hence these criteria are not entirely consistent with those adopted for the construction noise assessment. Where the construction noise criteria based on pre-existing background would be more conservative than the operational limits defined in the Regulations, this is commented on in the assessment of the predicted noise impacts (Section 5 of the report).

The noise levels presented in Table 2.2 must also be corrected to take account of tonal or impulsive characteristics. The relevant corrections as defined in Schedule 4 of the draft Regulations are presented in Table 2.3.

In Table 2.2 the following assessment periods also apply:

- Item 1: the specified noise level must not be exceeded for more than 10 % of the assessment period.
- Item 2: the specified noise level must not be exceeded for more than 1 % of the assessment period
- Item 3: the specified noise level must not be exceeded at any time.

TABLE 2.2 MAXIMUM NOISE POLLUTION LEVELS

Column 1	Column 2	Column 3		
		Noise Levels dB(A)		
Noise – Receiving Area	**Time of Day**	**Item 1**	**Item 2**	**Item 3**
Area 1 (Industrial and Utility Premises)	All hours	65	80	90
Area 2 (Commercial Premises)	All hours	60	75	80
Area 3 (Land not within Areas 1, 2, 4, 5 or 6)	All hours	50	65	70
Area 4 An area of noise-sensitive premises that is within 15m of a building used for noise-sensitive purposes on the premises, where the building is more than 100 meters from – (a) a road carrying more than 10,000 vehicles per day or (b) a significant business district	7am – 7pm Monday to Saturday	45	55	65
	9am – 7pm Sunday and public holidays	40	50	65
	7pm – 10pm all days	40	50	55
	10pm on any day to 7am Monday to Saturday and 9am Sunday and public holidays	35	45	55
Area 5 An area of noise-sensitive premises that is within 15m of a building used for noise-sensitive purposes on the premises, where the building is within 100 meters from – a) a road carrying more than 10,000 vehicles per day or b) a significant business district	7am – 7pm Monday to Saturday	50	60	70
	9am – 7pm Sunday and public holidays	45	55	70
	7pm – 10pm all days	45	55	60
	10pm on any day to 7am Monday to Saturday and 9am Sunday and public holidays	40	50	60

TABLE 2.3 ADJUSTMENTS TO EMITTED NOISE LEVELS

Adjustments where noise emission is not music		
These adjustments are cumulative to a maximum of 15dB		
Where impulsiveness is	Where modulation is present	Where tonality is present

present		
+ 10 dB	+ 5 dB	+ 5 dB

In terms of adjustments to emitted noise levels, factors for the noise sources are discussed further in Section 5.

For the proposed permanent accommodation on site, the Australian/New Zealand Standard Acoustics – Recommended design sound levels and reverberation times for building interiors 2107:2000 has been used (Section 5.2.2).

3 THE EXISTING ENVIRONMENT

3.1 SURROUNDING LANDUSE AND RECEPTOR LOCATIONS

Potentially sensitive human receptor locations have been identified for the gas processing plant, onshore/offshore pipeline and wellhead platform through a desk top review of topographic maps, photographs and other data provided by Sinclair Knight Merz.

The surroundings of the proposed onshore pipeline and gas processing plant is predominantly rural with no residential receptors identified within 1 km of any proposed operations. For the purposes of the assessment two receptor locations have been identified to represent the potential nearby residential receivers as follows:

- *Receptor 1:* The Tchindi Aboriginal Camping Ground (used on an ad hoc basis by the Wadeye Community) is located approximately 2.5 km away, however it is understood to have no permanent residents.

- *Receptor 2:* Wadeye township represents the closest permanent residential receptors to the proposed development site. Wadeye Township, an Aboriginal community of approximately 2,500 residents, is approximately 12 km away from the processing plant and onshore pipeline.

Given the surrounding landuses for Receptor 1, the Noise Receiving Area 4 criteria is considered appropriate (refer to Table 2.2) given that the area is more than 100 m from a major road, or town and as the background measurements (Section 3.2) are low. Noise Receiving Area 4 is considered appropriate (refer to Table 2.2) for Receptor 2 given that Wadeye Township is located more than 100 m from a major road carrying more than 10,000 vehicles a day, and is not a significant industrial or commercial district.

3.2 EXISTING NOISE LEVELS

3.2.1 Introduction

The terms of reference for the project require definition of typical background ambient noise levels for the surrounding landuses. Given this, noise monitoring was undertaken at two locations in the area surrounding the proposed project site in June 2004. The following sections give a brief overview of the methodology and results of the ambient noise monitoring undertaken.

3.2.2 Monitoring Locations

Two noise monitoring positions were selected to identify typical existing ambient noise levels for the identified receptor groups. Following is a brief description of the selected monitoring positions:

- *Position 1 (Remote Bushland)*: Position 1 was located in bushland at the proposed Blacktip gas processing plant to represent existing noise levels at the Tchindi Aboriginal Camping

Ground. The microphone was located at approximately 1.2 m above soft ground in a free-field position. Measurements were made using an ARL Type 2 environmental noise logger (serial number 15-299-452). (Plates 1 - 2 Appendix A).

✍ *Position 2 (Wadeye Township)*: Position 2 was selected as being representative of existing noise levels for Receptor 2. The monitoring position was located on top of the Police Station within Wadeye Township. The microphone was positioned approximately 4.5 metres above hard ground at this site due to security reasons. Measurements were made using an ARL Type 2 environmental noise logger (serial number 15-299-452). (Plates 3 – 5 Appendix A).

Figure 1 (Appendix A) identifies the monitoring locations selected for the purposes of the noise monitoring.

3.2.3 Noise Monitoring Methodology

Noise measurements were undertaken using an Acoustic Research Laboratories (ARL) Type 2 environmental noise logger (serial number 15-299-452). An averaging time of 15 minutes was adopted, and measurements were made over a full 24 hour period at each position (02/06/04 – 04/06/04). A windshield was fitted to the microphone throughout.

Meteorological data for Port Keats (Wadeye), the nearest station to the proposed development site was obtained from the Bureau of Meteorology. Noise levels during periods when winds exceeded 5 m/s or when rain was recorded have been excluded from the assessment to prevent weather related bias.

3.2.4 Results of Continuous Noise Monitoring

Appendix C presents in full the results of the background noise monitoring. Table 3.1 presents a summary of the existing noise levels for the two monitoring locations.

TABLE 3.1: AVERAGE MEASURED BACKGROUND NOISE LEVELS (dB(A))

Monitoring Location	Period	Average L_{A90}	Average L_{A10}	Average L_{Aeq}	Average L_{Amax}
1	Day 7 am – 6 pm	33.6	42.2	48.8	64.0
	Evening 6 pm – 10 pm	30.4	33.9	36.7	46.8
	Night 10 pm – 7 am	28.3	32.4	33.6	42.9
2	Day[1] 7 am – 6 pm	43.5	52.4	51.6	69.9
	Evening: 6 pm – 10 pm	41.8	50.6	48.9	68.8
	Night[2] 10 pm – 7 am	40	52.7	53.9	66.3

1 The monitoring data was not complete for the 3/6/04 and the 04/06/04, therefore the two days were combined to produce an average 1 day measurement.

2 AS 1055.3 – 1997 R3 Noise Area Category night-time L_{A90} noise criteria has been used.

During the measurements at the Wadeye Police Station the following existing noise sources were identified:

- Police sirens;
- Road traffic;
- Air conditioning unit (during the day).

With the exception of the air conditioning unit, the noise sources observed to be impacting on the monitoring position occurred over short-term periods and as such are unlikely to have a significant impact on measured background (L_{A90}) noise levels (the noise level exceeded for 90 % of the time). As such the air conditioning unit was considered to be the most significant external noise source during monitoring.

The measured night-time L_{A90} noise level for Wadeye Township of 43.9 dB(A) is higher than the measured day-time L_{A90}. This is unusual, and may indicate that activities at the Police Station at night are affecting the background noise levels at the measurement position. Therefore, to provide a more appropriate indication of likely night-time background noise levels for the Wadeye Township, reference has been made to *AS 1055.3 – 1997 Acoustics – Description and measurement of environmental noise Part 3: Acquisition of data pertinent to land use.* AS 1055.3 presents a series of typical average background noise levels for different land use classifications and times of day. For this assessment the L_{A90} night-time noise level for an R3 Noise Area Category, an area with medium density transportation or some commerce or industry from AS 1055.3 – 1997, has been used to represent night time background noise levels for the Wadeye township.

To enable an assessment of the construction noise impacts, the receptor component (L_{A90}) criteria has been determined from the background monitoring data. Table 3.2 shows the criteria for the proposed Blacktip processing plant based on background measurements taken on site, which is considered a representative criteria for the Tchindi Aboriginal Camping Ground (Receptor 1). Table 3.2 shows the criteria for the Wadeye Township (Receptor 2), based on the background measurements taken at Wadeye Township.

TABLE 3.2: SUMMARY OF CONSTRUCTION NOISE CRITERIA BASED ON BACKGROUND NOISE LEVELS PLUS ALLOWABLE INCREMENT

Period	Receptor Component Recommended Criteria (dB(A))	
	Receptor 1	**Receptor 2**
Day (7 am – 6 pm)	39	49
Evening (6 pm – 10 pm)	35	47
Night (10 pm – 7 am)	31	43[1]

1. The criteria for Receptor 2 assumes the recommended night-time background noise level from AS 1055 for the purposes of deriving the assessment criteria.

It is noted that the day-time criteria for construction are less stringent than those defined for operations (Area 4) in the Regulations. Conversely, for evening and night-time, the construction criteria are more stringent for Receptor 1 compared with the Area 4 criteria.

4 NOISE EMISSIONS

4.1 CONSTRUCTION PHASE

A summary of the construction activities and types of plant likely to be required for the construction of the proposed shore crossing, 2.5 km onshore pipeline and processing plant is presented in Appendix D. This assessment has assumed that the majority of the construction phase will occur during day-time hours or 7 am – 7 pm. However, night-time work may be required. As specified in the regulation, if work is to be undertaken outside of the day-time hours a construction noise management plan must be completed.

Typical source noise levels have been attributed to each of the construction plant to allow calculation of a total sound power level for each activity grouping. These sound power levels are used in the assessment of potential impacts for the construction phase presented in Chapter 6 of this report. The construction activities, types of plant, and construction noise sound pressure levels were provided by Woodside for the pipeline construction. Information on the equipment likely to be utilised for the shore crossing has been obtained from Chapter 4 of the SKM Preliminary Draft Project Description for Blacktip. For the gas plant, assumptions have been made about the likely equipment types and source noise levels based on previous experience of similar projects.

No correction factor for tonality or impulsiveness has been applied to the predicted receptor noise levels for the shore crossing, onshore pipeline, and processing plant construction. This approach has been adopted because the individual plant are assumed to be operating simultaneously. For a group of plant operating simultaneously, a broadband noise profile would normally be produced from the combined sources. Thus, it is not considered appropriate to apply intermittency or tonality corrections for the level of assessment undertaken.

4.2 OPERATIONAL PHASE

4.2.1 Introduction

This report considers potential noise impacts associated with the operation of the gas processing plant including both normal operations and maintenance periods.

It should be noted that this report does not consider the noise impacts associated with the operation of the offshore pipeline and wellhead platform. Further information on these operations can be obtained from the *Sinclair Knight Merz Draft EIS Marine Existing Environment Report*.

4.2.2 Gas Processing Plant - Normal Operations

The gas processing plant will produce between 110 and 119 TJ of dry gas daily for export, and will operate 24 hours a day, seven days a week throughout the year. Table 4.1 shows the processes that are likely to emit noise during the gas processing plant operation. Woodside has confirmed that the noise level of the operating gas processing plant will not exceed 85 dB at the site boundary.

TABLE 4.1: GAS PROCESSING PLANT CONTINUOUS & NON CONTINUOUS NOISE EMISSIONS

Equipment	Operation	Noise Level at 1 m (dB(A))
Power generation (either 2 x 100% Solar Saturns or 3 x 100% gas engines)	Continuous	85
Process pumps	Continuous	85
Air coolers	Continuous	85
Control valves	Continuous	85
Slugcatchers	Continuous	85
HP / LP Flare tips	Continuous	85
Export Compressor x3	Occasional requirement for dual compressor operation during change over	85
Relief / blow down valves	Spurious / unplanned events	85
Condensate offloading pumps condensate cargo	Only occasional when offloading	85
Fire water pumps during testing of system.	Either spurious unplanned event or during testing of system.	85
Instrument Air Compressor	Regular on / off (including pressure swing air dehydration units)	85
Standby Diesel Power Generation	Intermittent	85

Woodside has confirmed that noise from the HP/LP flare tips will be minimal during normal operation, and flaring from blow down will only occur during start-up and emergencies.

Woodside have confirmed that as a worse case, the noise level at the site boundary will be no more than 85 dB(A).

4.2.3 Gas Processing Plant – Maintenance

Full-scale maintenance operations, which will involve the complete shutdown of the plant will occur every three years for a period of three to five days. The maintenance activities will involve testing of the equipment, and replacement of the silica used for gas processing.

Woodside has confirmed that the HP/LP flare tip relief venting and flaring from blow down operations will occur during planned full-scale maintenance shutdowns, and possibly at other times where maintenance on equipment is necessary. For this assessment, it has been assumed that the noise level will be 110 dB at 1 m for the venting and flaring from blow down operations.

Flaring will occur quarterly, for a period of 1 to 24 hours. The source noise levels from this could be up to 110 dB.

There is the possibility that an underground valve may be located at the shore crossing, which will be approximately 2.5 km away from the Tchindi Aboriginal Camping Ground, where venting may occur.

4.2.4 Gas Processing Plant – Unplanned Releases

Unplanned releases generally relate to emergency events such as a rupture or equipment failure. In both instances there will be automatic control measures in place for the detection and control of accidental releases. Noise issues are likely to be limited to emergency and repair crews for events of this type, and the associated plant and equipment. As such activities would be limited in duration and the potential for impacts is likely to be relatively low.

It should also be noted that in the case of an emergency, issues such as noise (providing the noise levels are not above the limit at which hearing damage could occur) are generally exempt from normal environmental amenity criteria. This is because, in an emergency, other factors (such as life threatening releases) generally take priority over noise. Noise generally has no residual effect on the environment once the event has ceased, hence has little risk in terms of long term environmental impact. In view of this, unplanned releases have not been considered further in the assessment.

4.2.5 Traffic Movements

Woodside has confirmed that the onshore facilities will be manned by two to four personnel on site during operations, and that transport to the plant from Wadeye will be necessary. It is assumed that a 4 x 4 crewcab vehicle will be used. Given the low number of personnel involved, road traffic noise impacts on Wadeye Township will be minimal.

Full scale maintenance activities will be undertaken every three years for a period of three to five days, during which operations will shut down. Approximately 20 – 40 additional personnel will be required. It is assumed that transport through Wadeye Township will be kept to a minimum, with a maximum of 10 vehicles (i.e. 10 crewcab 4 x 4 vehicles) using this route. The noise impacts are expected to be minimal, as the overall number of vehicle movements remains small.

Given the small number of vehicle movements expected as a result of the operation of the project noise associated with traffic movements has not been assessed further in this report.

5 ASSESSMENT OF POTENTIAL IMPACTS

5.1 CONSTRUCTION NOISE

5.1.1 Modelling Methodology

To assess the potential for noise impacts as a result of both the construction and operational phase of the proposed gas processing plant and pipeline, predictive modelling has been undertaken. The noise modelling has been undertaken using the proprietary software 'Environmental Noise Model' (ENM). This model is widely approved by regulatory agencies for the prediction of potential noise impacts from proposed developments. The model allows incorporation and assessment of the influences of meteorology and terrain.

For the purposes of this assessment, a worst case meteorological scenario has been assumed:

- direct source to receptor wind direction;
- worst case atmospheric temperature gradient (stable inversion conditions); and
- 3 m s^{-1} wind speed, which is a worst case for temperature inversion conditions.

This meteorological scenario is recommended by the New South Wales (NSW) EPA as a worst case assessment scenario for noise modelling. Discussions with the Northern Territory Bureau of Meteorology confirm that temperature inversion conditions are also relevant for the Territory, mainly during the winter months. Therefore, the adoption of a temperature inversion for the modelling of noise emissions is appropriate. It should be noted, however, that although a temperature inversion has been included in the modelling, this is unlikely to occur during construction periods unless construction occurs at night. If night time construction is to take place, a noise management plan is required prior to commencement.

For the purposes of the modelling, no noise shielding by terrain features has been assumed. This is a worst case approach as it is assumed that any potentially noise sensitive receptor, such as a person would have a direct line of sight to the source of noise emissions.

5.1.2 Results of Noise Modelling

5.1.2.1 Shore Crossing

Predicted receptor noise levels associated with each stage of construction of the shore crossing for the identified receptor groups is presented in Table 5.1. Comparison of the predicted receptor noise levels with the criteria noise levels show compliance is predicted for all stages of the construction for day-time (7 am – 6 pm) construction works. However, it is predicted that blasting will not comply with the night-time (10 pm – 7 am) construction criteria.

TABLE 5.1: NOISE PREDICTIONS FOR SHORE CROSSING ACTIVITIES (dB(A))[1]

Activity	Receptor 1				Receptor 2			
	Predicted L_{A10}	Day	Evening	Night	Predicted L_{A10}	Day	Evening	Night
Trench dredging	29.4	39	35	31	<20	49	47	43
Blasting (preparation)	31.3	39	35	31	<20	49	47	43
Beach and dune excavation	21.4	39	35	31	<20	49	47	43
Pipeline installation	<20	39	35	31	<20	49	47	43
Padding, shading and backfilling	26.5	39	35	31	<20	49	47	43
Restoration and rehabilitation	23.3	39	35	31	<20	49	47	43

[1] Maximum predicted receptor noise levels have been calculated using minimum separation distances from source to receptor for the life of the project.

5.1.2.2 Onshore Pipeline

Table 5.2 presents predicted receptor noise levels associated with each stage of construction of the onshore pipeline for the identified receptor groups. Comparison of the predicted receptor noise levels with the criteria noise levels show compliance is predicted for all stages of the construction for day-time (7 am – 6 pm) operations, although the predicted noise levels for the clear and grade, and trenching stages are close to the criteria levels.

Compliance is not predicted for night-time (10 pm – 7 am) construction works for the clear and grade, trench dredging, and blasting stages. The trench dredging is also not predicted to comply for the evening (6 pm - 10 pm) construction criteria. The recommended management options for construction during night-time hours are discussed in Section 6.

TABLE 5.2: NOISE PREDICTIONS FOR ONSHORE PIPELINE CONSTRUCTION ACTIVITIES (dB(A)) [1]

Activity	Receptor 1				Receptor 2			
	Predicted L_{A10}	Day	Evening	Night	Predicted L_{A10}	Day	Evening	Night
Clear and grade	33.1	39	35	31	<20	49	47	43
Blasting (preparation)	31.3	39	35	31	<20	49	47	43

Activity	Receptor 1				Receptor 2			
	Predicted L_{A10}	Day	Evening	Night	Predicted L_{A10}	Day	Evening	Night
Trenching, trench breaking, stringing, bending and lowering in	36.2	39	35	31	<20	49	47	43
Welding and joint coating	27.2	39	35	31	<20	49	47	43
Hydrotesting and dewatering	24.5	39	35	31	<20	49	47	43
Padding, shading and backfilling	26.5	39	35	31	<20	49	47	43
String and pit tie-ins, and road crossings	29.9	39	35	31	<20	49	47	43
Restoration and rehabilitation	23.3	39	35	31	<20	49	47	43
Commissioning	23.3	39	35	31	<20	49	47	43

[1] *Maximum predicted receptor noise levels have been calculated using minimum separation distances from source to receptor for the life of the project.*

5.1.2.3 Gas Processing Plant

Table 5.3 presents predicted receptor noise levels associated with each stage of construction of the onshore pipeline for the identified receptor groups. Comparison of the predicted receptor noise levels with the criteria noise levels show compliance is predicted for all stages of the construction during day-time operations (7 am – 6 pm). Compliance is not predicted for evening (6 pm – 10 pm) and night-time (10 pm – 7 am) construction criteria for the clear and grade, blasting, and trenching stages. The recommended management options for construction during the evening and night-time are discussed in Section 6.

The predicted modelling of construction road traffic (modelled at 100 m) through Wadeye indicates that construction noise traffic (72.6 dB(A)) is only marginally above the measured daytime L_{Amax} at Wadeye of 69.9 dB. As this source of noise is expected to occur infrequently, it is not expected to pose a significant long term noise impact, although management of this potential noise impact is still recommended. In particular, heavy vehicle movements should be restricted to normal day-time hours of 7 am to 6 pm wherever possible.

TABLE 5.3: NOISE PREDICTIONS FOR GAS PROCESSING PLANT ACTIVITIES (dB(A)) [1]

Activity	Receptor 1				Receptor 2			
	Predicted L_{A10}	Day	Evening	Night	Predicted L_{A10}	Day	Evening	Night
Clearing of vegetation	33.1	39	35	31	<20	49	47	43
Blasting (if required)	31.3	39	35	31	<20	49	47	43
Laying foundations and erecting facilities	26.5	39	35	31	<20	49	47	43
Installing equipment and systems	26.5	39	35	31	<20	49	47	43
Installing ancillaries	26.5	39	35	31	<20	49	47	43
Testing and commissioning	23.3	39	35	31	<20	49	47	43
Clean-up & removal of construction related equipment	23.3	39	35	31	<20	49	47	43

[1] *Maximum predicted receptor noise levels have been calculated using minimum separation distances from source to receptor for the life of the project.*

5.2 OPERATIONAL NOISE

5.2.1 Onshore Pipeline

As the pipeline is relatively short (approximately 2 km in length), the usual above ground installations associated with the pipeline will not be installed due to the proximity to the gas processing plant. A pig trap will be installed within the plant, which is used for maintenance. During pigging a small amount of gas venting will occur within the plant. Although the gas venting is predicted to be minimal, venting of gas is generally designed to occur at sonic velocities for safety reasons. Because of this, venting may result in noise levels possibly in excess of 110 dB at the vent location (the gas processing plant) on infrequent occasions. The potential for noise impacts from this activity is assessed with the gas processing maintenance operations (Section 5.2.3).

There is the possibility that an underground valve may be located at the shore crossing, which will be approximately 2.5 km away from the Tchindi Aboriginal Camping Ground. During venting, gas may be released at this location.

5.2.2 Gas Processing Plant – Normal Operations

5.2.2.1 Surrounding Landuses

For the gas processing plant Woodside has confirmed that the maximum noise level at the processing plant edge will be 85 dB. The separation distance to the nearest potentially sensitive receptor at the proposed gas processing plant is approximately 2.5 km from the Tchindi Aboriginal Camping Ground, and approximately 12 km from Wadeye.

Likely receptor noise levels have been calculated as follows:

- an 85 dB(A) noise level at the site boundary;
- a 6 dB noise reduction per doubling of distance;
- a +5 dB correction for tonality; and
- a minimum separation distance of 2.5 km.

The resultant external receptor noise levels for the gas processing plant are predicted to be less than 25 dB at 2.5 km and less than 30 dB at 1 km. Therefore, noise levels at the Tchindi Aboriginal Camping Ground are predicted to be within the assessment criterion for Area 4. Wadeye Township, which has a larger separation distance, is predicted to be well within the Area 4 noise criteria. The predicted noise levels are also within the more stringent evening and night-time criteria adopted for construction noise impacts.

It is recommended that the site boundary noise levels are validated during the commissioning stage of the project to confirm that the assumptions adopted in this assessment are correct.

5.2.2.2 On-site Accommodation

Woodside propose to construct permanent accommodation on site. Australian Standard *AS 2107:2000 – Recommended design sound levels and reverberation times for building interiors* defines acceptable sound levels for hostels, residential halls and barracks as shown in Table 5.4. AS 2107 does not specify recommended noise levels for residential accommodation next to a gas processing plant, however, the recommended noise levels for a hostels, residential halls and barracks are considered appropriate to represent this situation.

TABLE 5.4: AS 2107:2000 RECOMMENDED INTERNAL NOISE LEVELS FOR HOSTELS, RESIDENTIAL HALLS AND BARRACKS

Residential activity	Recommended design sound level L_{Aeq}, dB (A)	
	Satisfactory	Maximum
Sleeping areas	30	35
Common areas	40	45
Cafeterias	45	50
Games Rooms	45	50

Kitchens and Service Areas	45	55

Assuming a noise level of 85 dB(A) at the plant edge, the predicted noise level of less than 30 dB(A) externally indicates that the internal noise levels will comply with the AS 2107:2000 recommendations as detailed in Table 5.4

5.2.3 Gas Processing Plant – Maintenance Operations

Planned maintenance operations are not expected to lead to significant changes in noise emissions, except where releases from relief valves and flaring from blow down activities occur. Woodside has confirmed that the HP/LP flare tips relief and flaring from blow down operations will occur during planned maintenance shutdowns every 3 to 5 years, with the possibility of flaring from blow downs at other times where maintenance of equipment is necessary. For this assessment, it has been assumed that the noise level will be 110 dB(A) at 1 m for the flaring from blow down or the flare tip relief operations. The flaring from blow down will occur quarterly and may last for up to 24 hours, although the noise levels are expected to be less than would occur during planned maintenance shutdown of the plant.

There is the possibility that an underground valve may be located at the shore crossing, which will be approximately 2.5 km away from the Tchindi Aboriginal Camping Ground, where venting may occur.

Likely receptor noise levels have been calculated as follows:

- 110 dB(A) source noise level;
- a 6 dB noise reduction per doubling of distance;
- a +5 dB correction for tonality; and
- a minimum separation distance of 2.5 km.

The resultant receptor noise level for the maintenance operations at the processing plant are predicted to be 47 dB(A) at 2.5 km. At the Tchindi Aboriginal Camping Ground the predicted noise level is within the Area 4 Noise Receiving criteria for daytime, evening and night-time operations not to be exceeded more than 1 % of the assessment period. As planned maintenance is likely to occur every 3 to 5 years, with the possibility of minor ad hoc maintenance on individual pieces of equipment, this would be acceptable. The noise levels from the quarterly flaring from blow down is predicted to be less than the planned shutdown of the plant, and would therefore also be expected to comply with the Area 4 criteria. The predicted noise levels are <35 dB(A) at the Wadeye Township and are therefore well within the Area 4 noise criteria due to the additional separation distance. The predicted noise levels at Wadeye Township are also within the more stringent evening and night-time criteria adopted for construction noise impacts.

As noise from the venting and flaring from blow down activities may be audible at the Tchindi Aboriginal Camping Ground, it is recommended that local representatives are notified in advance of a planned release event occurring. If possible, a minimum of 24 hours notice should be given.

6 SUMMARY AND CONCLUSIONS

6.1 OVERVIEW

Woodside Energy Limited (Woodside), in association with its joint venture partner ENI Australia (ENI), proposes to develop the Blacktip gas field in permit WA-279-P of the Joseph Bonaparte Gulf, approximately 245 km south west of Darwin. It is proposed that gas and associated reservoir liquids are exported from the Blacktip field via subsea pipeline to an onshore processing plant. The pipeline required will be approximately 110 km in length and will travel in a south-east direction to a suitable shore landing site. The shore landing for the export pipeline will be approximately 20 km west of the township of Wadeye.

Air Noise Environment Pty Ltd were commissioned by Sinclair Knight Merz on behalf of the joint venture to undertake a noise assessment for inclusion in the Environmental Impact Assessment being completed for the project. The assessment considered the potential impacts of noise associated with the processing plant and pipeline construction and operation on nearby receptors.

6.2 CONSTRUCTION NOISE IMPACTS

Overall, the assessment has concluded that there is a limited potential for noise impacts from the day-time construction of the proposed onshore pipeline and processing plant due to the significant buffer distances to potentially sensitive receptors at Wadeye Township and the Tchindi Aboriginal Camping Ground.

However, if night-time construction works are proposed for the clear and grade, blasting and trench dredging stages it is recommended that validation monitoring is carried out to assess the actual noise levels during the works. If the noise levels are found to be above the recommended noise criteria outlined in Table 3.2, a noise management plan will need to be implemented.

In order to minimise the potential for noise impacts on surrounding landuses it is recommended that the following best practice measures be undertaken during the construction phase of the project.

Blasting:

It is recommended that a noise management plan is submitted to the Northern Territory Office of Environment and Heritage where blasting is undertaken. This noise management procedure should include the following:

- potentially sensitive receptors within a 2 km radius should be notified of the proposed works a minimum of 24 hours in advance;
- where receptors occur at or within 1 km of the proposed blast site, prediction of potential air overblast pressure and vibration should be undertaken based on the proposed blast size and type;

- the results of the predictions should be provided to the regulatory authority prior to commencement of blasting for approval along with any proposed mitigation measures including the possibility to increase cover material depth, increase spacings between charges and reduce the size of charges detonated per event.

Road Traffic Noise:

Woodside has confirmed that a noise management plan and traffic management plan will be implemented to ensure appropriate management of construction road traffic through Wadeye Township. The noise management plan should as a minimum identify suitable transport routes through the town to minimise impact and where possible confine heavy vehicle movements to normal day-time periods of 7 am to 6 pm Monday to Saturday.

6.3 OPERATIONAL NOISE IMPACTS

Overall, the assessment has concluded that there is limited potential for noise impacts from the operation of the proposed onshore pipeline and gas processing plant due to the significant buffer distances to potentially sensitive receptors.

The potential for audible noise during planned maintenance has been identified, and following are recommendations for the minimisation of noise impacts during this operational element.

Planned Maintenance:

Prior to any planned maintenance such as flaring from blow down, it is recommended that representatives of the Tchindi Aboriginal Camping Ground and any dwellings within a 5km radius of the site should be notified at least 24 hours before the event.

It should be noted that the operational assessment has made assumptions about the noise levels expected from the site, and it is recommended that noise monitoring at the site boundary is completed at the commissioning phase of the project to confirm that that the conclusions of the assessment remain valid.

APPENDIX A

FIGURES AND PLATES

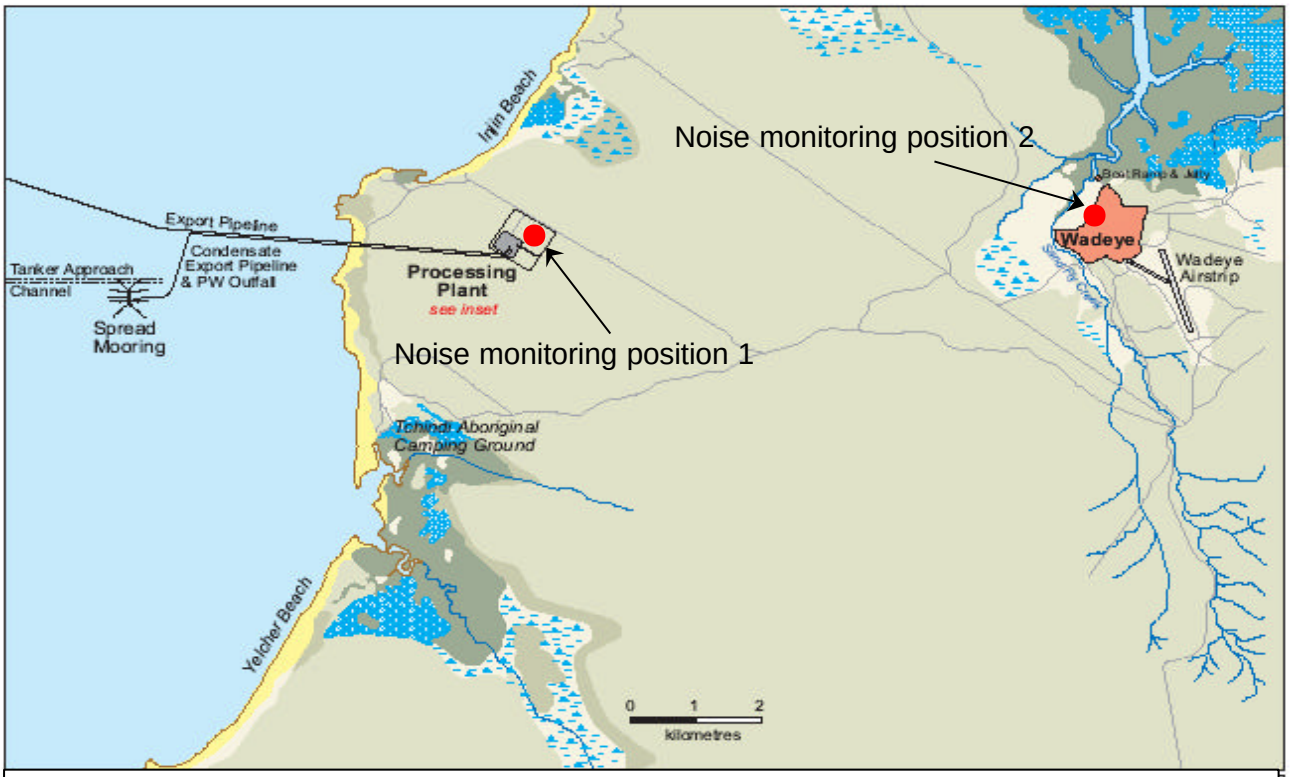


Figure 1: Location of the proposed Blacktip processing plant, and the background noise monitoring locations



Plate 1: Road to the proposed Blacktip processing plant where the background noise monitoring was undertaken.



Plate 2: Typical environment where the background noise monitoring was undertaken at the proposed Blacktip processing plant.



Plate 3: Front of the Police Station at Wadeye where the background noise monitoring was undertaken.



Plate 4: Location of the ARL logger microphone at the back of the Wadeye Police Station on top of a container roof.



Plate 5: Close up of the ARL logger microphone located on a roof of a container at the Wadeye Police Station.

APPENDIX B

ACOUSTIC GLOSSARY

APPENDIX B: GLOSSARY OF ACOUSTIC TERMINOLOGY

A-Weighting	A response provided by an electronic circuit which modifies sound in such a way that the resulting level is similar to that perceived by the human ear.
dB (decibel)	This is the scale on which sound pressure level is expressed. It is defined as 20 times the logarithm of the ratio between the root-mean-square pressure of the sound field and the reference pressure ($0.00002 N/m^2$).
dB(A)	This is a measure of the overall noise level of sound across the audible spectrum with a frequency weighting (ie 'A' weighting) to compensate for the varying sensitivity of the human ear to sound at different frequencies.
Facade Noise Level	Refers to a sound pressure level determined at a point close to an acoustically reflective surface (in addition to the ground). Typically a distance of 1 metre is used.
Free Field	Refers to a sound pressure level determined at a point away from reflective surfaces other than the ground with no significant contribution due to sound from other reflective surfaces; generally as measured outside and away from buildings.
Hertz (Hz)	A measure of the frequency of sound. It measures the number of pressure peaks per second passing a point when a pure tone is present.
L_{Aeq} **Equivalent Continuous Sound Level**	This is the equivalent steady sound level in dB(A) containing the same acoustic energy as the actual fluctuating sound level over the given period. For a steady sound with small fluctuations, its value is close to the average sound pressure level.
$L_{A90,T}$	This is the dB(A) level exceeded 90% of the time, T.
$L_{A10,T}$	This is the dB(A) level exceeded 10% of the time, T.
$L_{A50,T}$	This is the dB(A) level exceeded 50% of the time, T.
L_{WA}	The A-weighted sound power level in dB.

APPENDIX C

BACKGROUND NOISE LEVELS

Monitoring Location at the proposed Blacktip Gas Processing Facility

Date	Time	Lmax	L1	L5	L10	L50	L90	L95	L99	Lmin	Leq	Battery	Temp	Samples
2/06/2004	14:15	95.5	77.5	66	59	42	37.5	36.5	17.5	17	66	78	34	0
2/06/2004	14:30	62.5	52	47	44.5	40	36.5	36	35	34.5	43	78	35	0
2/06/2004	14:45	51	45	42.5	41	38	35.5	35	34.5	33.5	38.5	78	35.5	0
2/06/2004	15:00	61	46.5	44.5	43.5	39	35.5	35	34	33	40.5	78	35.5	0
2/06/2004	15:15	69	52	48	45.5	41	38.5	38	37.5	36.5	44.5	78	36	0
2/06/2004	15:30	69.5	54	45.5	43.5	40	38	37.5	36.5	36	45.5	78	36	0
2/06/2004	15:45	69	47.5	43.5	42.5	39.5	37	37	36	35.5	42.5	78	34.5	0
2/06/2004	16:00	55.5	47.5	46	44.5	41.5	39	38	37	36.5	42	78	34	0
2/06/2004	16:15	53	47	45.5	44.5	41	39	38.5	38	37.5	41.5	78	34	0
2/06/2004	16:30	66.5	58.5	45	43	39.5	37	36.5	35.5	35	45.5	78	34.5	0
2/06/2004	16:45	68	53.5	42	38.5	34.5	33	32.5	32	31.5	42.5	77	34.5	0
2/06/2004	17:00	51.5	40.5	36.5	35.5	33.5	31.5	31	30.5	30	34	78	34.5	0
2/06/2004	17:15	57.5	48	36	34.5	32	31	30.5	30	29.5	35.5	78	34	0
2/06/2004	17:30	58	53	44	39.5	32.5	31	30.5	30	29.5	39	78	33.5	0
2/06/2004	17:45	66.5	57.5	44.5	38	32.5	31	30.5	30.5	29.5	43	78	33	0
2/06/2004	18:00	64	52.5	40.5	36.5	31.5	30	29.5	29	28.5	40.5	77	32.5	0
2/06/2004	18:15	48.5	42.5	38.5	35	31.5	30	30	29.5	28.5	33.5	77	32	0
2/06/2004	18:30	64	55	42.5	39	34	32.5	32	31.5	31	41	78	31	0
2/06/2004	18:45	48	39.5	35.5	35	33.5	32	32	31.5	30.5	33.5	77	31	0
2/06/2004	19:00	48.5	40.5	36	35	33.5	31.5	31.5	30.5	29.5	33.5	78	30.5	0
2/06/2004	19:15	66.5	44.5	36.5	34.5	33	32	31.5	29	28.5	38	78	30	0
2/06/2004	19:30	53.5	49.5	46.5	43.5	33.5	31	30.5	29	28	39	77	29.5	0
2/06/2004	19:45	73	53	41	35.5	32.5	31.5	31.5	31	29.5	45	77	29	0
2/06/2004	20:00	39	34	33.5	33	31	30	29.5	29	28.5	31	77	29	0
2/06/2004	20:15	37	34.5	33.5	33	31	30	30	29	28.5	31	76	29	0
2/06/2004	20:30	35	32	31.5	31.5	30.5	29.5	29.5	29	28.5	30.5	77	28.5	0
2/06/2004	20:45	38	32	31.5	31	30	29.5	29	29	28.5	30	77	27.5	0
2/06/2004	21:00	48	34	31.5	31.5	30.5	29.5	29.5	29	28.5	30.5	77	28.5	0
2/06/2004	21:15	36	32.5	32	31.5	30.5	30	29.5	29.5	28.5	30.5	77	28.5	0
2/06/2004	21:30	39.5	32.5	32	32	31	30	29.5	29.5	29	30.5	77	28	0
2/06/2004	21:45	36	31	30.5	30.5	29.5	29	29	28.5	28	29.5	77	28	0
2/06/2004	22:00	37.5	33.5	31.5	30.5	29.5	29	28.5	28.5	28	29.5	76	27.5	0
2/06/2004	22:15	35.5	32	30.5	30.5	29.5	29	29	28.5	28	29.5	76	27	0
2/06/2004	22:30	50.5	46.5	39	35.5	30	29	29	28.5	28	34	77	28	0
2/06/2004	22:45	40	37.5	35	33.5	30	29.5	29	29	28	31	77	27.5	0
2/06/2004	23:00	41.5	31.5	30.5	30	29.5	29	29	28.5	28	29.5	76	27.5	0
2/06/2004	23:15	37	32	30	30	29	28.5	28	28	27.5	29	76	27	0
2/06/2004	23:30	39.5	32	29.5	29	28.5	27.5	27.5	27	27	28.5	76	26.5	0
2/06/2004	23:45	38.5	32	29.5	29	28	27.5	27.5	27.5	27	28	76	27	0
3/06/2004	0:00	34	29	28.5	28	27.5	27.5	27.5	27	26.5	27.5	77	27	0
3/06/2004	0:15	50.5	35	32	30	28	27.5	27.5	27	26.5	29	76	27	0
3/06/2004	0:30	45.5	34.5	31	29.5	28	27.5	27.5	27	26.5	28.5	77	26.5	0
3/06/2004	0:45	41	33	29.5	28.5	28	27.5	27.5	27	27	28	77	27	0
3/06/2004	1:00	43	35.5	29	28.5	28	27.5	27.5	27	27	28.5	76	27	0
3/06/2004	1:15	34.5	33	29.5	29	28	27.5	27.5	27.5	27	28	76	27	0
3/06/2004	1:30	35	32.5	30.5	29.5	28	27.5	27.5	27.5	27	28	76	26	0
3/06/2004	1:45	66	44	32.5	30.5	28	27.5	27.5	27.5	27	33.5	77	26	0
3/06/2004	2:00	37	31.5	29.5	29	28.5	28	27.5	27.5	27	28.5	77	26.5	0
3/06/2004	2:15	46	30.5	29.5	29	28	27	27	27	27	28	76	26	0
3/06/2004	2:30	38	31.5	29	28.5	27.5	27	27	27	26.5	27.5	76	26	0
3/06/2004	2:45	38	32.5	29	28.5	27.5	27	27	27	26.5	27.5	76	26	0
3/06/2004	3:00	39	34.5	30.5	29	27.5	27	27	27	26.5	28	76	26	0
3/06/2004	3:15	45	40	34.5	30.5	27.5	27	27	27	26.5	29.5	76	26	0
3/06/2004	3:30	40.5	35	31	29	27.5	27	27	27	26.5	28	76	26	0
3/06/2004	3:45	39	34	30	29	28	27.5	27.5	27	27	28	76	26	0
3/06/2004	4:00	39	32	29.5	29	28	27.5	27.5	27	27	28	76	26	0
3/06/2004	4:15	37.5	31	29.5	29	28.5	28	27.5	27.5	27.5	28.5	75	26	0
3/06/2004	4:30	51	35.5	32	31	29	28.5	28	28	27.5	29.5	76	26	0
3/06/2004	4:45	43	38.5	33.5	32	29.5	28.5	28	28	27.5	30.5	76	25.5	0
3/06/2004	5:00	43.5	41	38	33	29	28.5	28.5	28	27.5	31.5	75	26	0
3/06/2004	5:15	43.5	41.5	39.5	36	29	28.5	28.5	28	27.5	32.5	75	25.5	0
3/06/2004	5:30	43.5	42	39.5	36	30	29	29	28.5	28	33	75	26	0

3/06/2004	5:45	56	43.5	42	41	30.5	28.5	28.5	27.5	27	36	76	26	0
3/06/2004	6:00	45.5	44	43	42	32	29.5	29	29	28	37.5	75	25.5	0
3/06/2004	6:15	46	44.5	44	43	37.5	30	29.5	29	28.5	39.5	76	25.5	0
3/06/2004	6:30	49.5	45	44.5	44	41	32	31	29.5	28.5	41	75	25.5	0
3/06/2004	6:45	46.5	45	44.5	44	41.5	34.5	32.5	30.5	28.5	41.5	75	25.5	0
3/06/2004	7:00	46.5	45	44	43.5	36.5	28	27.5	27.5	27.5	39.5	76	25	0
3/06/2004	7:15	60.5	52	47.5	44	31.5	28.5	28.5	28	27.5	40.5	76	25	0
3/06/2004	7:30	66	51	41.5	39.5	32.5	29	28.5	28	27.5	41	75	25.5	0
3/06/2004	7:45	72	57	45	39	31	28.5	28.5	28	27.5	43.5	76	24.5	0
3/06/2004	8:00	75	62	50.5	39.5	30	28	28	27.5	27	48	74	25	0
3/06/2004	8:15	72	59	50	42	30	28.5	28	27.5	27.5	46	74	25	0
3/06/2004	8:30	72.5	61	46.5	41	31	29	28.5	28	27.5	47.5	75	25	0
3/06/2004	8:45	64	56	43.5	39	31	29.5	29	28.5	28	42	76	25	0
3/06/2004	9:00	70	50	42	39.5	32.5	29.5	29.5	28.5	28	40	76	24.5	0
3/06/2004	9:15	68.5	62	48.5	42.5	34.5	32	31.5	30.5	30	47	75	26	0
3/06/2004	9:30	56	46.5	42.5	41	35.5	32	31.5	31	30.5	38	75	26	0
3/06/2004	9:45	63.5	51	44.5	42.5	37.5	33.5	32.5	32	31.5	40	75	27	0
3/06/2004	10:00	67	53.5	48	46.5	40	36.5	36	35.5	35	44	75	27.5	0
3/06/2004	10:15	64	54.5	45.5	43.5	38	35.5	35.5	34.5	34	42	76	29	0
3/06/2004	10:30	69.5	59	51.5	49	43	36.5	35.5	34.5	34	47.5	76	29.5	0
3/06/2004	10:45	61	50.5	48	47	42	37	36.5	35	34	43.5	76	29.5	0
3/06/2004	11:00	57	49.5	45.5	44	38.5	35	34	33	32.5	40.5	75	31	0
3/06/2004	11:15	61.5	49.5	44	42.5	38	34.5	33.5	33	32.5	40.5	76	33	0
3/06/2004	11:30	64	51	44	42.5	40	36.5	36	35	34	42	76	34	0
3/06/2004	11:45	49	45	43.5	42.5	38	33.5	32.5	32	31.5	39	75	35	0
3/06/2004	12:00	56.5	45.5	43	42.5	38.5	34.5	33.5	32.5	31.5	39.5	75	35.5	0
3/06/2004	12:15	61	48.5	45.5	43	36	33	32	31	30.5	40	76	37	0
3/06/2004	12:30	56	41.5	39.5	38.5	35	33.5	33	32	31	36	75	37.5	0
3/06/2004	12:45	68	48	39	38	35	33	33	32.5	30	41	76	38	0
3/06/2004	13:00	49	46	44	43.5	39.5	37	36.5	36	35.5	40	76	37	0
3/06/2004	13:15	67	55	46	44.5	39.5	36	35.5	35	33.5	44.5	76	37.5	0
3/06/2004	13:30	68	54	46.5	45	39.5	34	33.5	32	31	44	76	38	0
3/06/2004	13:45	62.5	52.5	49	47.5	42	34.5	33	32.5	32	44.5	75	37.5	0
3/06/2004	14:00	56	47.5	44	43	39	36	35.5	34.5	34	40	75	37	0

Monitoring Location at Wadeye Township

Date	Time	Lmax	L1	L5	L10	L50	L90	L95	L99	Lmin	Leq	Battery	Temp	Samples
3/06/2004	15:30	74	65	55.5	53.5	48	45.5	45	44	43.5	52.5	76	39	0
3/06/2004	15:45	68	58	55	53	48.5	46	45.5	44.5	43	50	75	41	0
3/06/2004	16:00	72.5	60	55	53	48	45	44.5	43.5	43	50	76	41.5	0
3/06/2004	16:15	70	59	54.5	52.5	47	44.5	44	43.5	42.5	50	76	41	0
3/06/2004	16:30	66.5	60	56	53	47.5	45	44.5	43.5	42.5	50.5	77	41.5	0
3/06/2004	16:45	64	59.5	56.5	54.5	47	44.5	44	43	42.5	50.5	76	42	0
3/06/2004	17:00	68.5	64	58	55	47	44.5	44	43	42	52	75	41.5	0
3/06/2004	17:15	74	57	54	51	45.5	43.5	43	42.5	42	48.5	76	40.5	0
3/06/2004	17:30	61	57	53	50	44.5	43	42.5	42	41.5	47	76	40	0
3/06/2004	17:45	65	58.5	54	50.5	44.5	43	43	42.5	42	48	77	39	0
3/06/2004	18:00	62	58	52.5	50	45	43.5	43	42.5	41.5	47.5	75	39	0
3/06/2004	18:15	65.5	58.5	54	51	45	43.5	43	42.5	42	48	76	38	0
3/06/2004	18:30	69.5	59	54	51	46	43.5	43	42.5	42	48.5	76	37.5	0
3/06/2004	18:45	77	59.5	54.5	51	45.5	43.5	43	42.5	41.5	51.5	75	37.5	0
3/06/2004	19:00	84	59	55.5	52.5	45.5	43	43	42.5	41.5	51	75	37.5	0
3/06/2004	19:15	68.5	62	55.5	53	46	43.5	43	42.5	41.5	50.5	75	36	0
3/06/2004	19:30	70	60.5	55.5	53	45	43	43	42.5	41.5	50	75	34	0
3/06/2004	19:45	69	59	54.5	52.5	45.5	43.5	43	42.5	42	49.5	74	32.5	0
3/06/2004	20:00	69.5	64	60	56	46	43.5	43	42.5	42	52.5	74	31.5	0
3/06/2004	20:15	70	58.5	53	49.5	43.5	41	40.5	39.5	39	47.5	74	30	0
3/06/2004	20:30	64	59.5	54	51.5	43.5	40.5	40.5	39.5	39	48	75	30	0
3/06/2004	20:45	63	56	50.5	47.5	43	40.5	40	39	38	45.5	75	28.5	0
3/06/2004	21:00	76.5	56.5	50.5	47.5	42	39.5	39	38.5	37.5	48	75	28.5	0
3/06/2004	21:15	67.5	55	49.5	47	41.5	39.5	39	38.5	37.5	45	75	28	0
3/06/2004	21:30	65	55	49	46.5	40.5	39	38.5	38	37	44.5	75	27.5	0
3/06/2004	21:45	62.5	55.5	49.5	46.5	42	39.5	39	37.5	36	45	74	26.5	0
3/06/2004	22:00	60	56	54.5	53.5	43.5	42	41.5	41	40.5	48	74	27	0

3/06/2004	22:15	68.5	57	55.5	54.5	50.5	43.5	42.5	41	40.5	51.5	74	26.5	0
3/06/2004	22:30	65.5	56	55	53.5	42.5	41	41	40.5	40	47.5	74	26.5	0
3/06/2004	22:45	67	57.5	51	49	43	41	41	40.5	40	46.5	74	26	0
3/06/2004	23:00	57	52	46	43.5	41.5	40.5	40.5	40.5	40	42.5	73	26	0
3/06/2004	23:15	72	66	62	56	42.5	41	41	40.5	40	53.5	73	25.5	0
3/06/2004	23:30	64	54	46	44	42	41.5	41.5	41	40.5	44	74	24.5	0
3/06/2004	23:45	70.5	67.5	59	52	42	39	38.5	38	37	53.5	73	25	0
4/06/2004	0:00	71.5	65.5	58	51.5	40	38	37.5	37	36	51.5	72	24.5	0
4/06/2004	0:15	76	68	60.5	58.5	54.5	44	42.5	40.5	37.5	56.5	73	24	0
4/06/2004	0:30	70.5	64	60	60	59	57	56.5	54.5	51	59	73	24	0
4/06/2004	0:45	61.5	61	60.5	59.5	54	50	49	41	37.5	55.5	73	23.5	0
4/06/2004	1:00	58.5	56.5	55.5	55	53	47.5	45	38	35.5	52.5	74	23.5	0
4/06/2004	1:15	70.5	59.5	57	56	51	39	37.5	36	34.5	52.5	73	23	0
4/06/2004	1:30	74.5	59	58.5	58	56.5	54	53	48.5	36.5	56.5	73	23	0
4/06/2004	1:45	60	59	58	57.5	51.5	39	38.5	37	35	52.5	72	23	0
4/06/2004	2:00	67	60.5	53.5	51.5	46	40.5	40	38	36.5	49.5	73	22.5	0
4/06/2004	2:15	77.5	70	64	60	53	45	41.5	40.5	37.5	58	73	22	0
4/06/2004	2:30	69	57	55	53.5	38	36	35.5	34.5	33.5	47.5	73	22	0
4/06/2004	2:45	74	67.5	61.5	57	54	40.5	39.5	36	34	56	73	22	0
4/06/2004	3:00	76	69	63.5	59.5	56.5	54	53	51.5	45	58.5	73	22.5	0
4/06/2004	3:15	75	68	64	60.5	58.5	56	55	52.5	39.5	59.5	73	22	0
4/06/2004	3:30	71.5	65.5	60.5	58	56.5	54	53.5	51.5	42.5	57	72	21.5	0
4/06/2004	3:45	76	69.5	65	60	57.5	55	54.5	52.5	45	59.5	73	21.5	0
4/06/2004	4:00	78.5	63.5	59	58.5	56	44	43	42	39	56.5	72	22	0
4/06/2004	4:15	68	63	53.5	51	44.5	42.5	42	41.5	39	50	73	21.5	0
4/06/2004	4:30	58.5	55	54.5	54	50.5	45.5	45	44	41	51	73	21	0
4/06/2004	4:45	62.5	57.5	56.5	56	53	50	49.5	43.5	40	53.5	72	20.5	0
4/06/2004	5:00	58	57	54.5	45.5	41.5	37.5	36	35	34	46	72	21	0
4/06/2004	5:15	59	52	45	44	39	36	35.5	35	34.5	42	73	21	0
4/06/2004	5:30	54	47	46	45.5	44	42	41.5	40.5	36.5	44	72	20.5	0
4/06/2004	5:45	53	47.5	46	45	43.5	41.5	41	40	36	43.5	72	20.5	0
4/06/2004	6:00	74	56	47.5	45.5	42	38.5	37	36	35	47.5	72	20.5	0
4/06/2004	6:15	64.5	54	50.5	48.5	44.5	43	42	41	37.5	46	72	21	0
4/06/2004	6:30	52.5	47.5	46.5	46	44.5	42	41.5	40	37.5	44	72	20.5	0
4/06/2004	6:45	52.5	45.5	44.5	44	42.5	40.5	40	39	37	42	71	20.5	0
4/06/2004	7:00	58.5	50	47	45	43	41.5	41	40	37.5	43.5	71	20.5	0
4/06/2004	7:15	76	56.5	51	49.5	45.5	38.5	37.5	37	36	49	70	20.5	0
4/06/2004	7:30	79	70	58	47.5	39	37.5	37	36.5	35.5	55.5	71	20.5	0
4/06/2004	7:45	78.5	57.5	50	47	41	38.5	37.5	36.5	35	49	72	19.5	0
4/06/2004	8:00	77.5	60.5	51.5	46.5	39	37	36.5	36	35	50	71	20.5	0
4/06/2004	8:15	76.5	58.5	50.5	46	40	37	36.5	35.5	33.5	47	71	20.5	0
4/06/2004	8:30	79	77	54.5	50.5	41.5	37.5	37	36	34.5	59.5	72	22	0
4/06/2004	8:45	72	60	55.5	52.5	42.5	37.5	37	36	35	49	72	22	0
4/06/2004	9:00	70	59.5	55	50.5	45	43.5	43	42.5	40.5	49	71	22.5	0
4/06/2004	9:15	67.5	57.5	53	51.5	47	44	43.5	43	42.5	48.5	71	23	0
4/06/2004	9:30	78	69.5	58.5	56	47.5	44.5	44	43.5	43	56.5	72	26	0
4/06/2004	9:45	78.5	70	63	60	47.5	44.5	44	43	42.5	58	72	28	0
4/06/2004	10:00	76	69.5	65	62.5	47.5	44.5	44	43.5	42.5	57.5	72	31	0
4/06/2004	10:15	69	63.5	60	57.5	46.5	44.5	44	43	42	52.5	73	34	0
4/06/2004	10:30	69	65	56.5	53	47	44.5	44	43.5	43	52	73	36.5	0
4/06/2004	10:45	73.5	64.5	56.5	54	46	43.5	43.5	43	42.5	52.5	72	38	0
4/06/2004	11:00	64.5	60.5	56.5	54.5	46.5	44	43.5	42.5	42	50.5	72	37.5	0
4/06/2004	11:15	61.5	58.5	55	53	46	44	44	43.5	42.5	49	73	38	0
4/06/2004	11:30	79	60	54.5	51.5	46	44	43.5	43	42	53.5	73	38.5	0
4/06/2004	11:45	66	58	54.5	52	47	45	44.5	43.5	42.5	49	73	38.5	0
4/06/2004	12:00	76.5	61.5	57	55	48	45.5	45	44.5	43.5	54	74	40	0
4/06/2004	12:15	75	64	53.5	51	47	45	44.5	43.5	42	51.5	74	40.5	0
4/06/2004	12:30	76.5	64.5	56	54	49	45.5	45	44.5	43.5	54	74	41.5	0
4/06/2004	12:45	63.5	56	53.5	52	47.5	45.5	45	44	43.5	49	73	42.5	0
4/06/2004	13:00	60.5	56.5	53.5	52	48	45.5	45	44	43.5	49	74	43	0
4/06/2004	13:15	60	57	54	52.5	47	44.5	44	43.5	43	49	74	43	0
4/06/2004	13:30	74.5	61.5	55.5	54	49	46	45.5	44.5	43.5	52	74	43.5	0

APPENDIX D

CONSTRUCTION STAGES

APPENDIX D: CONSTRUCTION STAGING

The types of construction activity and typical plant associated with each activity for the shore crossing is presented in Table D1, and for the 2 km pipeline in Table D2. The type of plant and numbers would be associated at each work site for the given phase of activities. More than one work site may be operating at any given time along the construction route. Typical sound pressure levels for each plant item and for each group of plant (assuming all operate simultaneously) are also presented in Table D1, and D2. Table D3 presents the construction noise information for the facilities.

TABLE D1 GENERAL CONSTRUCTION ACTIVITIES FOR SHORE CROSSING

Stage	Description	Typical Plant Types & Numbers	Sound Power Levels dB(A)
Nearshore trench dredging	Soft sediments and fractured rock will be dredged from the trench and stockpiled on the barge.	Dredge diesel rotary drill hydraulic excavator Boat	105 118 113 99
Blasting	Controlled drilling and blasting may be required for large rocks.	Rotary and Percussive Rock drill Drill rig 1 4x4 crewcab	109 128 85
Beach/Dune trench excavation	Onshore section of the landfall is to be excavated, and material stored for reuse once pipeline installation is complete.	hydraulic excavator 1 off D9 Dozer	113 117
Pipeline installation	Pipeline will be pulled ashore from a barge using winch set up.	Pneumatic winch Boat	108 99
Padding, shading and backfilling	To avoid damage to the pipeline, the trench is padded with sand or fine soil to a depth of 150mm. The trench is then backfilled, and the soil compacted.	2 off Padding machine (Ozzie Padder) 1 4x4 crewcab 1 off Dozer (backfill) 1 off Rubber tyre grader (compaction)	120 85 117 117
Restoration and rehabilitation	Stockpiled topsoil, and vegetation is spread back over the work area.	1 off Dozer 1 off Grader 1 off Tractor	117 117 110

TABLE D2 GENERAL CONSTRUCTION ACTIVITIES FOR PIPELINE

Stage	Description	Typical Plant Types & Numbers	Sound Power Levels dB(A)
Clear and grade	Pipeline corridor (30 m width) will be cleared of heavy vegetation, and stockpiled for later reuse. Topsoil will be stripped & set aside for later reuse.	20 off D9 Dozer 1 off Grader 1 4x4 crewcab	117 117 85
Blasting	In areas with large amounts of rock, blasting may be required.	Rotary and Percussive Rock drill Drill rig 1 4x4 crewcab	109 128 85
Trenching, trench breaking stringing, bending and lowering in	A trench for the pipeline will be excavated. The pipe joints will be distributed along the pipeline laydown area, bent as required and placed on skids to protect pipe coating from damage. Side booms are used to lower the pipe into the trench. Spray foam walls will be installed on steeper slopes to avoid erosion of the trench.	1 off Bucket wheel trencher Cleveland 1 off Rock saw Vermeer 2 off Hydraulic excavators 15 off Extendable semi trailers 1 off Vaculift (vacuum lifting device for pipe) 2 4x4 crewcab 1 off 2.5 tonne flatbed for skids and sawdust bags 1 off 2.5 tonne flatbed 1 off Diesel driven hydraulic bending machine 1 off Sideboom tractor 1 off Diesel generator	117 120 116 120 117 85 110 110 117 117 113
Welding and joint coating	Pipe sections are welded together. 2-3 crews are used to perform each weld. Welded joints will be grit blasted.	2 off Sideboom tractors 7 off Diesel welding machines 1 off Diesel air compressor 1 off Diesel generator set 1 off Diesel welding machine 1 off 2.5 tonne flatbed 1 off Diesel air compressor (grit blasting) 1 off Diesel generator (epoxy spray equipment)	117 110 110 117 110 110 110 113
Hydrotesting and dewatering and drying	Pipeline will be hydrostatically pressure tested using water. Water will be moved to next section or disposed of and pipeline section will be dried.	1 off Diesel driven centrifugal fill pump 1 off Diesel air compressor 1 off Semitrailer 1 off Diesel generator 1 off Diesel refrigeration drier 1 off Diesel air compressor	108 110 117 113 117 110

Stage	Description	Typical Plant Types & Numbers	Sound Power Levels dB(A)
Padding, shading and backfilling	To avoid damage to the pipeline, the trench is padded with sand or fine soil to a depth of 150mm. The trench is then backfilled, and the soil compacted.	2 off Padding machine (Ozzie Padder) 1 4x4 crewcab 1 off Dozer (backfill) 1 off Rubber tyre grader (compaction)	120 85 117 117
String and pit tie-ins, and road crossings	This is required to tie one string to another & where the route crosses a road.	2 off Sideboom tractors 1 off Hydraulic excavator 2 off Diesel welding machine 1 off Diesel air compressor (grit blasting) 2 off Hydraulic excavators 2 off Diesel welding machine 1 off Diesel air compressor (grit blasting) 1 off Diesel generator (epoxy spray equipment)	117 117 117 110 117 117 110 113
Restoration and rehabilitation	Stockpiled topsoil, and vegetation is spread back over the work area.	1 off Dozer 1 off Grader 1 off Tractor	117 117 110
Commissioning	Fill the pipeline with nitrogen and then with gas.	1 off Nitrogen tanker and vaporiser 1 off 2.5 tonne flatbed	120 110

TABLE D3 GENERAL CONSTRUCTION ACTIVITIES FOR GAS PROCESSING PLANT

Stage	Description	Typical Plant Types & Numbers	Sound Power Levels dB(A)
Vegetation clearing	Plant area will be cleared of vegetation.	20 off D9 Dozer 1 off Grader 1 4x4 crewcab	117 117 85
Blasting	Blasting may be required if rock is encountered.	Rotary and Percussive Rock drill Drill rig 1 4x4 crewcab	109 128 85
Laying foundations and erecting facilities	Laying concrete foundations of site, and erecting facilities.	Compactor 2 off D9 Dozer 3 off Diesel welding machine 1 off Diesel air compressor 1 off Diesel generator set 3 concrete mixer 154 t dump truck	116.5 117 110 110 117 109 113
Installing equipment and systems	Will include installing communication, instrument and electrical systems.	crane 2 truck 2 forklift truck	118 113 118
Installing ancillaries		crane 2 truck 2 forklift truck	118 113 118
Testing and commissioning	Testing and adjustment of equipment for all components. Please note as equipment details were not provided, the information on equipment supplied for the pipeline have been utilised here.	1 off Nitrogen tanker and vaporiser 1 off 2.5 tonne flatbed	120 110
Clean-up and removal of construction related equipment	Removal of all construction related material from construction of the plant.	forklift truck 2 truck	118 113
Road Traffic	Road traffic through Wadeye Township	Semi-trailer	120

Appendix B

Blacktip Project Offshore and Intertidal Environmental Surveys prepared by Sinclair Knight Merz






This page has been left intentionally blank

Blacktip Project Offshore and Intertidal Environmental Surveys



- Rev 0
- 15/10/2004

Blacktip Project Offshore and Intertidal Environmental Surveys

- Rev 0
- 15/10/2004

Sinclair Knight Merz
ABN 37 001 024 095
7th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia
Tel: +61 8 9268 4400
Fax: +61 8 9268 4488
Web: www.skmconsulting.com

COPYRIGHT: The concepts and information contained in this document are the property of Sinclair Knight Merz Pty Ltd. Use or copying of this document in whole or in part without the written permission of Sinclair Knight Merz constitutes an infringement of copyright.

Contents

1. Executive Summary 1

2. Introduction 3

3. Methods 5

3.1 Survey Locations 5
3.1.1 Offshore 5
3.1.2 Intertidal 5
3.2 Parameters 6
3.2.1 Sediments 6
3.2.2 Water Sampling 15
3.2.3 Fauna 15
3.2.3.1 Observations 16

4. Results and Discussion 17

4.1 Sediments 17
4.1.1 Chemistry 17
4.1.1.1 Hydrocarbons 17
4.1.1.2 Metals 18
4.1.2 Sediment Particle Size 18
4.2 Water Quality 21
4.3 Fauna and Flora 21
4.3.1 Intertidal 21
4.3.2 Offshore 37
4.3.2.1 Faunal Observations 38

5. References 41

Appendix A Sediment Hydrocarbons (TRH-mg/kg) 43

Appendix B Sediment Metals (mg/kg) 45

Appendix C Sediment Particle Size (% weight) 47

Appendix D Intertidal Fauna 49

Appendix E Subtidal Fauna arranged by Phyla 55

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	10/8/04	U Phelan	U Phelan		
B	08/09/04	U Phelan	U Phelan		
C	11/10/04	B Brown	B Brown	11/10/04	Editorials

Distribution of copies

Revision	Copy no	Quantity	Issued to
A			
B			
C	Electronic	1	Ceri Morgan

Printed:	18 October 2004
Last saved:	11 October 2004 06:22 PM
File name:	I:\WVES\Projects\WV02540\Technical\Environmental Survey\Report\R11BFC_EnvSur_Rev C_review.doc
Author:	Brian Cohen
Project manager:	Una Phelan
Name of organisation:	Woodside Energy Ltd
Name of project:	Blacktip Project
Name of document:	Offshore and Intertidal Environmental Surveys
Document version:	Draft C
Project number:	WVO2540

1. Executive Summary

An intertidal and offshore environmental survey of the proposed Blacktip Project area was conducted to provide information on the existing marine environment for the Blacktip Project Environmental Impact Statement (EIS).

Sediment hydrocarbon and metal concentrations indicate that the Blacktip Project area is mostly free of significant sediment contamination, even at the proposed platform location despite it being near the previous drilling activity associated with the Blacktip-1 well. This result is not surprising, as there are only low levels of anthropogenic activity in the Joseph Bonaparte Gulf. Low concentrations of long chained hydrocarbons were found in some mangrove sediment samples, which were probably associated with hydrocarbon seeps from the Petrel and Tern Fields. This result suggests that the measurement of hydrocarbon concentrations in mangrove sediments may be an effective tool for monitoring hydrocarbon discharges associated with the proposed Blacktip Project, particularly hydrocarbons associated with the produced water (PW) discharge.

Preliminary water quality data indicates that during the dry season the water column is well mixed and therefore will not limit dilution of the PW discharge plume. Additional data is required for the wet season to determine if stratification of the water column occurs, particularly at the proposed produced water discharge location. Waters near the coast are very turbid which appears limits the occurrence of seagrass, macroalgae and coral. There were no indications to suggest that seagrass beds, macroalgal beds or coral reefs occur within the Blacktip Project area. The data collected suggests that turtle activity in the project area is low. No cetacean activity was recorded during any of the offshore surveys. Woodside should continue to monitor cetacean activity whenever they conduct activities in the proposed project area to determine if any seasonal cetacean activity occurs in the Joseph Bonaparte Gulf.

Intertidal and subtidal infauna is species rich. A number of intertidal species have been identified which would be suitable for monitoring of shore crossing construction activities including the littorinid gastropod *Echinolittorinia trochoides,* which occurs on rocky substrates, and *Littoraria filosa,* which occurs in the mangroves, and the the bivalve, *Donax faba*, which occurs on sandy beaches. The data collected is suitable for power analysis, which should be undertaken to design a construction-monitoring program if the proposed project is approved.

This page has been intentionally left blank

2. Introduction

The primary objective of the intertidal and offshore environmental surveys was to provide information to assist with the description of the existing marine environment for the Blacktip Project Environmental Impact Statement (EIS).

The information gathered during these surveys will also:

- assist with the development of future monitoring programmes;
- allow differences between predicted and actual impacts to be quantified and the need for additional environmental management identified;
- enable reporting to regulators and stakeholders on environmental performance and determination of whether environmental performance targets are met;
- determine rehabilitation success eg at the beach crossing;
- ultimately ensure that no adverse environmental impacts are occurring.

This page has been left intentionally blank

3. Methods

3.1 Survey Locations

3.1.1 Offshore

The offshore environmental survey covered the:

- platform location
- pipeline route including shore approach
- PW discharge area and the condensate export mooring, located approximately 3 km and 4 km offshore from the proposed pipeline beach crossing, respectively.

Sampling sites along the pipeline route were stratified using the results of the geophysical survey (**Table 1**), to ensure coverage of all the identified seabed habitats. Most of the seabed along the pipeline route was categorised as either:

- flat and featureless seabed containing soft to firm silty clay
- area of hummocky seabed containing megaripples/sand waves.

The offshore sampling regime is presented in **Table 2** and **Figure 1**. Sampling was conducted from the MV *Island Explorer* between the 19th and 22nd of May 2004.

3.1.2 Intertidal

The proposed gas export subsea pipeline is planned to come onshore at northern Yelcher Beach, a small beach approximately 700 m long, located 12 km from Wadeye (formerly Port Keats). Three main intertidal habitats occur near the pipeline crossing location. They are:

- sandy beach
- rock platform
- mangroves.

Three areas (approximately 50 – 100 m apart) representing the high, mid and low intertidal zone were sampled on the sandy beach. At northern Yelcher Beach, three transects running perpendicular to the shore (ie from landward to seaward) were sampled, one on the pipeline alignment near the centre of the beach and the others approximately 200 m to the north and south of the pipeline corridor (**Table 3** and **Figure 2**). Sampling was also undertaken at Yelcher Beach to the south, selected due to its similar intertidal width, aspect and wave. Two transects were established using the same strategy implemented at northern Yelcher Beach.

At each end of northern Yelcher Beach are rock platforms and mangroves. Yulow Point, to the south, separates northern Yelcher and Yelcher Beach and Maninh Point, to the north, separates Yelcher Beach from Injin Beach (**Figure 2**). The mangroves at Maninh Point are of significance to the traditional owners due to the presence of the Cheesefruit Tree (*Morinda citrifolia*) and

sampling at this location was not possible. The survey of the adjacent mangroves of Maninh Point was conducted in association with the traditional owners. All intertidal sampling was conducted by Kristin Metcalfe between the 2nd and 4th June 2004. **Table 3** summarises the intertidal sampling regime.

3.2 Parameters

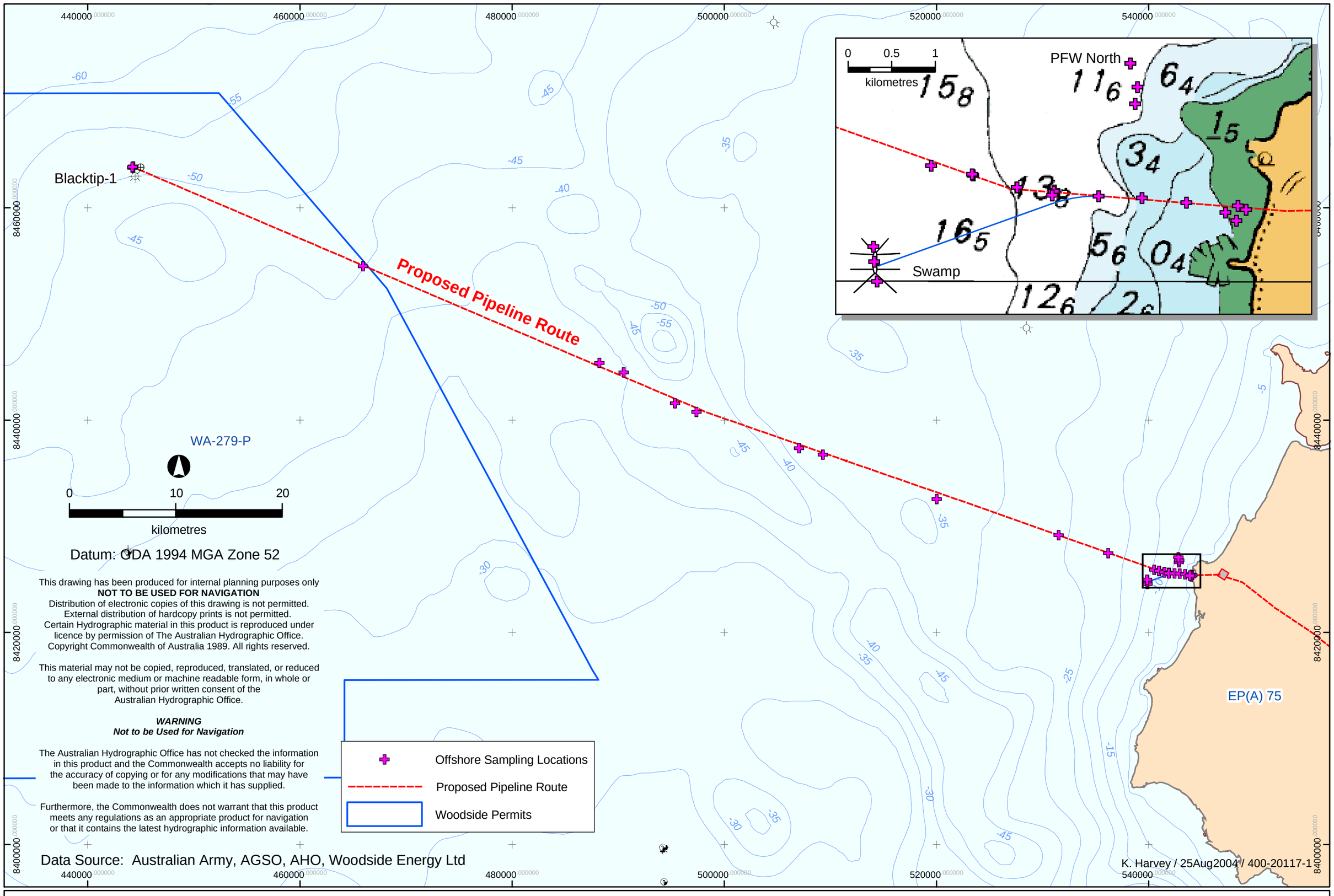
3.2.1 Sediments

Sediment samples were collected from all offshore sites and the intertidal beach and mangrove sites (not rock platform sites). Sediments were analysed for the following:

- Total Recoverable Hydrocarbons (TRH), speciated into
  - C_6-C_9
  - C_{10}-C_{14}
  - C_{15}-C_{28}
  - C_{29}-C_{36}.
- Sediment particle size distribution
- Metals as specified in **Table 1**.

Offshore sediment samples were collected using a Van Veen Grab. Intertidal sediments were collected directly during low tides. Samples for TRH analyses were collected directly into cleaned 300 ml glass jars (acid rinsed by the laboratory), samples for metals into 100 ml plastic containers and samples for sediment particle size distribution into 300 ml whirlpacks. All sample containers were labelled, recorded on the sample register sheet and placed into a freezer or fridge for storage and transport to the laboratories. Between all sample sites, sample collection buckets and ladles were washed with a dilute solution of Decon 90 cleaner and rinsed thoroughly with sea water.

The analyses were undertaken by SGS Australia Pty Ltd. (TRH and particle size distribution), the Marine And Freshwater Research Laboratory (sediment metals and offshore infauna) and Kristin Metclafe and the Northern Territory Museum (intertidal biota). Both SGS and MAFRL are NATA accredited laboratories.



Blacktip Project

DRIMS-#1572636

OFFSHORE SAMPLING LOCATIONS

Figure 1

This page has been left intentionally blank

- **Table 1 Fugro's Geophysical Assessment of Seabed Habitats along the Proposed Pipeline Route**

From KP to KP	Seabed Type
0.000 to 47.445	Flat and featureless seabed containing very soft to firm silty clay.
47.445 to 47.942	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae. Drop core recovered partially indurated gravel containing soft corals at KP47.847.
47.942 to 49.596	Flat and featureless seabed containing very soft to firm gravelly clay.
49.596 to 50.567	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
50.567 to 52.789	Flat and featureless seabed containing very soft to firm gravelly clay.
52.789 to 53.542	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
53.542 to 54.781	Flat and featureless seabed containing very soft to firm gravelly clay.
54.781 to 56.390	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
56.390 to 59.341	Flat and featureless seabed containing very soft to firm gravelly clay.
59.341 to 59.945	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae. Drop core recovered unconsolidated gravel containing shell and coral fragments at KP59.600.
59.945 to 64.751	Flat and featureless seabed containing very soft to firm gravelly clay.
64.751 to 66.656	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
66.656 to 67.746	Flat and featureless seabed containing very soft to firm gravelly clay.
67.746 to 68.405	Area of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
68.405 to 72.594	Flat and featureless seabed containing very soft to firm gravelly clay.
72.594 to 76.174	Alternating flat and featureless seabed containing very soft to firm gravelly clay and areas of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae.
76.174 to 78.424	Flat and featureless seabed containing very soft to firm gravelly clay.
78.424 to 84.314	Alternating flat and featureless seabed containing very soft to firm gravelly clay and areas of hummocky seabed containing megaripple/sand waves. Generally consisting of unconsolidated coarse sand, fine gravel. Occasionally sediments are consolidated/cemented and contain hard/soft coral and algae. Drop core recovered a cemented gravel covered in corals at KP82.000.
84.314 to 89.000	Flat and featureless seabed containing very soft to firm gravelly clay.
89.000 to 103.390	Flat and featureless seabed containing very soft to firm gravelly clay with some areas of hummocky seabed containing megaripple/sand waves. Sand waves areas generally consisting of unconsolidated coarse sand/fine gravel, which can be consolidated/cemented and contain hard/soft coral and algae. Drop core recovered unconsolidated worm tube debris at KP99.151.
103.390 to 104.000	Subcropping/outcropping indurated gravelly clay containing hard and soft corals.

KP = kilometre along pipeline route from proposed platform location

- **Table 2 Offshore Sampling Locations**

Site Description	Date	Time	Grid Coordinates (GDA94)		Pipeline KM	Depth (m)	Sediment Chemistry	Infauna	Water Quality
			EASTING	NORTHING	(Platform =0 km)				
Platform North	5/22/2004	10:08	444293.9	8463910.2	0.004	55.0	✓	✓	x
Platform East	5/22/2004	10:53	444276.4	8463790.9	0.035	55.0	✓	✓	✓
Platform South	5/22/2004	11:18	444192.9	8463794.3	-0.043	55.0	✓	✓	x
Platform West	5/22/2004	9:38	444222.9	8463869.5	-0.045	55.0	✓	✓	✓
Pipeline 01	5/21/2004	18:55	465954.5	8454505.1	23.627	44.0	✓	✓	✓
Pipeline 02	5/21/2004	16:49	488235.8	8445389.4	47.708	33.0	✓	✓	✓
Pipeline 03	5/21/2004	16:17	490510.8	8444517.1	50.143	33.0	✓	✓	✓
Pipeline 04	5/21/2004	15:33	495351.9	8441594.0	55.746	40.0	✓	✓	✓
Pipeline 05	5/21/2004	14:33	497380.7	8440794.1	57.927	46.0	✓	✓	✓
Pipeline 06	5/19/2004	15:31	507063.0	8437373.9	68.180	37.9	✓	✓	✓
Pipeline 07	5/19/2004	16:30	509305.3	8436749.2	70.504	34.3	✓	✓	✓
Pipeline 08	5/19/2004	18:14	520019.8	8432563.5	82.004	34.4	✓	✓	✓
Pipeline 09	5/20/2004	7:43	531522.7	8429165.2	93.989	29.8	✓	✓	✓
Pipeline 10	5/20/2004	8:28	536199.4	8427460.0	98.968	29.1	✓	✓	✓
Pipeline 11	5/20/2004	11:02	540517.9	8425907.2	103.559	20.3	✓	✓	✓
PW3.5 Rep1	5/20/2004	11:39	540994.1	8425797.6	104.045	19.7	✓	✓	x
PW3.5 Rep2	5/20/2004	12:07	540999.5	8425796.1	104.050	19.2	✓	✓	✓
PW3.5 Rep3	5/20/2004	12:19	540987.7	8425808.0	104.035	18.9	x	✓	x
PW3.0 Rep1	5/20/2004	12:56	541498.6	8425658.5	104.570	18.0	✓	✓	x
PW3.0 Rep2	5/20/2004	13:00	541499.5	8425658.5	104.571	18.2	✓	✓	✓
PW3.0 Rep3	5/20/2004	13:03	541501.9	8425659.1	104.574	18.1	✓	✓	x
PW2.5 Rep1	5/20/2004	15:18	541928.1	8425625.1	105.003	17.1	✓	✓	x
PW2.5 Rep2	5/20/2004	15:24	541922.0	8425611.5	104.998	17.2	✓	✓	✓
PW2.5 Rep3	5/20/2004	15:30	541903.4	8425567.6	104.983	17.2	✓	✓	x
PWNorth Rep1	5/20/2004	14:13	542852.3	8426614.7	n/a	15.3	✓	✓	x
PWNorth Rep2	5/20/2004	14:33	542881.3	8426806.5	n/a	15.7	✓	✓	✓
PWNorth Rep3	5/20/2004	14:46	542799.8	8427077.8	n/a	14.6	✓	✓	x
Condensate Rep1	5/20/2004	9:38	539896.9	8424581.9	n/a	23.7	✓	✓	x
Condensate Rep2	5/20/2004	10:01	539866.1	8424808.5	n/a	22.9	✓	✓	✓

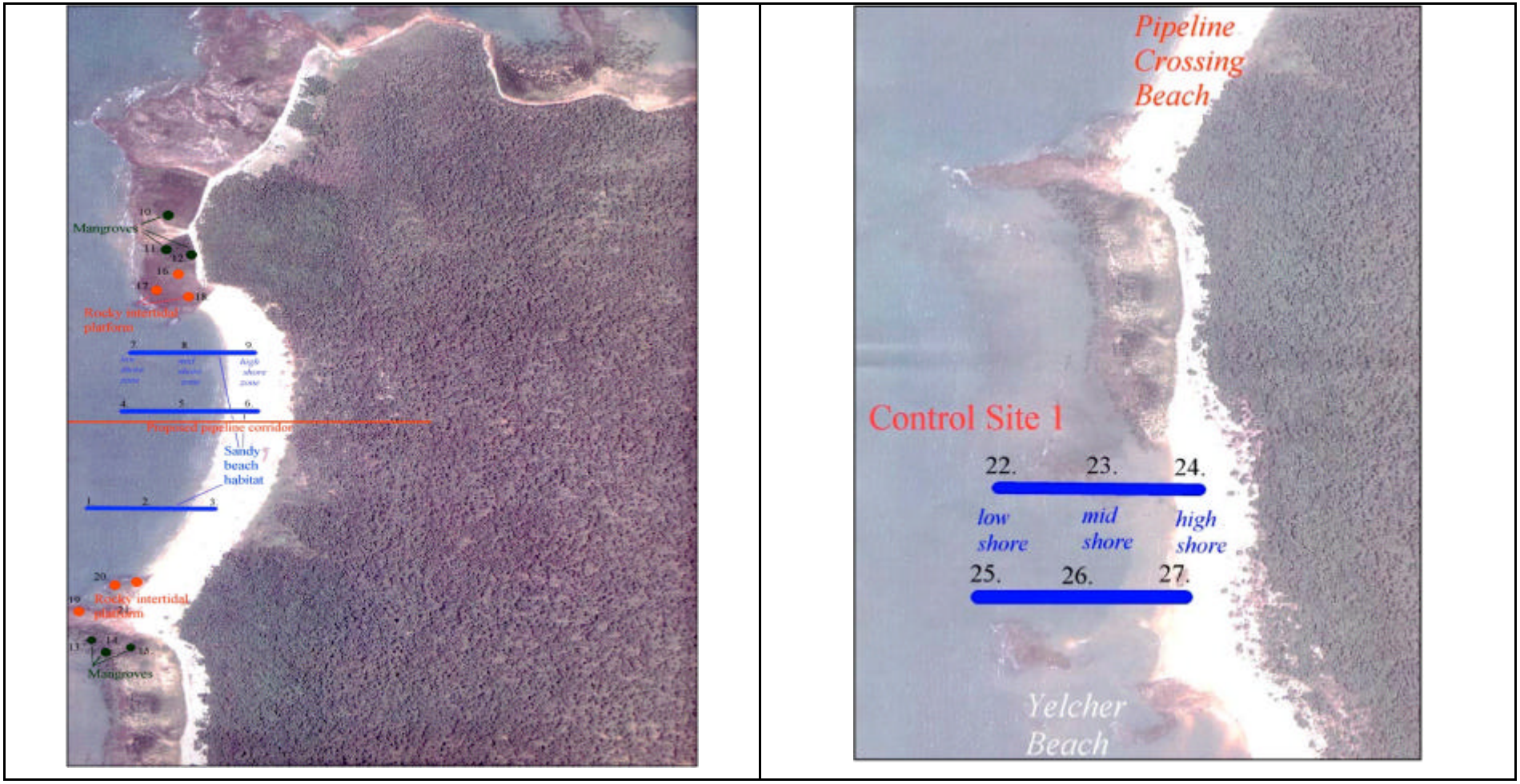
			Grid Coordinates (GDA94)						
Condensate Rep3	5/20/2004	10:35	539855.8	8424979.7	n/a	22.1	✓	✓	x
Nearshore 2.0 km	5/20/2004	16:11	542436.2	8425557.5	105.515	16.6	✓	✓	✓
Nearshore 1.5 km*	5/20/2004	16:28	542932.9	8425536.9	106.012	9.3	x	x	✓
Nearshore 1.0 km*	5/20/2004	16:50	543442.3	8425483.1	106.524	8.4	x	x	✓
Inshore 0.0 km Rep1	5/20/2004	17:16	544030.6	8425447.4	107.113	6.0	✓	✓	x
Inshore 0.0 km Rep2	5/20/2004	17:35	544124.7	8425403.5	107.211	5.6	✓	✓	x
Inshore 0.0 km Rep3	5/20/2004	17:40	544013.5	8425278.2	107.110	6.0	✓	✓	✓
Inshore 0.0 km Rep4	5/20/2004	17:46	543889.8	8425371.5	106.979	6.3	✓	✓	x

See **Section 2.1.2** for description of sediment chemistry, **Section 2.1.3** for water quality and **Section 2.1.4** for description of faunal sampling.
* Van Veen Grab failed three times in a row and depth sounder suggested substrate was very hard ie rock bottom.

Table 3 Intertidal Sampling Locations

Site Description	Date	Grid Coordinates (GDA94)		Sediment Chemistry	Faunal quadrats			Anoxic mats	Pitfall trap
		EASTING (m)	NORTHING (m)		0.5 x 0.5	1.0 x 1.0	0.3 x 0.3		
Northern Yelcher Beach B1	2/6/04	544236	8425228	✓			✓		
Northern Yelcher Beach B2	2/6/04	544282	8425210	✓			✓		
Northern Yelcher Beach B3	2/6/04	544317	8425196	✓			✓		
Northern Yelcher Beach B4	2/6/04	544306	8425394	✓			✓		
Northern Yelcher Beach B5	2/6/04	544352	8425386	✓			✓		
Northern Yelcher Beach B6	2/6/04	544381	8425378	✓			✓		
Northern Yelcher Beach B7	2/6/04	544340	8425582	✓			✓		
Northern Yelcher Beach B8	2/6/04	544377	8425582	✓			✓		
Northern Yelcher Beach B9	2/6/04	544418	8425580	✓			✓		
Maninh Point Mangroves M10	3/6/04	543958	8424736	✓		✓		✓	✓
Maninh Point Mangroves M11	3/6/04	544019	8424740	✓		✓		✓	✓
Maninh Point Mangroves M12	3/6/04	544066	8424718	✓		✓		✓	✓
Yulow Point Mangroves M13	4/6/04	544207	8425996	✓		✓		✓	✓
Yulow Point Mangroves M14	4/6/04	544202	8425960	✓		✓		✓	✓
Yulow Point Mangroves M15	4/6/04	544236	8425998	✓		✓		✓	✓
Yulow Point Rock Platform R16	3/6/04	544401	8423502	**X**	✓				
Yulow Point Rock Platform R17	3/6/04	543875	8424826	**X**	✓				
Yulow Point Rock Platform R18	3/6/04	543830	8424812	**X**	✓				
Yelcher Beach B19	2/6/04	544007	8423140	✓			✓		
Yelcher Beach B20	2/6/04	544128	8423106	✓			✓		
Yelcher Beach B21	2/6/04	544450	8423302	✓			✓		
Yelcher Beach B22	2/6/04	544061	8423336	✓			✓		
Yelcher Beach B23	2/6/04	544189	8423354	✓			✓		
Yelcher Beach B24	2/6/04	544382	8423490	✓			✓		

See **Section 2.1.2** for description of sediment chemistry and **Section 2.1.4** for description faunal sampling



Rocky Intertidal Platform sites 19-21 not sampled

- **Figure 2 Intertidal Sampling Locations**

This page has been left intentionally blank

- **Table 4 Sediment Metals Analyses**

Metals in Sediment	Analytical Detection Limit (mg/ kg DW)	ANZECC guideline (mg/ kg DW)
Antimony	<2	2
Aluminium (Al)	<20	--
Arsenic (As)	<1	20
Barium (Ba)	<0.5	--
Cadmium (Cd)	<0.1	1.5
Chromium (Cr)	<0.2	80
Cobalt (Co)	<0.2	
Copper (Cu)	<0.1	65
Iron (Fe)	<5	--
Lead (Pb)	<1	50
Mercury (Hg)	<0.15	0.15
Nickel (Ni)	<0.4	21
Silver (Ag)	<1	1
Tin (Sn)	<2	--
Vanadium (V)	<0.1	--
Zinc (Zn)	<0.5	200

3.2.2 Water Sampling

Offshore water quality was profiled using an automated YS660 Probe attached to a 25 m long cable. The YS660 probe was configured to record the following parameters during deployment:

- depth
- temperature
- turbidity
- salinity
- dissolved oxygen
- ph

At some sites, shallow water and strong tidal currents, limited the depth to which the probe could be successfully lowered. However, the first 5 m of the water column were successfully sampled at all sites.

3.2.3 Fauna

Offshore infauna samples were collected using a 90 mm diameter polycarbonate plastic core inserted to a depth of 100 mm to remove a sample directly from the sediment in the Van Veen grab. The core sample was sieved through a 1 mm sieve to remove the fine sediment material and the remaining fauna and sediment was washed into a whirlpack plastic bag and preserved with a

small volume of 70% ethanol. Grab samples were also searched for large biota such as macroalgae, corals and seagrass.

Sandy beach infauna were sampled using two haphazardly placed 30 by 30 cm quadrats per sampling site, excavated to a depth of 10-15 cm and, due to the coarse nature of the sediments, sieved using a 2 mm sieve.

Rock Platform epifauna at Yulow Point were sampled using two haphazardly placed 50 cm by 50 cm quadrats per sampling station from which all macrofauna were identified directly, or removed and preserved for later identification. Incidental sampling in the vicinity of each station was also undertaken to document less abundant fauna. Three sampling stations at Yulow Point (6 quadrats) were sampled during this survey.

Mangrove fauna at Yulow and Maninh Points were sampled using a variety of techniques. Benthic fauna was sampled within 1 m by 1 m quadrats, placed adjacent to the nearest tree, using timed observation followed by active searches to a height of 2 m up the tree and a depth of 5 cm into the sediments. Infauna was also sampled using anoxic mats, small 0.01 m^2 plastic discs, which were left on the mud surface overnight to draw infauna. Free-ranging fauna, including fauna in standing water, were sampled using pitfall trap.

3.2.3.1 Observations

Cetacean, seabirds, dugongs, turtles sightings and shipping and fishing activity were recorded during the offshore survey along with any information on the distribution of significant benthic communities such as coral reefs or seagrass beds. A more comprehensive survey of turtle and dugong activity was undertaken by Charles Darwin University and is reported in Guinea (2004). All grab samples were searched for the presence of seagrass, macroalgae and corals.

4. Results and Discussion

4.1 Sediments

4.1.1 Chemistry

4.1.1.1 Hydrocarbons

Total Recoverable Hydrocarbon (TRH) were below detection limits in all samples except for three mangrove samples (**Appendix A**), one from Maninh Point and two from Yulow Point (**Table 5**).

- **Table 5 Recoverable Hydrocarbons (mg/kg)**

Site	TRH C_{10}-C_{14}	TRH C_{15}-C_{28}	TRH C_{29}-C_{36}
Maninh Point Mangroves M10	**2**	**27**	<10
Yulow Point Mangroves M14	<2	**6**	<10
Yulow Point Mangroves M15	<2	**6**	**13**

Refer to **Appendix A** for full set of results

Identification of the hydrocarbons in the sample "Maninh Point Mangroves M10" was investigated further using a Gas Chromatography-Mass Spectrometry and the analytes identified using the National Institute of Standards and Technology Mass Spectra library. A single peak was responsible for the hydrocarbons in the C_{10}-C_{14} range and it was identified as:

- 1,2,3,4-tetrahydronaphthalene.

For the C_{15}-C_{28} range, about 50% of the value reported was due to two single peaks which were identified as:

- 9,10-dihydro-9-anthracenamine
- (4-acetylphenyl) phenylmethane.

All three chemicals are long chained hydrocarbon products; 1,2,3,4-tetrahydronaphthalene and (4-acetylphenyl) phenylmethane are Polycyclic Aromatic Hydrocarbons (PAH). While it is not possible to identify the definite source of these chemicals, it is likely that all three are the breakdown products of crude oil. The Petrel and Tern wells, to the north west of the pipeline crossing, are known to leak hydrocarbons (Mick Guinea, Charles Darwin University, *pers comm.* 2004) and the predominate winds during the wet season, which are from the north west, would drive crude oil from these fields ashore. Crude petroleum has a high affinity for organically rich sediments, which is why crude accumulates readily in mangrove sediments. Sand and gravel have little ability to absorb these chemicals and are probably less sensitive indicators for ongoing monitoring.

It is also worth noting that TRH levels were below detection limits in the four samples collected from around the proposed Blacktip platform location, which is positioned about 1000 m from the Blacktip-1 well drilled in 2001.

4.1.1.2 Metals

Sediment metal concentrations are presented in **Appendix B**. Concentrations of most metals were below ANZECC sediment quality guideline values (**Table 4**). One sample collected 2.5 km off the coast (PW2.5 Rep 2) had a chromium concentration of 85 mg/kg, marginally above the ANZECC sediment quality guideline value of 80 mg/kg.

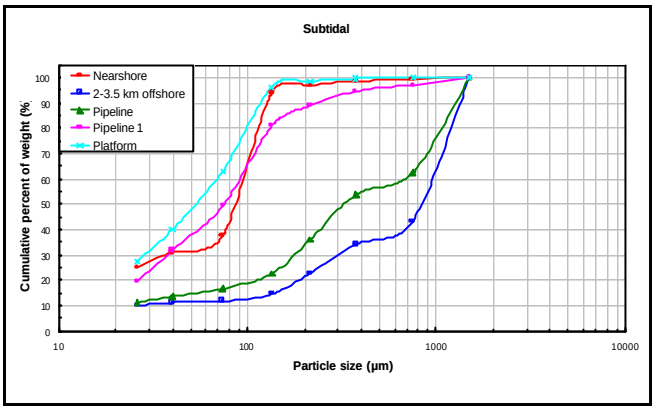
Samples from fifteen offshore sites and one mangrove sample contained sediment arsenic concentrations above the ANZECC sediment quality guideline value of 20 mg/kg, concentrated at sites located 1 to 3 km from the shore crossing. The maximum concentration was 72 mg/kg at the site PWNorth, located 1.5 km from the coast. Similar arsenic levels occur in Darwin Harbour, which are attributed to local geology rather than anthropogenic sources (Padovan 2003).

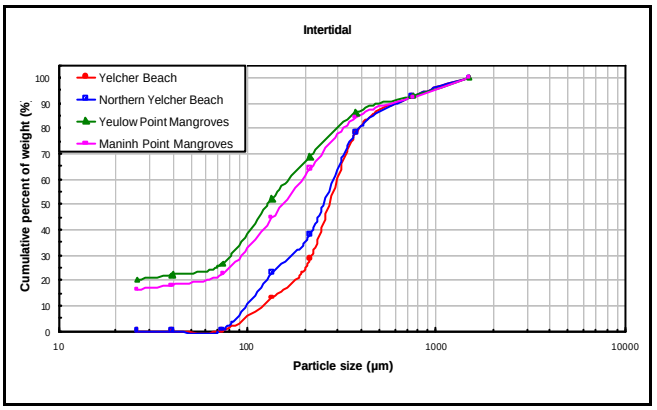
As there are no known anthropogenic heavy metal sources in the Joseph Bonaparte Gulf, the evaluated sediment arsenic and chromium levels, relative to the guideline values, are also likely to be the result of local geology rather than external contamination.

4.1.2 Sediment Particle Size

The sediment particle size results are presented in **Appendix C** and summarised in **Figure 3**. The variation in sediment particle size distributions is not surprising given the large geographic area (over 100 km) and the range of benthic habitats sampled. Sediments were finest at the platform location and in the intertidal zone, just above the drying height on navigational charts (Inshore sites). Very fine sands with some silt fractions dominated at these sites (**Figure 3**). Sediments were coarsest just off the coast with sediments in the vicinity of the proposed produced water discharge and condensate export mooring locations dominated by very coarse sands, with large amounts of gravel and boulder sized particles (*pers. obs.*). The sediments at these locations were poorly sorted with gravel and boulder sized particles loosely cemented on the seabed surface, covering finer sediment below this cemented surface layer. This very coarse, loosely cemented surface layer limited the effectiveness of the Van Veen Grab, which is more suited to sampling finer sediments. Sediments along the pipeline route from the Victoria River channel inshore were also very coarse mostly comprising coarse to very coarse sands (**Figure 3**).

Intertidal sediments on the beach were generally very fine to medium sands at both northern Yelcher Beach and to the south, at Yelcher Beach. The sediments in the mangroves were relatively coarse, dominated by sand fractions with only about 20% of the sediment weight made up by silt fraction. Sediments at Yulow Point mangroves were slightly finer than the sediments at Maninh Point.





- **Figure 3 Cumulative Sediment Particle Size Distribution**

This page has been left intentionally blank

4.2 Water Quality

The offshore water quality sampling occurred during spring tides between the 20st and 22nd of May 2004 (**Figure 4**). Water temperature, salinity, ph, dissolved oxygen and turbidity profiles did not vary with increasing depth within each sampling location, indicating that the water column was well mixed and no stratification was occurring. Stratification may be more likely in the wet season as a result of the large freshwater input into the Joseph Bonaparte Gulf, however this should be confirmed as it may have implications for the produced water discharge. Ph values were all around 8.1, within the ANZECC range for inshore tropical marine waters (8.0 to 8.4). Dissolved oxygen was also generally above 90% saturation, the ANZECC default trigger value for tropical marine waters. Dissolved oxygen levels and ph were consistent and did not vary from the shore crossing to the platform location.

Salinity increased minimally from around 33 ppts near shore to nearly 35 ppts offshore (**Figure 5A**). Again, the range in salinity is likely to be much greater during the wet season, with salinity values lower closer to the coast due to large freshwater input.

Temperature and turbidity showed a more complex pattern with distance offshore (**Figure 5B and 5C**), though the range in temperature was small only ranging between 28 and 29°C. By contrast, the range in turbidity was marked. Lower values (around 2 NTU) were recorded from about the 30 km mark offshore. Values peaked near 40 NTU, 3 km from the coast but where high (> 10 NTU) from 2 to 15 km from the coast. Inshore of the 2 km mark, NTU were slightly lower.

Inshore turbidity values were well above the ANZECC default trigger value range of 1-20 NTU for inshore tropical waters. However, the Joseph Bonparte Gulf has naturally high levels of turbidity (**Figure 6**) due to large freshwater inputs and large tides which can resuspend sediments. In addition, higher levels of turbidity are likely to occur during the wet season as a result of the input of large volumes of muddy, freshwater.

Water temperature showed a similar, though inverted, pattern to turbidity. The patterns in turbidity and temperature can broadly be related to the strength and direction of tidal currents across the Blacktip Project area. Hydrodynamics modelling indicates the presence of a current eddy, roughly positioned between the rocky headlands at each end of the northern Yelcher Beach (IRCE 2004). This eddy extends from the coast offshore for approximately 1.5 km during spring tides. Inside this eddy, currents are significantly weaker than in waters just offshore of the eddy, from where currents slowly decrease in strength with increasing distance offshore.

4.3 Fauna and Flora

4.3.1 Intertidal

Beach Habitat: Northern Yelcher Beach is fringed with a steep sand dune to 2 m high. Landward of the dune is a broad sandy grassland area that merges with upland monsoon vine-forest and woodland. Only scattered trees including the Tamarind (*Tamarindus indica)* and White Bush

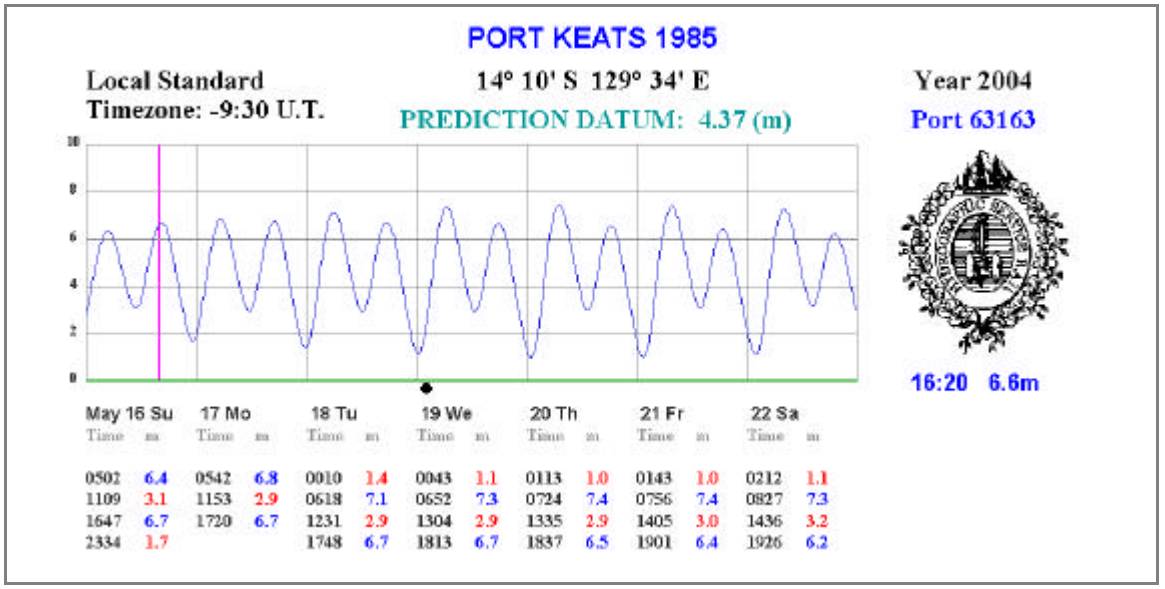
Apple (*Syzygium eucalyptoides* spp. *eucalyptoides)* occur within the grassland. The dominant species in the grassland area behind the beach is Annual Sorghum (*Sorghum timorense)* with Beach Spinifex (*Spinifex longifolius)* and the vines *Ipomoea pes-caprae* and *Carnavalia rosea*. Occasional low trees and shrubs include *Pandanus spiralis, Flueggia virosa* and the Class B noxious weed *Calotropis procera* (Smith 2002). The subshrub *Triumphetta* sp. and the sedge *Fimbristylis cymosa* are locally abundant and in combination with Annual Sorghum represent the three most important ground cover species in stabilising the substrate in this sandy habitat.

Below the beach dune but above the high spring tide level (at approximately 8 m Wadeye Hydrogeographic Service tidal datum) the beach is gently sloping and composed of very coarse sand with coral fragments and rock. Timber, mangrove leaves and other flotsam and jetsam are abundant in this habitat, though no drift seagrass or macroalgae was observed (**Figure 7A**). This flotsam and jetsam provides shelter for high densities of the terrestrial hermit crab *Coenobita variabilis* (up to 80 hermit crabs per m^2). This species is known to extend up to 100 m or so from the beach (Jones and Morgan 2002).

The upper intertidal zone sloped relatively steeply to the flatter mid tidal zone. The invertebrate infauna was abundant, though species richness was low and dominated by the bivalve *Donax faba.* In contrast, the mid-tidal zone at Yelcher Beach is more variable, both in terms of topography and invertebrate fauna. It characteristically had low invetebrate abundance but highest richness. The lower intertidal zone (at approximately 3 m elevation Wadeye Hydrogeographic Service tidal datum) was similarly flat and had the lowest species richness and abundance of the three zones.

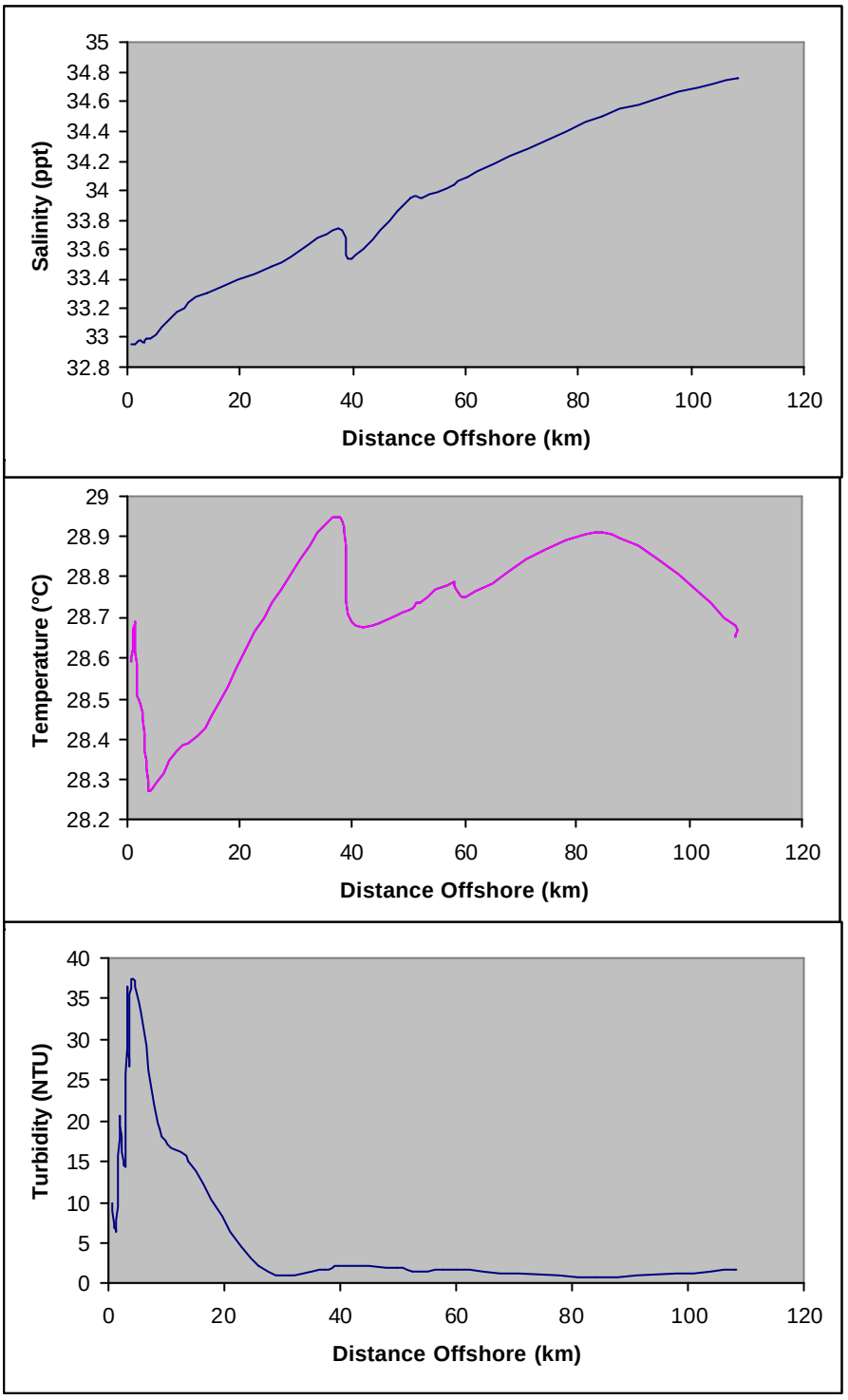
Northern Yelcher Beach has a relatively steep gradient and the width of the intertidal zone is not particularly broad (**Figure 7B**), in comparison to the intertidal zone at Yelcher Beach which is much wider and this beach has a more complex topography (**Figure 7C**). Rocky areas to the north and intertidal sand spits may influence the biotic character of this beach. For instance, large numbers of Soldier Crabs (*Mictyris* sp.) (**Figure 7D**) were common in sections of this beach but uncommon on Northern Yelcher Beach. Also, the mid- and lower intertidal zones on the northern transect at Yelcher Beach, closest to Yulow Point had dark coloured sediments at approximately 5 cm depth and a notably higher invertebrate species richness and abundance. In contrast, 200 m further south, on the second Yelcher Beach transect, the invertebrate fauna was similar to that occurring on Northern Yelcher Beach.

Rocky Shore Habitat: The Yulow Point rock platform at the south of Northern Yelcher Beach comprises a flat lateritic point that extends approximately 400 m from the beach (**Figure 7E**). It is relatively steep sided and flanked with an extensive area of lateritic boulders, up to 100 m wide to the north (**Figure 7F**) and standing water and mangroves to the south. The distribution of the biota was highly variable reflecting microtopography. However, visual assessments indicate that the more seaward section of the rock platform supports a higher diversity and abundance of invertebrate fauna, including sparse corals, anemones, chitons and larger crustaceans than the nearshore sections. No macroalgae was observed.



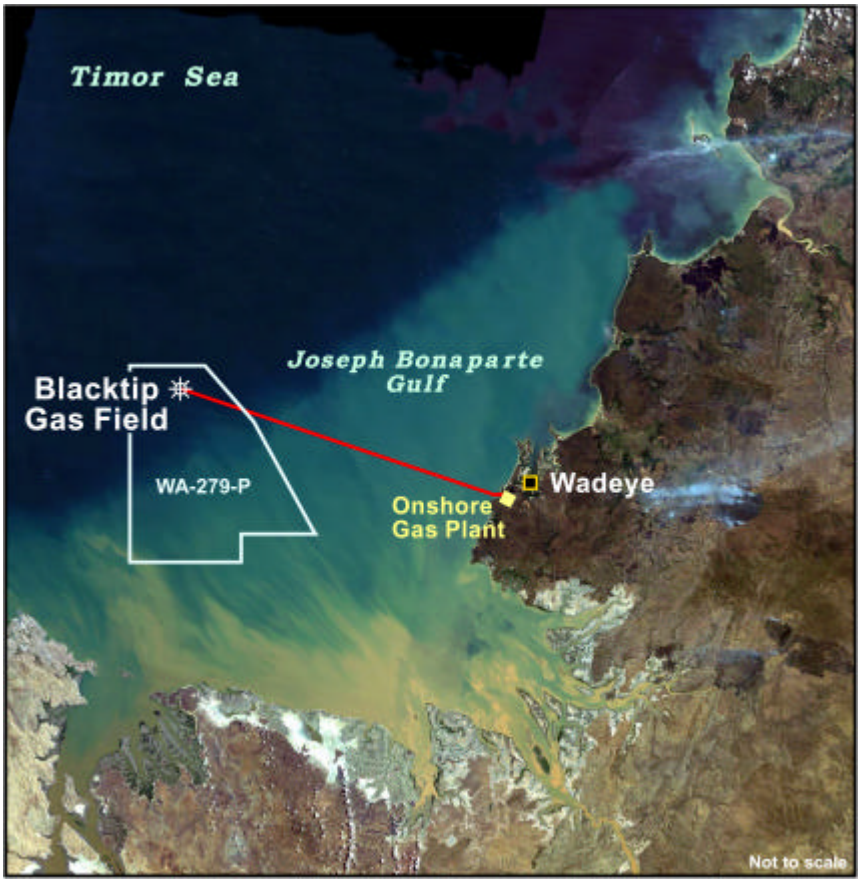
- **Figure 4 Tides at Wadeye (formerly Port Keats)**

This page has been left intentionally blank



- **Figure 5 Water Quality along the Blacktip Pipeline Route from the Shore Crossing to the Platform**

This page has been left intentionally blank



Date of image unknown but it was not taken during the offshore survey.

- **Figure 6 Turbidity in the Joseph Bonaparte Gulf**

This page has been left intentionally blank



A: Northern Yelcher Beach looking north

B: Infauna sampling on northern Yelcher Beach

C: Intertidal zone at Yelcher Beach to the south of the proposed pipeline crossing beach

D: Solder crabs on Yelcher Beach

E: Yulow Point

F: Boulders on Yulow Point

G: *Rhizophora stylosa* mangrove habitat

H: Mud creeper *Terebralia* spp.

- **Figure 7 Intertidal Habitats**

This page has been left intentionally blank

***Mangrove Habitats*:** The Yulow Point mangroves to the south of Northern Yelcher Beach form a strip less than 700 m long and between 100 to 300 m wide. The mangrove habitat at this location is extremely sandy with muds only occurring in the most seaward zone. The mangrove forest is quite sparse with well-spaced trees and a relatively open canopy. This contrasts with the extremely dense mangroves to the north of the proposed shore crossing, which have a muddy to gravelly substrate.

Four mangrove species were recorded within the Yulow Point mangroves (*Sonneratia alba, Rhizophora stylosa, Aegialitis annulata* and *Avicennia marina*). The mangroves at this location show clear zonation with three main communities arranged in bands roughly parallel to the shoreline (**Figure 8**). The most seaward area has scattered rock outcrop amongst muddy sand and supports a thin forest of *Sonneratia alba* to 12 m high. This narrow seaward strip is densest at the northern end of the mangrove close to the rock platform. The *Sonneratia* zone intergrades with low *Rhizophora stylosa* forest 3 to 7 m high. The *Rhizophora* forest (**Figure 7G**) is the most extensive assemblage or zone at this location extending up to and adjoining the rock platform to the north. To landward, the *Rhizophora* forest is fringed by a band of low *Avicennia marina* (Grey Mangrove) that forms a shrubland of mid-dense trees less than 2 m high. In this landward zone, *Aegialitis annulata* (Club Mangrove) occurs as scattered low trees to 1.5 m along the hinterland margin or beach.

The mangroves occurring on Maninh Point, to the north of northern Yelcher Beach, have a substrate comprising firm, root-structured marine muds. The muddy substrate becomes gravelly to rocky where it abuts the surrounding intertidal rocky habitat. It contrasts markedly with the sandy mangrove habitat at the southern end of northern Yelcher Beach. The mangrove forest at Maninh Point is taller and more dense. The mud mangrove substrate supports a different invertebrate fauna with several species recorded in the northern mangrove area (including the large molluscs *Terebralia palustris, T. semistriata* and*)* were not observed in the southern forest.

Eight species of mangrove were observed in mangroves in this area, including the four species identified from the Yulow Point mangroves (**Figure 9**). The dominant species *Rhizophora stylosa* forms dense mono-specific stands 5 to 7 m high supported by branching stilt roots to several metres high. The landward fringe of the forest adjoins a narrow sandy beach, which merges with coastal vine-forest. and comprised a range of mangrove species not observed at Yulow Point including *Camptostemon schultzii, Bruguiera exaristata* and *Ceriops australis.* The River Mangrove *Aegiceras corniculatum* was also common as a low shrub on the fringes of the Maninh Point mangrove.

A total of 8 mangrove species were recorded from both mangrove areas during the intertidal survey. However, the extensive mangroves surrounding tidal creeks to the north and south of Northern Yelcher Beach were not visited as part of this survey and are likely to contain additional mangrove species.

The Joseph Bonaparte Gulf is not considered to be a significant mangrove area, although mangroves occur throughout the Gulf and there are locally important groups, mainly on the southern coast of the Gulf (LDM 1994). There are 48 species of mangroves recorded in northern Australia, of which 38 species have been recorded at Darwin, 39 on the Gove Peninsula and only 20 at the Joseph Bonaparte Gulf (LDM 1994). A total of 18 mangrove species are known from the 1°by 1° grid cell of latitude and longitude that includes Wadeye (Wightman 1989). The Joseph Bonaparte Gulf appears to be one of the least diverse regions in term of mangrove species richness and densities are up to 20 times lower in the Joseph Bonaparte Gulf than at Gove or Darwin (LDM 1994).

***Intertidal Fauna*:** Ninety-five nominal species were identified during the intertidal survey from the three habitats surveyed (**Appendix D**): 18 in the sandy beach habitat, 60 in the mangrove habitat and 20 in the rocky headland habitat.

Sandy Beach: The sandy beach habitat was dominated, in terms of abundance and occurrence, by the bivalve *Donax faba*. This species had a mean abundance of nearly 300 m^{-2} in the upper shore zone of northern Yelcher Beach and 135 m^{-2} in the upper zone of Yelcher beach to the south. However, abundances in the mid and lower zones were considerably lower, ranging between 0–70 m^{-2}. Statistical comparison indicated that there were no significant differences in abundance of this bivalve between the two beaches (ANOVA df:1,3 F=1.61, P=0.294) but, as outlined above, there were marked differences in abundance between the three different zones (ANOVA df: 2,3 F=37.68, P=0.00). The only other species to occur in significant numbers was the gastropod, *Isanda coronata,* however, this species was only recorded on Yecher Beach to the south of the proposed shore crossing.

Mangroves: The dominant fauna in the mangroves were hermit crabs and littorinid gastropods. Hermit crabs predominantly occurred on the sediment surface and the littorinid gastropods reside on the trunks of mangroves. Of note, three specimens of the littorinid, *Littoraria ianthostoma*, were collected from the mangroves at Maninh Point, at the northern end of the pipeline crossing beach. This species is epiphytic on the trunks of mangrove trees in the seaward zone and is endemic to the Joseph Bonaparte Gulf. The barnacle, *Chthamalus malayensis,* was also abundant but was only recorded in two of the 12 epifaunal quadrats. Four species of the fiddler crabs and two species of mud creepers (**Figure 7H**) were also collected.

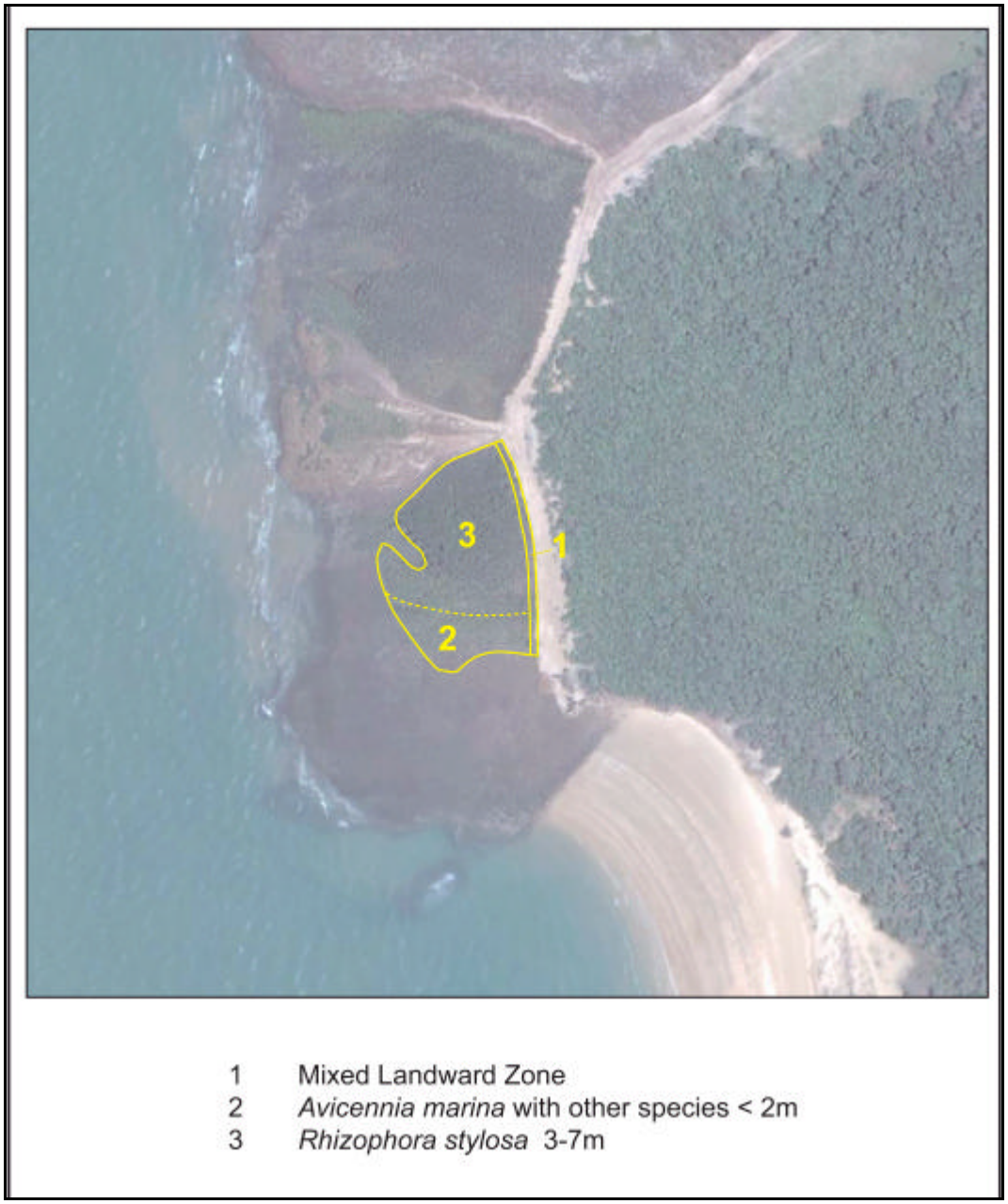
Rocky Headland: Sampling effort on the rocky headlands was low with only the Yulow Point rocky headland being sampled. This rocky substrate was also dominated by a littorinid gastropod, *Echinolittorinia trochoides,* with an average density of 70 m^2.

This littorinid, along with the littorinids and hermit crabs in the mangroves and the bivalve, *Donax faba*, are numerically abundant which makes them suitable taxa for ongoing monitoring programs.



- **Figure 8 Zonation of Mangroves on Yulow Point at the Southern End of the Pipeline Crossing Beach**

This page has been left intentionally blank



- **Figure 9 Zonation of Mangroves on Maninh Point at the Northern End of the Pipeline Crossing Beach**

This page has been left intentionally blank

4.3.2 Offshore

No attached, drift or remnants of seagrass or macroalgae were collected in any sample of the 35 successful grab samples. The grab failed to collect any sediment from the 1.5 and 1 km near shore locations where the vessel's depth sounder suggested that the substrate at and between these two locations was probably a flat hard reef. While a grab is an inefficient sampling device for hard substrates, no hard or soft coral fragments or macroalage were collected in the six grabs attempted across these two location suggesting that the substrate did not support a high abundance of scleractinian or reef building corals or macroalgae. Even on the intertidal Yulow Point rock platform, only a few scattered corals (probably *Goniastrea)* and no macroalgae were observed, again indicating that the project area is unlikely to support significant benthic communities. Subtidally, corals were limited to two small gorgonian corals collected at Site Pipeline 11, four kilometres from the pipeline crossing beach.

The infauna collected was species rich with 135 nominal species identified. By contrast, faunal abundance was low with only 528 individuals recorded and only 14 species recording more than 10 individuals across all the offshore samples. The most abundant species were a porcelain crab followed by a brittle star (**Appendix E**). Both the abundance of infauna and the number of species were generally greater at sites near the coast, particularly at sites between about 2 to 3.5 km off the coast, than at sites further offshore. However, the correlations in abundance and species richness with distance were marginally not significant (r^2=0.31 P=0.065 and r^2=0.32 P=0.0712, respectively). Significant correlations were observed between the coarsest sediment fraction gravel (very coarse sands and above) and both abundance and species richness (r^2=0.47 P=0.005 and r^2=0.46 P=0.006, respectively). This contrasts with another study conducted in the Joseph Bonaparte Gulf which found that infauna species richness and abundance increased with distance from the mouth of the Victoria River, which coincided with an increasing proportion of fine particles in the sediment (BBG 2000).

An NMDS ordination of the infaunal community is presented in **Figure 10**. No clear groupings are obvious however there is some evidence of a pattern with sites with finer sediments on the right hand side of the plot and sites with coarser sediments to the left of the plot. The strongest correlation between the similarity measures and the environmental variables was recorded for the coarse sand fraction (r^2=0.281).

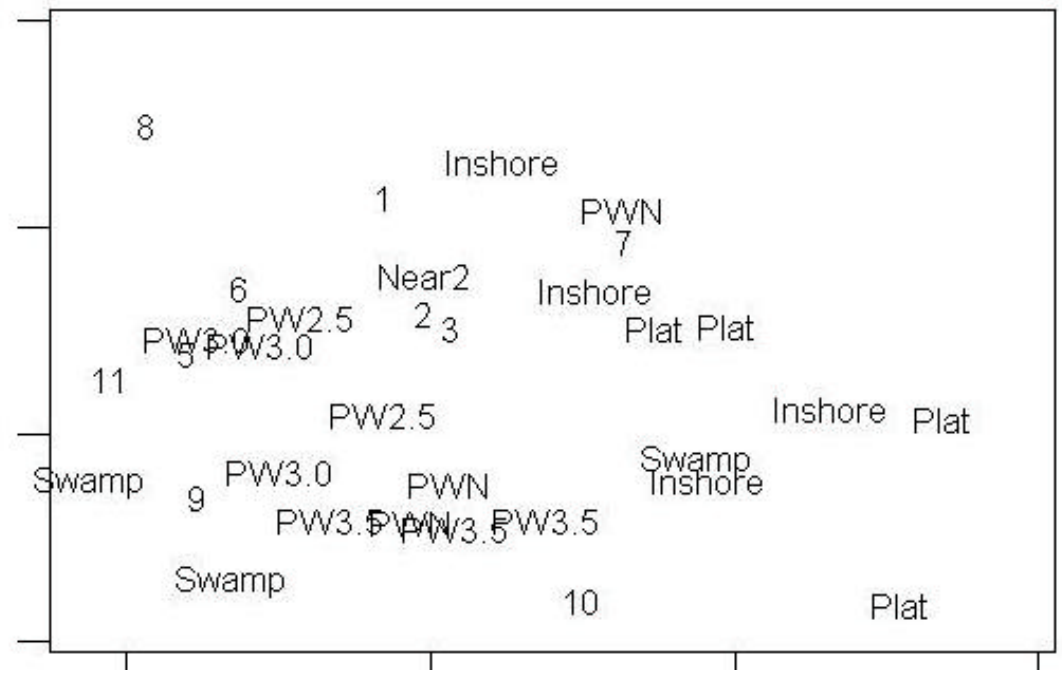
The composition of the infaunal community is unusual as continental shelf infauna are generally dominated by polychaete worms. However, nearly three times as many crustaceans were collected as polychaetes; bryozoans and hydroids were the next most abundant group after the crustaceans; and, nearly as many molluscs and echinoderms were collected as polychaetes. The BBG (2000) study observed that sites near the Victoria River mouth, which generally had coarser sediments, had a greater proportional abundance of crustaceans and cnidarians (hydroids and soft corals) compared to sites further offshore, which supported a predominantly deposit feeding infauna. The very coarse sediments probably limit the development of a deposit feeding community.

4.3.2.1 Faunal Observations

Fauna observed during the offshore environmental survey are presented in **Table 6**. No cetaceans were sighted during the offshore environmental survey or any of the offshore geophysical and geotechnical surveys which occurred throughout most of May and June 2004. Similarly, no seabirds were observed and turtle numbers were low with only four turtles observed during the offshore survey.

- **Table 6 Macrofaunal Observations**

Date	Time	Grid Co-ordinates (GDA 94)		KP	Depth (m)	Sighting details
		Easting	Northing			
5/22/2004	8:38	444187	8463798	-0.051	55	2x Prawn trawlers, steaming to sw. One with trial nets in the water.
5/21/2004	21:15	465886	8454621	23.52	44	2 sea snakes (separate) - black/white banded 1x 2ft, 1x 4ft, moving with current
5/21/2004	19:45	465921	845432	23.59	44	Sea snake - 3ft long, curled up. Pale, difficult to distinguish colours at night.
5/21/2004	18:10	472547	8451895	30.72	42	Sea snake - black/white banded, approx 7ft long
5/21/2004	13:23	497444	8440828	57.973	46	Turtle - flatback, adult
5/21/2004	13:35	497429	8440717	58.001	46	Manta Ray - approx 1.5m across, 100m off vessel
5/21/2004	13:16	499185	8440214	59.804	46	Turtle - flatback, 0.6m across shell.
5/21/2004	12:45	507645	8437468	68.701	38	Turtle - small flatback, heading SSE
5/19/2004	16:53	510024	8436438	71.287	34	Turtle - small. Probably green, but possibly flatback
5/21/2004	02:00	540190	8426000	103.218	20	Tree Martin - landed on board vessel during fresh winds 0200-0800
5/20/2004	10:31	539863	8424981	103.246	22	Redbacked Kingfisher, landed on vessel, then resumed flight to east



Site codes: Plat=Platform, PWN=PWF NORTH, numbers refer to sample number along pipeline eg 1=pipeline .

- **Figure 10 A Two Dimensional NMDS Ordination of Infauna Collected from the Sites Listed in Table 2 (stress=0.19)**

This page has been left intentionally blank

5. References

ANZECC, 2000 *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* Australian and New Zealand Environment and Conservation Council.

BBG, 2000. *Environmental BaselineSsurveys in Joseph Bonaparte Gulf in June 2000*. Unpublished report for Woodside Energy Limited.

Fugro, 2004. *Geotechnical survey report for Blacktip Project.* Unpublished report by Fugro for Woodside Energy Limited. In preparation.

Guinea, M 2004. *Turtle and Dugong Activity in the Vicinity of the Proposed Blacktip Project Shore Crossing*. Unpublished being prepared for Woodside Energy Limited.

IRC Environment, (2004). *Draft Blacktip Produced Formation Water Assessment.*

Jones Diana and G. Morgan, (1994). A Field Guide to Crustaceans of Australian Waters. Reed Books, Australia.

LDM, 1994. E*xploration Drilling, EP32 And EP57 Joseph Bonaparte Gulf Northern Territory Environmental Review report.* Report to: Teikoku Oil.

Padovan, A 2003 *Darwin Harbour Water and Sediment Quality*. Proceedings of the Darwin Harbour Public Presentations February 2003

Smith, N M (2002) *Weeds of the Wet/Dry Tropics of Australia.* Environment Centre NT Inc. Darwin, Northern Territory.

Wightmann, G M (1989) *Mangroves of the Northern Territory*. Northern Territory Botanical Bulletin No. 7. Conservation Commission of the Northern Territory.

This page has been left intentionally blank

Appendix A Sediment Hydrocarbons (TRH-mg/kg)

Site Description	Date	Depth	TRH C6-C9	TRH C10-C14	TRH C15-C28	TRH C29-C36
Platform North	5/22/04	55.0	<5	<2	<5	<10
Platform East	5/22/04	55.0	<5	<2	<5	<10
Platform South	5/22/04	55.0	<5	<2	<5	<10
Platform West	5/22/04	55.0	<5	<2	<5	<10
Pipeline 01	5/21/04	44.0	<5	<2	<5	<10
Pipeline 02	5/21/04	33.0	<5	<2	<5	<10
Pipeline 03	5/21/04	33.0	<5	<2	<5	<10
Pipeline 04	5/21/04	40.0	<5	<2	<5	<10
Pipeline 05	5/21/04	46.0	<5	<2	<5	<10
Pipeline 06	5/19/04	37.9	<5	<2	<5	<10
Pipeline 07	5/19/04	34.3	<5	<2	<5	<10
Pipeline 08	5/19/04	34.4	<5	<2	<5	<10
Pipeline 09	5/20/04	29.8	<5	<2	<5	<10
Pipeline 10	5/20/04	29.1	<5	<2	<5	<10
Pipeline 11	5/20/04	20.3	<5	<2	<5	<10
PW3.5 Rep1	5/20/04	19.7	<5	<2	<5	<10
PW3.5 Rep2	5/20/04	19.2	<5	<2	<5	<10
PW3.5 Rep3	5/20/04	18.9	**No sample**	**No sample**	**No sample**	**No sample**
PW3.0 Rep1	5/20/04	18.0	<5	<2	<5	<10
PW3.0 Rep2	5/20/04	18.2	<5	<2	<5	<10
PW3.0 Rep3	5/20/04	18.1	<5	<2	<5	<10
PW2.5 Rep1	5/20/04	17.1	<5	<2	<5	<10
PW2.5 Rep2	5/20/04	17.2	<5	<2	<5	<10
PW2.5 Rep3	5/20/04	17.2	<5	<2	<5	<10
PWNorth Rep1	5/20/04	15.3	<5	<2	<5	<10
PWNorth Rep2	5/20/04	15.7	<5	<2	<5	<10
PWNorth Rep3	5/20/04	14.6	<5	<2	<5	<10
Condensate Rep1	5/20/04	23.7	<5	<2	<5	<10
Condensate Rep2	5/20/04	22.9	<5	<2	<5	<10
Condensate Rep3	5/20/04	22.1	<5	<2	<5	<10
Nearshore 2.0 km	5/20/04	16.6	<5	<2	<5	<10
Nearshore 1.5 km*	5/20/04	9.3	**No sample**	**No sample**	**No sample**	**No sample**
Nearshore 1.0 km*	5/20/04	8.4	**No sample**	**No sample**	**No sample**	**No sample**
Nearshore 0.0 km Rep1	5/20/04	6.0	<5	<2	<5	<10
Nearshore 0.0 km Rep2	5/20/04	5.6	<5	<2	<5	<10
Nearshore 0.0 km Rep3	5/20/04	6.0	<5	<2	<5	<10
Nearshore 0.0 km Rep4	5/20/04	6.3	<5	<2	<5	<10
Northern Yelcher Beach B1	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B2	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B3	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B4	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B5	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B6	2/6/04	Intertidal	<5	<2	<5	<10

Site Description	Date	Depth	TRH C6-C9	TRH C10-C14	TRH C15-C28	TRH C29-C36
Northern Yelcher Beach B7	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B8	2/6/04	Intertidal	<5	<2	<5	<10
Northern Yelcher Beach B9	2/6/04	Intertidal	<5	<2	<5	<10
Maninh Point Mangroves M10	3/6/04	Intertidal	<5	**2**	**27**	<10
Maninh Point Mangroves M11	3/6/04	Intertidal	<5	<2	<5	<10
Maninh Point Mangroves M12	3/6/04	Intertidal	<5	<2	<5	<10
Yulow Point Mangroves M13	4/6/04	Intertidal	<5	<2	<5	<10
Yulow Point Mangroves M14	4/6/04	Intertidal	<5	<2	**6**	<10
Yulow Point Mangroves M15	4/6/04	Intertidal	<5	<2	**6**	**13**
Yelcher Beach B19	2/6/04	Intertidal	<5	<2	<5	<10
Yelcher Beach B20	2/6/04	Intertidal	<5	<2	<5	<10
Yelcher Beach B21	2/6/04	Intertidal	<5	<2	<5	<10
Yelcher Beach B22	2/6/04	Intertidal	<5	<2	<5	<10
Yelcher Beach B23	2/6/04	Intertidal	<5	<2	<5	<10
Yelcher Beach B24	2/6/04	Intertidal	<5	<2	<5	<10

Appendix B Sediment Metals (mg/kg)

Site Description	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Sb	Sn	V	Zn	TOC (%)
Platform North	<1	12000	6	14	<0.06	8.3	20	5.2	14000	<0.01	8.9	<5	<2	<2	28	13	<0.4
Platform East	<1	11000	5	14	<0.06	7.7	18	4.7	14000	<0.01	8.3	<5	<2	<2	26	12	<0.4
Platform South	<1	11000	5	13	<0.06	7.9	18	4.8	14000	<0.01	8.7	<5	<2	<2	26	12	<0.4
Platform West	<1	13000	5	14	<0.06	8.5	20	5.4	15000	0.01	9.3	<5	<2	<2	28	13	<0.4
Pipeline 01	<1	9700	5	10	<0.06	7.4	16	4.1	13000	<0.01	7.6	<5	<2	<2	27	10	<0.4
Pipeline 02	<1	4100	20	6.7	<0.06	5.7	11	1.9	12000	<0.01	4.7	<5	<2	<2	31	5.6	<0.4
Pipeline 03	<1	4000	18	6.7	<0.06	7.2	11	2.8	14000	<0.01	5.0	<5	<2	<2	60	8.7	<0.4
Pipeline 04	<1	3500	14	5.5	<0.06	6.3	9.2	1.9	11000	<0.01	4.6	<5	<2	<2	32	5.8	<0.4
Pipeline 05	<1	11000	9	11	<0.06	9.4	20	5.8	18000	<0.01	8.5	<5	<2	<2	55	14	<0.4
Pipeline 06	<1	6600	18	8.5	<0.06	6.3	11	2.9	13000	<0.01	5.1	<5	<2	<2	31	6.5	<0.4
Pipeline 07	<1	12000	13	11	<0.06	8.6	19	5.5	15000	0.03	8.0	<5	<2	<2	42	12	<0.4
Pipeline 08	<1	6300	27	9.2	<0.06	5.9	11	2.9	15000	0.02	5.2	<5	<2	<2	27	5.3	<0.4
Pipeline 09	<1	14000	19	18	<0.06	8.6	19	6.0	15000	0.02	8.2	5	<2	<2	38	11	<0.4
Pipeline 10	<1	13000	17	12	<0.06	7.8	19	5.4	17000	0.01	7.8	<5	<2	<2	34	10	<0.4
Pipeline 11	<1	9100	18	9.5	<0.06	5.8	15	3.6	15000	0.01	5.4	<5	<2	<2	26	8.6	<0.4
PW3.5 Rep1	<1	11000	20	12	<0.06	7.5	18	5.1	16000	0.01	6.9	<5	<2	<2	32	9.8	<0.4
PW3.5 Rep2	<1	17000	21	16	<0.06	10	25	8.0	20000	0.01	9.4	<5	<2	<2	38	16	<0.4
PW3.5 Rep3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
PW3.0 Rep1	<1	14000	26	14	<0.06	10	30	6.5	25000	0.02	9.4	<5	<2	<2	47	13	<0.4
PW3.0 Rep2	<1	8800	33	11	<0.06	7.8	30	4.3	27000	0.01	6.5	<5	<2	<2	51	7.8	<0.4
PW3.0 Rep3	<1	13000	21	13	<0.06	8.2	23	5.8	20000	0.02	7.6	<5	<2	<2	38	11	<0.4
PW2.5 Rep1	<1	9300	55	25	<0.06	9.0	62	5.7	53000	0.01	7.7	12	<2	<2	120	11	<0.4
PW2.5 Rep2	<1	6900	52	10	<0.06	8.6	52	5.2	47000	<0.01	9.0	6	<2	<2	100	10	<0.4
PW2.5 Rep3	<1	6600	61	9.6	<0.06	9.5	85	4.0	63000	<0.01	12	8	<2	<2	140	13	<0.4
PWNorth Rep1	<1	17000	48	18	<0.06	12	46	10	53000	0.02	14	7	<2	<2	96	22	<0.4
PWNorth Rep2	<1	16000	72	20	<0.06	11	64	11	67000	0.02	14	7	<2	<2	130	26	<0.4
PWNorth Rep3	<1	6100	65	22	<0.06	11	50	4.4	48000	<0.01	7.4	6	<2	<2	110	7.1	<0.4
Condensate Rep1	<1	4800	33	7.1	<0.06	5.2	9.1	1.7	13000	0.01	3.1	<5	<2	<2	24	2.8	<0.4
Condensate Rep2	<1	6800	18	7.3	<0.06	5.1	12	2.7	11000	0.01	3.6	<5	<2	<2	23	4.2	<0.4
Condensate Rep3	<1	9700	18	9.5	<0.06	6.3	16	4.2	13000	<0.01	5.8	<5	<2	<2	28	7.0	<0.4
Nearshore 2.0 km	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nearshore 1.5 km*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nearshore 1.0 km*	<1	11000	58	15	<0.06	8.5	57	6.3	52000	0.01	11	9	<2	<2	120	17	<0.4
Nearshore 0.0 km Rep1	<1	8600	10	12	<0.06	6.1	16	4.2	14000	0.02	5.7	<5	<2	<2	27	13	<0.4
Nearshore 0.0 km Rep2	<1	10000	9	14	<0.06	6.9	19	4.8	15000	0.01	6.5	<5	<2	<2	30	13	<0.4
Nearshore 0.0 km Rep3	<1	4700	11	8.9	<0.06	4.3	13	1.9	11000	<0.01	3.8	<5	<2	<2	22	7.9	<0.4
Nearshore 0.0 km Rep4	<1	3000	14	14	<0.06	3.6	11	1.3	9000	<0.01	2.9	<5	<2	<2	20	6.6	<0.4

Site Description	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Sb	Sn	V	Zn	TOC (%)
Northern Yelcher Beach B1	<1	1900	17	8.1	<0.06	1.6	9.6	1.1	9700	0.02	2.2	<5	<2	<2	21	5.7	<0.4
Northern Yelcher Beach B2	<1	1700	17	8.2	<0.06	1.8	11	0.9	10000	0.01	1.8	<5	<2	<2	25	3.5	<0.4
Northern Yelcher Beach B3	<1	1800	19	8.6	<0.06	1.8	12	0.9	11000	0.02	1.7	<5	<2	<2	27	3.7	<0.4
Northern Yelcher Beach B4	<1	1500	19	6.4	<0.06	1.2	6.2	0.7	6900	0.01	1.3	<5	<2	<2	17	2.5	<0.4
Northern Yelcher Beach B5	<1	1800	17	5.8	<0.06	1.5	9.2	0.9	8600	<0.01	1.6	<5	<2	<2	22	2.9	<0.4
Northern Yelcher Beach B6	<1	1600	15	6.0	<0.06	1.3	7.7	0.7	7600	<0.01	1.4	<5	<2	<2	19	2.5	<0.4
Northern Yelcher Beach B7	<1	1500	15	7.3	<0.06	1.3	6.8	0.8	7000	<0.01	1.4	<5	<2	<2	17	2.8	<0.4
Northern Yelcher Beach B8	<1	1300	11	5.4	<0.06	1.3	4.9	0.5	4800	<0.01	1.3	<5	<2	<2	12	2.2	<0.4
Northern Yelcher Beach B9	<1	1300	12	4.5	<0.06	1.3	6.1	0.6	5900	<0.01	1.4	<5	<2	<2	15	2.4	<0.4
Maninh Point Mangroves M10	<1	7800	7	9.9	<0.06	3.7	14	3.0	10000	<0.01	4.0	<5	<2	<2	22	6.8	<0.4
Maninh Point Mangroves M11	<1	6300	11	7.1	<0.06	3.3	16	2.6	11000	<0.01	3.7	<5	<2	<2	29	5.9	<0.4
Maninh Point Mangroves M12	<1	1400	8	5.2	<0.06	1.3	6.4	0.6	5000	<0.01	1.2	<5	<2	<2	13	2.2	<0.4
Yulow Point Mangroves M13	<1	14000	15	13	<0.06	6.8	25	6.4	22000	<0.01	8.3	<5	<2	<2	43	13	1.5
Yulow Point Mangroves M14	<1	9000	21	12	<0.06	5.1	37	4.7	29000	<0.01	8.2	<5	<2	<2	61	15	0.9
Yulow Point Mangroves M15	<1	11000	10	11	<0.06	5.4	20	4.7	17000	0.02	6.9	<5	<2	<2	34	11	1.2
Yelcher Beach B19	<1	1200	11	1.7	<0.06	1.1	12	0.4	6300	<0.01	1.3	<5	<2	<2	15	1.6	<0.4
Yelcher Beach B20	<1	1600	14	2.7	<0.06	1.3	11	0.5	7800	<0.01	1.4	<5	<2	<2	20	2.0	<0.4
Yelcher Beach B21	<1	1300	9	4.6	<0.06	1.2	5.2	0.5	4400	<0.01	1.1	<5	<2	<2	11	1.8	<0.4
Yelcher Beach B22	<1	1100	11	1.9	<0.06	1.2	6.8	0.4	5000	<0.01	1.1	<5	<2	<2	13	1.4	<0.4
Yelcher Beach B23	<1	1200	11	2.2	<0.06	1.1	8.3	0.7	5600	<0.01	1.0	<5	<2	<2	14	1.7	<0.4
Yelcher Beach B24	<1	1500	11	4.2	<0.06	1.2	6.6	0.5	5600	<0.01	1.2	<5	<2	<2	14	2.1	<0.4

Appendix C Sediment Particle Size (% weight)

Site Description	>1mm	500µm-1mm	250-500 µm	180-250 µm	90-180 µm	63-90 µm	38-63µm	< 38 µm
Platform North	<0.1	<0.1	0.6	1.6	29.8	24.6	15.2	28.1
Platform East	0.1	0.2	0.7	1.6	27.5	24	12.8	33.2
Platform South	<0.1	0.3	1.4	2.8	39.2	22.3	11.2	22.5
Platform West	0.1	0.3	1.5	2.8	37	21.2	11.2	25.9
Pipeline 01	2.9	2.4	5.8	7.9	31.6	17.7	12.2	19.5
Pipeline 02	48.3	8.2	17.3	15.8	3.8	1.6	1.2	3.7
Pipeline 03	34.9	14.8	30.3	9	2	0.7	0.8	7.4
Pipeline 04	27.1	4.3	38	11.9	4.3	2.1	1.6	10.7
Pipeline 05	17	0.7	16.3	28.2	11.1	3.5	3.4	19.7
Pipeline 06	27.3	12.7	23.2	9.2	7.4	5.2	4	11
Pipeline 07	24.3	8.6	10.5	13.4	10.9	7.3	5.5	19.7
Pipeline 08	55.9	13.1	11.9	8.9	4	1.9	1.2	3.1
Pipeline 09	43.3	11.3	9.8	12.8	6.3	3.2	3	10.3
Pipeline 10	45.1	7	13.6	5.2	5	3.5	3.3	17.2
Pipeline 11	52.4	4.5	7.8	19.3	6.4	0.5	1.2	8
PW3.5 Rep1	73.2	4.4	4.4	3.2	1.7	0.6	1.2	11.3
PW3.5 Rep2	55.2	6	8	5.8	2.2	1	1.8	19.9
PW3.5 Rep3	72.1	5.5	5	2.7	2.9	0.5	0.6	10.6
PW3.0 Rep1	50.7	12.1	13.2	2	2.2	1	1.9	17
PW3.0 Rep2	61	13.7	12.3	1.5	1.4	0.5	1.2	8.4
PW3.0 Rep3	52.3	12.4	13	1.9	2.2	1.1	2.4	14.8
PW2.5 Rep1	57.4	12.2	19.5	2.7	1.4	0.4	0.6	5.8
PW2.5 Rep2	73.5	8.1	12.5	1.8	1	0.2	0.3	2.7
PW2.5 Rep3	61.1	11	19.2	2.6	1.2	0.2	0.4	4.2
PWNorth Rep1	58.4	8.4	6.6	3.1	4	1	1.3	17.1
PWNorth Rep2	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
PWNorth Rep3	58.7	24.3	14.6	1	0.5	0.1	0.2	0.6
Condensate Rep1	48.5	3.7	8.1	22.9	6.5	0.4	1	8.8
Condensate Rep2	36	5.1	11.5	26.9	5.9	0.7	1.8	12.1
Condensate Rep3	33.3	4.8	11.7	31.8	5.7	0.6	1.7	10.5
Nearshore 2.0 km	58.5	4.9	12.8	11.2	4.6	0.3	0.4	7.4
Nearshore 1.5km*	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Nearshore 1.0 km*	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Nearshore 0.0 km Rep1	0.3	0.8	2	2.6	38	8	8.8	39.5
Nearshore 0.0 km Rep2	1.2	1	1.7	1.8	31	8	10.6	44.9
Nearshore 0.0 km Rep3	0.4	0.5	1	3.2	78.6	5.3	2.4	8.6
Nearshore 0.0 km Rep4	0.8	0.7	1.5	3.5	78.8	5.5	1.6	7.5
Northern Yelcher Beach B1	7.4	19.9	30.6	13.3	27.8	0.8	<0.1	0.1
Northern Yelcher Beach B2	1.9	7.1	37.3	19.1	34	0.4	0.1	<0.1
Northern Yelcher Beach B3	10.2	4.8	25.5	30.9	28.4	0.2	<0.1	<0.1
Northern Yelcher Beach B4	13.6	28.3	31.2	10.1	16.4	0.4	<0.1	<0.1
Northern Yelcher Beach B5	6.8	12.5	32.8	15.3	32	0.6	<0.1	<0.1
Northern Yelcher Beach B6	9.7	6.6	25.7	25.2	32.6	0.1	<0.1	<0.1
Northern Yelcher Beach B7	10.4	22.7	25.8	12.6	28.1	0.4	<0.1	<0.1
Northern Yelcher Beach B8	9.5	16.9	21.6	12.7	38.2	1.1	<0.1	<0.1
Northern Yelcher Beach B9	5.8	4	11.3	18.6	59.6	0.7	<0.1	<0.1
Maninh Point Mangroves M10	3.5	0.6	2	3.5	44	2.9	3.9	39.6
Maninh Point Mangroves M11	0.5	0.3	1.5	4.3	70.8	3.3	1.3	18
Maninh Point Mangroves M12	1.5	6.6	23	67.9	0.3	<0.1	<0.1	0.6
Yulow Point Mangroves M13	15.4	16.9	10.6	3	10.4	13.7	2.8	27.3
Yulow Point Mangroves M14	15	5.9	21.5	18.3	20.4	3.6	2.5	12.8
Yulow Point Mangroves M15	6.4	9.6	44.9	4.1	7	2.3	2.5	23.2
Yelcher Beach B19	1.4	7	74.4	13.9	3.4	<0.1	<0.1	<0.1
Yelcher Beach B20	8	28.7	42.8	14.4	6	<0.1	<0.1	<0.1
Yelcher Beach B21	14.6	23.2	26.6	10.4	24.6	0.4	0.2	<0.1
Yelcher Beach B22	0.6	3	64.6	24.5	7.3	<0.1	<0.1	<0.1
Yelcher Beach B23	3.1	13.2	64.7	13.9	5.1	<0.1	<0.1	<0.1
Yelcher Beach B24	17	11.3	25.5	14.5	30.9	0.8	<0.1	<0.1

Appendix D Intertidal Fauna

Habitat	Location	Sample	Phyla	Species	Abundance
Beach	B1	Quadrat 1	Mollusca	Donax faba	2
Beach	B19	Incidentals	Crustacea	Anomura	1
Beach	B19	Incidentals	Crustacea	Anomura	1
Beach	B19	Incidentals	Crustacea	Macrophthalmus sp. 2	1
Beach	B19	Incidentals	Crustacea	Penaeidae sp.2	1
Beach	B19	Quadrat 1	Mollusca	Isanda coronata	1
Beach	B19	Quadrat 1	Mollusca	Cadella semen	1
Beach	B19	Quadrat 1	Mollusca	Divaricella irpex	1
Beach	B2	Quadrat 1	Crustacea	Anomura	1
Beach	B20	Quadrat 1	Mollusca	Cadella semen	2
Beach	B20	Quadrat 1	Mollusca	Isanda coronata	3
Beach	B20	Quadrat 2	Mollusca	Cadella semen	1
Beach	B20	Quadrat 2	Echinodermata	Echinoid sp. 1	1
Beach	B20	Quadrat 2	Mollusca	Isanda coronata	2
Beach	B20	Quadrat 2	Polychaeta	Polychaete	1
Beach	B21	Quadrat 1	Mollusca	Donax faba	6
Beach	B21	Quadrat 2	Mollusca	Donax faba	4
Beach	B21	Quadrat 2	Crustacea	Isopoda sp. 3	1
Beach	B22	Quadrat 1	Mollusca	Barbatia iota	1
Beach	B22	Quadrat 1	Mollusca	Cadella semen	2
Beach	B22	Quadrat 1	Mollusca	Dosinia laminata	1
Beach	B22	Quadrat 1	Mollusca	Isanda coronata	11
Beach	B22	Quadrat 1	Polychaeta	Polychaete	1
Beach	B22	Quadrat 2	Mollusca	Isanda coronata	9
Beach	B22	Quadrat 2	Polychaeta	Polychaete	2
Beach	B23	Quadrat 1	Mollusca	Donax faba	9
Beach	B23	Quadrat 1	Mollusca	Isanda coronata	3
Beach	B23	Quadrat 1	Crustacea	Mictyris sp.	2
Beach	B23	Quadrat 2	Crustacea	Anomura	1
Beach	B23	Quadrat 2	Mollusca	Donax faba	8
Beach	B23	Quadrat 2	Mollusca	Dosinia laminata	1
Beach	B23	Quadrat 2	Echiura	Echiuran sp. 1	1
Beach	B23	Quadrat 2	Mollusca	Isanda coronata	2
Beach	B23	Quadrat 2	Crustacea	Mictyris sp.	1
Beach	B23	Quadrat 2	Polychaeta	Polychaete	1
Beach	B24	Quadrat 1	Mollusca	Donax faba	1
Beach	B24	Quadrat 1	Mollusca	Donax faba	1
Beach	B24	Quadrat 1	Mollusca	Donax faba	19
Beach	B24	Quadrat 1	Polychaeta	Glyceridae sp. 1	1
Beach	B24	Quadrat 1	Crustacea	Isopoda sp. 3	3
Beach	B24	Quadrat 2	Mollusca	Donax faba	17
Beach	B24	Quadrat 2	Polychaeta	Polychaete	1
Beach	B28	Quadrat 1	Mollusca	Cadella semen	1
Beach	B3	Incidentals	Crustacea	Anomura	2
Beach	B3	Incidentals	Insecta	Insect sp. 1	1
Beach	B3	Incidentals	Insecta	Insect sp. 2	1
Beach	B3	Incidentals	Insecta	Insect sp. 3	1
Beach	B3	Incidentals	Crustacea	Talitridae	1
Beach	B3	Quadrat 1	Mollusca	Donax faba	17
Beach	B3	Quadrat 2	Mollusca	Donax faba	24
Beach	B4	Quadrat 2	Mollusca	Donax faba	2
Beach	B4	Quadrat 2	Polychaeta	Polychaete	1
Beach	B5	Incidentals	Crustacea	Matuta sp.	1

Habitat	Location	Sample	Phyla	Species	Abundance
Beach	B5	Incidentals	Echinodermata	Echinoid sp. 1	2
Beach	B5	Quadrat 1	Crustacea	Mictyris sp.	1
Beach	B5	Quadrat 2	Mollusca	Donax faba	2
Beach	B5	Quadrat 2	Polychaeta	Polychaete	1
Beach	B5	Quadrat 2	Polychaeta	Polychaete	1
Beach	B6	Quadrat 1	Mollusca	Donax faba	27
Beach	B6	Quadrat 2	Mollusca	Donax faba	30
Beach	B6	Quadrat 2	Polychaeta	Glyceridae sp. 1	1
Beach	B7	Quadrat 1	Mollusca	Donax faba	1
Beach	B8	Quadrat 1	Mollusca	Donax faba	6
Beach	B8	Quadrat 1	Crustacea	Mictyris sp.	1
Beach	B8	Quadrat 2	Mollusca	Donax faba	2
Beach	B8	Quadrat 2	Polychaeta	Glyceridae sp. 1	1
Beach	B9	Quadrat 1	Mollusca	Donax faba	28
Beach	B9	Quadrat 1	Polychaeta	Glyceridae sp. 1	1
Beach	B9	Quadrat 1	Crustacea	Isopoda sp. 2	1
Beach	B9	Quadrat 2	Mollusca	Donax faba	29
Beach	B9	Quadrat 2	Crustacea	Isopoda sp. 2	2
Beach	B9	Quadrat 2	Polychaeta	Polychaete	1
Mangrove	M10	Anoxic mat 1	Polychaeta	Polychaete	6
Mangrove	M10	Anoxic mat 1	Polychaeta	Polychaete	2
Mangrove	M10	Anoxic mat 2	Polychaeta	Polychaete	1
Mangrove	M10	Anoxic mat 2	Crustacea	Uca sp. 2	1
Mangrove	M10	Epifauna 1	Crustacea	Anomura	1
Mangrove	M10	Epifauna 1	Crustacea	Anomura	27
Mangrove	M10	Epifauna 1	Mollusca	Littoraria articulata	1
Mangrove	M10	Epifauna 1	Mollusca	Littoraria ianthostoma	1
Mangrove	M10	Epifauna 1	Mollusca	Pseudoanachis duclosianus	1
Mangrove	M10	Epifauna 2	Mollusca	Littoraria articulata	4
Mangrove	M10	Epifauna 2	Mollusca	Littoraria filosa	4
Mangrove	M10	Pitfall 1	Crustacea	Alpheidae sp. 2	1
Mangrove	M10	Pitfall 1	Crustacea	Anomura	12
Mangrove	M10	Pitfall 1	Mollusca	Circe australis	1
Mangrove	M10	Pitfall 1	Crustacea	Leandrites celebensis	1
Mangrove	M10	Pitfall 1	Mollusca	Littoraria ianthostoma	1
Mangrove	M10	Pitfall 1	Crustacea	Nanosesarma batavicum	1
Mangrove	M10	Pitfall 2	Crustacea	Anomura	5
Mangrove	M10	Pitfall 2	Crustacea	Leandrites celebensis	7
Mangrove	M10	Pitfall 2	Crustacea	Periclimenes ? suvadivensis	3
Mangrove	M10	Pitfall 2	Crustacea	Portunus sp.	1
Mangrove	M10	Quadrat 1	Crustacea	Anomura	49
Mangrove	M10	Quadrat 1	Crustacea	Sphaeromatidae	1
Mangrove	M10	Quadrat 2	Crustacea	Anomura	16
Mangrove	M10	Quadrat 2	Mollusca	Cerithideopsilla cingulata	9
Mangrove	M10	Quadrat 2	Mollusca	Clypeomorphus batillariaeformis	2
Mangrove	M10	Quadrat 2	Mollusca	Clypeomorphus bifasciata	1
Mangrove	M10	Quadrat 2	Mollusca	Clypeomorphus bifasciata	1
Mangrove	M10	Quadrat 2	Crustacea	Macrophthalmus sp. 1	2
Mangrove	M10	Quadrat 2	Mollusca	Nassarius moestus	3
Mangrove	M10	Quadrat 2	Mollusca	Patelloida cryptalirata	1
Mangrove	M11	Epifauna 1	Mollusca	Clypeomorphus bifasciata	1
Mangrove	M11	Epifauna 1	Mollusca	Clypeomorphus bifasciata	2
Mangrove	M11	Epifauna 1	Mollusca	Littoraria filosa	9
Mangrove	M11	Epifauna 1	Mollusca	Littoraria ianthostoma	1
Mangrove	M11	Epifauna 1	Mollusca	Pseudoanachis duclosianus	2
Mangrove	M11	Epifauna 2	Mollusca	Clypeomorphus batillariaeformis	1

Habitat	Location	Sample	Phyla	Species	Abundance
Mangrove	M11	Epifauna 2	Mollusca	Littoraria filosa	20
Mangrove	M11	Epifauna 2	Crustacea	Metapograpsus frontalis	1
Mangrove	M11	Epifauna 2	Mollusca	Pseudoanachis duclosianus	1
Mangrove	M11	Pitfall 1	Crustacea	Anomura	9
Mangrove	M11	Pitfall 1	Crustacea	Ilyograpsus paludicola	1
Mangrove	M11	Pitfall 1	Crustacea	Periclimenes suvadivensis	1
Mangrove	M11	Pitfall 2	Chordata: Pieces	Amoya gracilis	1
Mangrove	M11	Pitfall 2	Mollusca	Clypeomorphus bifasciata	4
Mangrove	M11	Pitfall 2	Crustacea	Heteropanope glabra	1
Mangrove	M11	Pitfall 2	Crustacea	Ilyograpsus paludicola	1
Mangrove	M11	Pitfall 2	Crustacea	Leandrites celebensis	1
Mangrove	M11	Pitfall 2	Crustacea	Macrophthalmus sp. 1	1
Mangrove	M11	Quadrat 1	Crustacea	Anomura	31
Mangrove	M11	Quadrat 1	Crustacea	Clibanarius longitarsus	1
Mangrove	M11	Quadrat 1	Chordata: Pieces	Periophthalmus sp. 1	1
Mangrove	M11	Quadrat 1	Crustacea	Uca hirsutimanus	1
Mangrove	M11	Quadrat 1	Crustacea	Uca polita	1
Mangrove	M11	Quadrat 2	Crustacea	Anomura	9
Mangrove	M11	Quadrat 2	Mollusca	Patelloida cryptalitrata	1
Mangrove	M11	Quadrat 2	Crustacea	Uca mjobergi	1
Mangrove	M12	Epifauna 1	Crustacea	Chthamalus malayensis	100
Mangrove	M12	Epifauna 1	Mollusca	Littoraria articulata	2
Mangrove	M12	Epifauna 1	Mollusca	Littoraria filosa	7
Mangrove	M12	Epifauna 2	Mollusca	Littoraria filosa	11
Mangrove	M12	Pitfall 1	Crustacea	Anomura	4
Mangrove	M12	Pitfall 1	Crustacea	Clibanarius longitarsus	1
Mangrove	M12	Pitfall 1	Chordata: Pieces	Mugilogobius (probably M. mertoni)	1
Mangrove	M12	Pitfall 1	Crustacea	Penaeidae sp.1	4
Mangrove	M12	Pitfall 2	Crustacea	Anomura	13
Mangrove	M12	Quadrat 1	Crustacea	Anomura	2
Mangrove	M12	Quadrat 1	Mollusca	Cerithideopsilla cingulata	1
Mangrove	M12	Quadrat 1	Mollusca	Clypeomorphus batillariaeformis	1
Mangrove	M12	Quadrat 1	Mollusca	Clypeomorphus bifasciata	8
Mangrove	M12	Quadrat 1	Mollusca	Littoraria filosa	1
Mangrove	M12	Quadrat 1	Crustacea	Melita sp.	1
Mangrove	M12	Quadrat 1	Chordata: Pieces	Periophthalmus sp. 1	1
Mangrove	M12	Quadrat 2	Mollusca	Cerithideopsilla cingulata	2
Mangrove	M12	Quadrat 2	Crustacea	Clibanarius longitarsus	1
Mangrove	M12	Quadrat 2	Chordata: Pieces	Periophthalmus sp. 1	1
Mangrove	M13	Epifauna 1	Mollusca	Littoraria filosa	8
Mangrove	M13	Epifauna 2	Crustacea	Clibanarius longitarsus	1
Mangrove	M13	Epifauna 2	Mollusca	Littoraria filosa	5
Mangrove	M13	Epifauna 2	Mollusca	Monodonta labio	2
Mangrove	M13	Epifauna 2	Mollusca	Nerita balteata	1
Mangrove	M13	Incidentals	Crustacea	Uca capricornis	1
Mangrove	M13	Pitfall 1	Chordata: Pieces	Acentrogobius viridipunctatus	1
Mangrove	M13	Pitfall 1	Crustacea	Heteropanope glabra	1
Mangrove	M13	Pitfall 2	Crustacea	Ilyograpsus paludicola	1
Mangrove	M13	Pitfall 2	Crustacea	Leandrites celebensis	1
Mangrove	M13	Pitfall 2	Crustacea	Periclimenes suvadivensis	1
Mangrove	M13	Quadrat 1	Crustacea	Anomura	4
Mangrove	M13	Quadrat 1	Crustacea	Heteropanope glabra	1
Mangrove	M13	Quadrat 1	Chordata: Pieces	Periophthalmus argentilineatus	1
Mangrove	M13	Quadrat 1	Crustacea	Perisesarma semperi	1
Mangrove	M13	Quadrat 1	Crustacea	Uca flammula	4
Mangrove	M13	Quadrat 2	Crustacea	Metapograpsus frontalis	1

Habitat	Location	Sample	Phyla	Species	Abundance
Mangrove	M13	Quadrat 2	Polychaeta	Polychaete	1
Mangrove	M14	Anoxic mat 1	Polychaeta	Polychaete	1
Mangrove	M14	Anoxic mat 1	Polychaeta	Polychaete	1
Mangrove	M14	Anoxic mat 2	Polychaeta	Polychaete	1
Mangrove	M14	Epifauna 1	Crustacea	Isopoda sp. 1	1
Mangrove	M14	Epifauna 1	Mollusca	Littoraria filosa	14
Mangrove	M14	Epifauna 1	Mollusca	Littoraria filosa	1
Mangrove	M14	Epifauna 1	Mollusca	Monodonta labio	1
Mangrove	M14	Epifauna 1	Crustacea	Talitridae	1
Mangrove	M14	Epifauna 2	Mollusca	Littoraria filosa	12
Mangrove	M14	Epifauna 2	Mollusca	Monodonta labio	1
Mangrove	M14	Epifauna 2	Mollusca	Nerita balteata	2
Mangrove	M14	Incidentals	Mollusca	Gaffraria tubum	1
Mangrove	M14	Incidentals	Insecta	Hymenoptera	1
Mangrove	M14	Incidentals	Mollusca	Littoraria filosa	1
Mangrove	M14	Incidentals	Mollusca	Littoraria filosa	1
Mangrove	M14	Incidentals	Mollusca	Nassarius melanoides	1
Mangrove	M14	Pitfall 1	Crustacea	Alpheidae sp. 1	1
Mangrove	M14	Pitfall 1	Crustacea	Anomura	18
Mangrove	M14	Pitfall 1	Crustacea	Periclimenes ? suvadivensis	1
Mangrove	M14	Pitfall 2	Crustacea	Alpheidae sp. 1	3
Mangrove	M14	Pitfall 2	Crustacea	Anomura	4
Mangrove	M14	Pitfall 2	Chordata: Pieces	Gobiidae (juv. - Mugilogobius or Calamiana)	1
Mangrove	M14	Pitfall 2	Crustacea	Ilyograpsus paludicola	1
Mangrove	M14	Quadrat 1	Crustacea	Anomura	4
Mangrove	M14	Quadrat 1	Mollusca	Clypeomorphus bifasciata	10
Mangrove	M14	Quadrat 1	Crustacea	Metapograpsus frontalis	1
Mangrove	M14	Quadrat 1	Mollusca	Monodonta labio	1
Mangrove	M14	Quadrat 1	Mollusca	Patelloida cryptalitrata	1
Mangrove	M14	Quadrat 1	Polychaeta	Polychaete	1
Mangrove	M14	Quadrat 1	Crustacea	Uca sp. 2	6
Mangrove	M14	Quadrat 2	Crustacea	Anomura	1
Mangrove	M14	Quadrat 2	Crustacea	Clibanarius longitarsus	1
Mangrove	M14	Quadrat 2	Mollusca	Clypeomorphus bifasciata	1
Mangrove	M14	Quadrat 2	Mollusca	Monodonta labio	1
Mangrove	M14	Quadrat 2	Mollusca	Neritina violacea	1
Mangrove	M15	Anoxic mat 1	Crustacea	Sarmatium germaini	1
Mangrove	M15	Anoxic mat 2	Polychaeta	Polychaete	2
Mangrove	M15	Anoxic mat 2	Crustacea	Thalassina squamifera	1
Mangrove	M15	Epifauna 1	Mollusca	Littoraria articulata	1
Mangrove	M15	Epifauna 1	Mollusca	Littoraria filosa	1
Mangrove	M15	Epifauna 1	Mollusca	Nerita balteata	2
Mangrove	M15	Epifauna 2	Crustacea	Chthamalus malayensis	5
Mangrove	M15	Epifauna 2	Mollusca	Littoraria filosa	5
Mangrove	M15	Epifauna 2	Mollusca	Littoraria filosa	1
Mangrove	M15	Epifauna 2	Crustacea	Metapograpsus frontalis	7
Mangrove	M15	Epifauna 2	Mollusca	Nerita balteata	2
Mangrove	M15	Incidentals	Crustacea	Saelatium brockii	1
Mangrove	M15	Pitfall 1	Crustacea	Clibanarius longitarsus	1
Mangrove	M15	Pitfall 1	Crustacea	Heteropanope longipedes	2
Mangrove	M15	Pitfall 2	Crustacea	Heteropanope glabra	1
Mangrove	M15	Pitfall 2	Crustacea	Heteropanope longipedes	2
Mangrove	M15	Pitfall 2	Mollusca	Nassarius moestus	1
Mangrove	M15	Pitfall 2	Crustacea	Penaeidae sp.2	1
Mangrove	M15	Quadrat 1	Crustacea	Clibanarius longitarsus	1
Mangrove	M15	Quadrat 1	Chordata: Pieces	Periophthalmus sp. 1	1

Habitat	Location	Sample	Phyla	Species	Abundance
Mangrove	M15	Quadrat 1	Crustacea	Perisesarma semperi	1
Mangrove	M15	Quadrat 1	Mollusca	Terebralia palustris	3
Mangrove	M15	Quadrat 1	Mollusca	Terebralia semistriata	5
Mangrove	M15	Quadrat 1	Crustacea	Uca sp. 1	1
Mangrove	M15	Quadrat 2	Crustacea	Clistocoeloma merguiensis	1
Mangrove	M15	Quadrat 2	Sipuncula	Sipunculid	1
Mangrove	M15	Quadrat 2	Mollusca	Terebralia palustris	10
Mangrove	M15	Quadrat 2	Crustacea	Uca flammula	2
Rocky shore	Lower	Incidentals	Mollusca	Anthopleura gemmata	1
Rocky shore	Lower	Incidentals	Mollusca	Emarginula variegata	1
Rocky shore	Lower	Incidentals	Mollusca	Isognomon ephippium	3
Rocky shore	Lower	Incidentals	Mollusca	Morula marguariticola	1
Rocky shore	Lower	Incidentals	Mollusca	Thais biturcularis	1
Rocky shore	R16	Incidentals	Mollusca	Clypeomorus batillariaeformis	1
Rocky shore	R16	Incidentals	Chordata: Pieces	Valamugil sp. (juv)	1
Rocky shore	R16	Quadrat 1	Unknown	Porifera	1
Rocky shore	R16	Quadrat 1	Chordata: Pieces	Mugilogobius (probably M. mertoni) juv.	3
Rocky shore	R17	Incidentals	Crustacea	Anomura	1
Rocky shore	R17	Incidentals	Crustacea	Anomura	1
Rocky shore	R17	Incidentals	Mollusca	Planaxis sulcatus	4
Rocky shore	R17	Incidentals	Mollusca	Saccostrea cucullina	2
Rocky shore	R17	Quadrat 1	Mollusca	Echinolittorina trochoides	89
Rocky shore	R17	Quadrat 2	Unknown	Ascidian	2
Rocky shore	R17	Quadrat 2	Mollusca	Echinolittorina trochoides	8
Rocky shore	R17	Quadrat 2	Mollusca	Littoraria filosa	1
Rocky shore	R17	Quadrat 2	Crustacea	Periclimenes ? suvadivensis	5
Rocky shore	R17	Quadrat 2	Mollusca	Saccostrea cucullina	2
Rocky shore	R18	Incidentals	Crustacea	Metapograpsus frontalis	1
Rocky shore	R18	Incidentals	Mollusca	Morula marguariticola	1
Rocky shore	R18	Incidentals	Mollusca	Nerita balteata	1
Rocky shore	R18	Incidentals	Chordata: Pieces	Periophthalmus novaeguineaensis	1
Rocky shore	R18	Incidentals	Crustacea	Tetraclita squamosa	2
Rocky shore	R18	Quadrat 1	Mollusca	Echinolittorina trochoides	2
Rocky shore	R18	Quadrat 2	Mollusca	Echinolittorina trochoides	6
Rocky shore	R18	Quadrat 2	Crustacea	Metapograpsus frontalis	1

Appendix E Subtidal Fauna arranged by Phyla

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
acoetid sp.										1													2	1											
Ampharetid sp.										1																							1	1	
capitellid sp. 1							1																1												
capitellid sp. 2																	1		1				1			1	2	1		1			1	1	
chrysopetallid sp. 1	1																							1					1						
cirratulid sp.																														1					
eunicid sp. 1	1							1																	1	1									
eunicid sp. 2			1																										1						
eunicid sp. 3																						1													
goniadid sp.		1	1	2				2						1			1	1	1																
lumbrinerid sp. 1	1	2	1	1	1	1		1							1											1					2				
lumbrinerid sp. 2																																			1
magelonid sp.																																		1	
maldanid sp.												1					1										1								
nephtydid sp.		2	1														1														1				
nereid sp.																						1													
onuphid sp. 1	1					1	1																												
ophelid sp.				1													1																		
orbinid sp.																							2												
Paralacyclonid sp.		1																								1			1						
paraonid sp.			1															1																	
poeceliochaetid sp.																										1				1		1	1		
polynoid sp. 1																							1												

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
polynoid sp. 2																							2												
Sabellarid sp1				1																				1											
sigalionid sp.																															1				
spionid sp.	1																								3						2		1	1	
syllid sp. 1											1																								
syllid sp. 2		1																																	
syllid sp. 3																											1								
terebellid sp. 1																								3											
terebellid sp. 2		1																																	
trichobranchid sp.	1																		1					1											
Bryozoan sp1						1																1	3		2										
Bryozoan sp10		1																																	
Bryozoan sp11																					7		1												
Bryozoan sp12						2																													
Bryozoan sp13						1																													
Bryozoan sp14						1																													
Bryozoan sp15																								1											
Bryozoan sp16																							1												
Bryozoan sp17																											1								
Bryozoan sp2				5																															
Bryozoan sp3				1																															
Bryozoan sp4																						6													
Bryozoan sp5							1												1																
Bryozoan sp6									3		1	7	1			1		1	1		1	1	1	1	2										
Bryozoan sp7											4										1	1		8	3										

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
Bryozoan sp8		1																						15	6									
Bryozoan sp9		1																																	
Gorgonian sp1											1																								
Hydroid sp1																							3												
Hydroid sp2										1													8												
Hydroid sp3																1	1		1	1															
Hydroid sp4			1			1																1													
Hydroid sp5						1									20																				
Hydroid sp6								1																											
Hydroid sp7																							2												
Hydroid sp8																							3												
Plumularid sp1									6															3												
Sertularid sp1															3		1																		
alphaid sp.				1						1										1		3		4	3										
Amphipod sp. 1										1					2								1		1									1	
Amphipod sp. 11							1																1						1						
Amphipod sp. 12																									1										
Amphipod sp. 13																																		1	
Amphipod sp. 14																													3						
Amphipod sp. 2										1																									
Amphipod sp. 3										1																									
Amphipod sp. 4								1	1																										
Amphipod sp. 5									1																		1								
Amphipod sp. 6																																	1		
Amphipod sp. 7								1							3		1	2	1	1	5			1	1					1				2	

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
Amphipod sp. 8																						1													
Amphipod sp. 9																									1	1									
Barnacle sp1									1		4	2																							
callianasid sp. 1														1								1		1	1							1	2	4	1
crustacean sp. 1																							1												
cumacean sp. 1																							1					3					1		
cumacean sp. 2																	1														1				
cumacean sp. 3																									1										
gnathophyllid sp.										1		1																	1	1					
grapsid sp. 1																								1											
isopod sp. 1																					1	1	2		1		1								
isopod sp. 2											1																								
isopod sp. 3								1										1																	
isopod sp. 4																														1					
leucosid sp.												1								1				1											
majid sp.																	1					1													
mysid sp.																							1					1	1						
mysid sp.																	1			3											2				
penaeid																																		2	
porcelanid sp. 1				1					1	9					1					1	8	16	23	7	11		1	1							
porcelanid sp. 2																							1												
portunid sp. 1																																		1	
stomatopod sp.				1																															
tanaid sp. 1				4	1				1						1								1		7										
tanaid sp. 2																													1						

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
Thalamita sp1																					1														
trapezid sp. 1										1																									
trapezid sp. 2																							1												
Asteroid sp1		1																																	
Crinoid sp1																		1																	
Ophiuroid sp. 3		1	1		1				1			1	1		1	1				1	2	5		6	14									
Ophiuroid sp. 4																											1								
Ophiuroid sp1																							1												
Ophiuroid sp2																							24												
Buccinid sp1				2																															
Cerithid sp1											1																				1				
Littorinid sp1						1					1															2									
Mollusc sp1											1																								
Mollusc sp2																												1							
Mollusc sp3																		1																	
Mollusc sp4																						1													
Mytilid sp1																							1	1	1										
Nassarid sp1																													1						
Ostreid sp1																																		1	
Scaphopod sp1						1																													
Venerid sp1																											1								
Venerid sp2																													1		1			1	
nemertean sp.		2	1			1		2					1																						
Poriferan sp. 1	1																					1													
Poriferan sp. 2																						1													

Taxa	Pipeline 1	Pipeline 2	Pipeline 3	Pipeline 4	Pipeline 5	Pipeline 6	Pipeline 7	Pipeline 8	Pipeline 9	Pipeline 10	Pipeline 11	Condensate 1	Condensate 2	Condensate 3	PW 2.5 1	PW 2.5 2	PW 2.5 3	PW 3. 0 1	PW 3. 0 2	PW 3. 0 3	PW 3.5. 1	PW 3.5 2	PW 3.5 3	PW North 1	PW North 2	PW North 3	Nearshore 2	Inshore 1	Inshore 2	Inshore 3	Inshore 4	Platform E	Platform N	Platform W	Platform S
Tunicate sp. 1								1							1												1								
Tunicate sp. 1												1									3		1												
Tunicate sp. 2				1													1																		
Tunicate sp. 3																					2														
known sp. 5																												7	2						
known sp. 6																												1							
known sp. 7																												2	1						
unknown sp. 1						1																		1											
unknown sp. 2		3						1							1		1							2									1		
unknown sp. 3																							1										1		
unknown sp. 4																						1	1												

Appendix C

Technical Report Sea Turtles, Dugongs and Seagrasses in the Region of the Blacktip Project prepared by Dr Michael Guinea, Charles Darwin University






This page has been left intentionally blank

Technical Report

Sea Turtles, Dugongs, and Seagrasses

In the region of the Black Tip Project

Compiled for Sinclair Knight Merz
7th Floor Durack Centre
263 Adelaide Terrace Perth
WA 6000

By
Dr Michael L. Guinea
Faculty of Education Health and Science
Charles Darwin University
Darwin 0909
Northern Territory
July 2004

Contents

Summary: 3

Introduction: 4

Methods 4

Results 5

Discussion 7

Pipeline Landfall 8

Lights 10

Vibrations 11

Produced Water 11

Community Involvement 11

Acknowledgements 13

References 14

Diary of Events: 15

4 June 2004 15

Aerial Survey:4 June 2004 16

Visit to Anthony's Country. 16

Visit to Cyril's Country 17

Visit to Angus's Country 19

List of Photographs taken during this survey: 20

Summary:

A preliminary survey for sea turtle and dugong habitat was conducted along the coastline to the north and south of the proposed pipeline landfall site at Yelcher Beach. The survey consisted of an aerial survey of the beaches and a survey of the intertidal zone seaward of the shoreline on 4 June 2004. Informal interviews were conducted with three traditional owners and their family groups. The Traditional Owners of the country that was surveyed participated in the aerial survey and subsequent land-based survey of the beaches. Sea turtles nesting density was compared with that of Bare Sand Island where flatback sea turtle nesting has been monitored for nine years.

Flatback Sea Turtles nest on Yelcher Beach, the site of the proposed pipeline landfall. Annually it is expected that on this beach there would be some tens of nests, laid by possibly less than 20 individuals. Larger nesting populations of flatback sea turtles occur to the north at Dorcherty Island and to the south at Pearce Point. In each of these two regions it is anticipated that some tens to hundreds of flatback sea turtles nest each year. Olive ridley sea turtles nest along the beaches as well. Although no nests of olive ridley sea turtles were found on Yelcher Beach it is anticipated that they would nest there as well. An olive ridley nest was collected from the neighbouring beach some days prior to this survey.

Dugongs were reported by the traditional owners to frequent the rock flats at Cape Hay on Dorcherty Island, the mouth of the Moyle River and the southern regions of Joseph Bonaparte Gulf. In the region of the pipeline a dugong was shot from a boat some years ago.

Seagrasses were reported from the western side of Dorcherty Island. In addition, in the region seaward of Yelcher Beach, I was told that during the lowest tides of the year the locals have walked to the low tide mark and found long seagrasses about the width of a belt (cf. *Enhalus acoroides*). In amongst these seagrasses are dugong-feeding trails.

The people of the area do not hunt sea turtles or dugongs. They do not kill turtles on the beach. There was no sign of hearths or skeletal material of sea turtles or dugongs at any of the sites surveyed. The traditional owners do not have turtle spears or harpoons and appear to have little experience in capturing turtles. This is in contrast to areas further north in Joseph Bonaparte Gulf.

As sea turtles nest on the beach where the pipeline is due to cross there will need to be special attention to restoration of the beach, its profile and strand vegetation. The beach should retain its functionality as a turtle nesting site. The Sea Rangers of Wadeye appear to be the best choice for conducting the risk abatement and monitoring of sea turtles on Yelcher Beach and neighbouring beaches.

Introduction

Few records exist of sightings of sea turtles and dugongs in the southern regions of the Joseph Bonaparte Gulf. Captain Phillip Parker King sent one of his crew (Mr Roe) ashore on Lacrosse Island on September 16, 1819 to collect sea turtles. King (1827) described the turtle as "one of the hawksbill species that contained fifty eggs". A clutch size of 50 eggs is more characteristic of a flatback sea turtle than a hawksbill that normally lay more than twice that number of eggs. This journal entry also indicated that the turtle season included September. John Lort Stokes (1846) in 1839 reported a scene of devastation in which hundreds of sea turtles were stranded on the mud flats of Turtle Point, presumably after some catastrophic event. More recently, it has been estimated that up to 1000 flatback turtles nest each year at Cape Dommett (Prince, 1994, IOSEA data base). Nesting track densities have been estimated at more than 100 tracks per km but the species was unidentified and thought to be either flatback or green sea turtle (Chatto, 1998). It is the purpose of this survey to identify the species of sea turtles nesting in the area and the densities of nests in the region of the export pipeline. This is an initial reconnaissance survey which could be the catalyst for future community based programs should this survey identify any nesting sites for sea turtles.

Little is known of the numbers of dugongs and their habitat preferences in the southern regions of the Joseph Bonaparte Gulf. The Port Keats area was excluded by the aerial surveys for marine fauna (Bayliss, 1986). Observations by Whiting (2002) revealed that dugongs fed on macro algae on rocky reefs in tropical Australia. These observations expanded the number of habitats utilised by dugongs. Satellite tracking of dugongs in the Darwin region revealed the some dugongs travel substantial distances. A male travelled from the Vernon Islands north of Darwin into the Joseph Bonaparte Gulf visiting each patch of rocky reef before loosing the transmitter at Cape Scott (Whiting 2004). As part of this preliminary survey, all observations on dugongs were to be documented and possible negative interactions recorded.

Methods

Three methods were employed in this preliminary survey of the sea turtles, dugongs and seagrasses of the proposed project area.

1. A regional or large scale survey involved the use of an aerial survey at low altitude in the IMCRA bioregion of Anson and Beagle (No 18). The aerial survey was conducted in the morning of 4 June 2004. The high tide at Fish Reef in the northern part of the survey was 7 metres above datum at 6.26 am and was 8.0 metres at 7.32am at Port Keats in the southern part of the survey area. These survey conditions meant that the beach had been swept clean by the tide the morning of the survey and only tracks from the morning tide were visible during a low altitude aerial survey. The aerial survey in the Port Keats region was conducted during the period of low tide from 11.57 to 13.13 when the tide reached it minimum of 2.7 metres at 13.48. This enabled maximum viewing of the intertidal region for seagrasses. An ideal tide for sighting

dugongs would have been during the rising tide when dugongs could gain access to the intertidal foraging areas.

2. Discussions were held with Traditional Owners of the coastal regions likely to incur an impact by the proposed pipeline. The discussions were facilitated by over 100 photographs of sea turtle related topics. The photographs were based on almost ten years of sea turtle research on Bare Sand Island and include sequences of catching sea turtles from boats and the usual research techniques of measuring, tagging, counting eggs and identification of the various species. Life-sized diagrams of turtle eggs were useful in identifying the species of sea turtles that were present.

3. Beach surveys by foot and vehicle were used in areas where sea turtles had been reported nesting. All nests were identified to species responsible by the tracks of the nesting turtle, the size of the eggs, numbers of the eggs and the morphology of the nest. The location of each nest was recorded with Global Positioning Satellite (GPS) receiver. All foot and vehicle surveys were conducted in the presence of the Traditional Owners.

Results

The aerial survey of the northern areas of the Anson Beagle Bioregion revealed that five sea turtles had nested in the previous evening on Bare Sand Island. This island supports about 500 flatback sea turtle nests each year. Each turtle lays on average three times per season and deposits approximately 50 eggs on each occasion. Using proportions, it is estimated that one track visible from the air at the time of the survey was indicative of approximately 100 turtle nests annually. This is meant as a guide only as the errors associated with this kind of survey and the assumptions about proportionality make the estimates "ball park" figures only and necessitate follow up surveys by either foot or vehicle of the beaches surveyed. Estimates therefore are presented as orders of magnitude such as tens, hundreds etc.

The aerial survey consisted of flying south over Whale Flats and north along the coast line to just north of Cape Dombey. The aircraft then turned southwards and flew approximately 1 km seaward of the shoreline to Fossil Head and then onto Wadeye Airdrome (Figure 1). Only two turtle tracks were seen from the air in the southern Anson Beagle Bioregion. Both were on the western side of Dorcherty Island. Following the above guidelines it is assumed that some hundreds, possibly two hundred flatback turtle nests are laid on Dorcherty Island each year.

Discussions with the Traditional Owners always involved several people including personnel from the Northern Land Council (NLC). The photographs were large enough for several people to view the images at once and this initiated discussions amongst the Traditional Owners in their own language and usually a response in English. Although several people of each group had seen live turtles some were unsure of the identity of the turtles that lay on their beaches until they saw the images of sea turtle eggs. Few had difficulty in identifying the large eggs of the Flatback Sea Turtle (*Natator depressus*) that is known as the Greenback to the Traditional Owners. Some people were familiar with the numerous but small eggs of the Olive Ridley sea turtle (*Lepidochelys olivacea*). All were familiar with turtle tracks and the shape of the sea turtle nests. Few were familiar with the sub-adult green and hawksbill turtles

because few people hunted turtles. Each of the three family groups involved in the survey were eager to share their knowledge of the sea turtles and the localities where they nested.

A total of 23 sea turtle nests were seen during the survey including the two nests seen on Dorcherty Island (Table 1). Two Flatback Sea Turtle nests were on Yelcher Beach in Angus's country, the site of the pipeline landfall. Two nests by the same species were 12.5 km north in Anthony's country on the beach near the old mission. Another two Flatback Sea Turtle nests were located 14.5 km to the south in Cyril's country at Ditchi and another 14 nests were 18.7 km south of the pipeline landfall near Nangu. A single nest belonging to an Olive Ridley Sea Turtle was reported during the survey period 6 km north of the pipeline landfall.

From the discussions there appeared to be little in the way of sea turtle and dugong hunting in the area. This was not because of the lack of animals but rather the skills of hunting had in part been either unused or lost. There was no evidence of fireplaces or hearths where sea turtles had been eaten in the dune country through which the survey passed. The Traditional Owners knew of the dugongs but had not taken part in a hunt for many years.

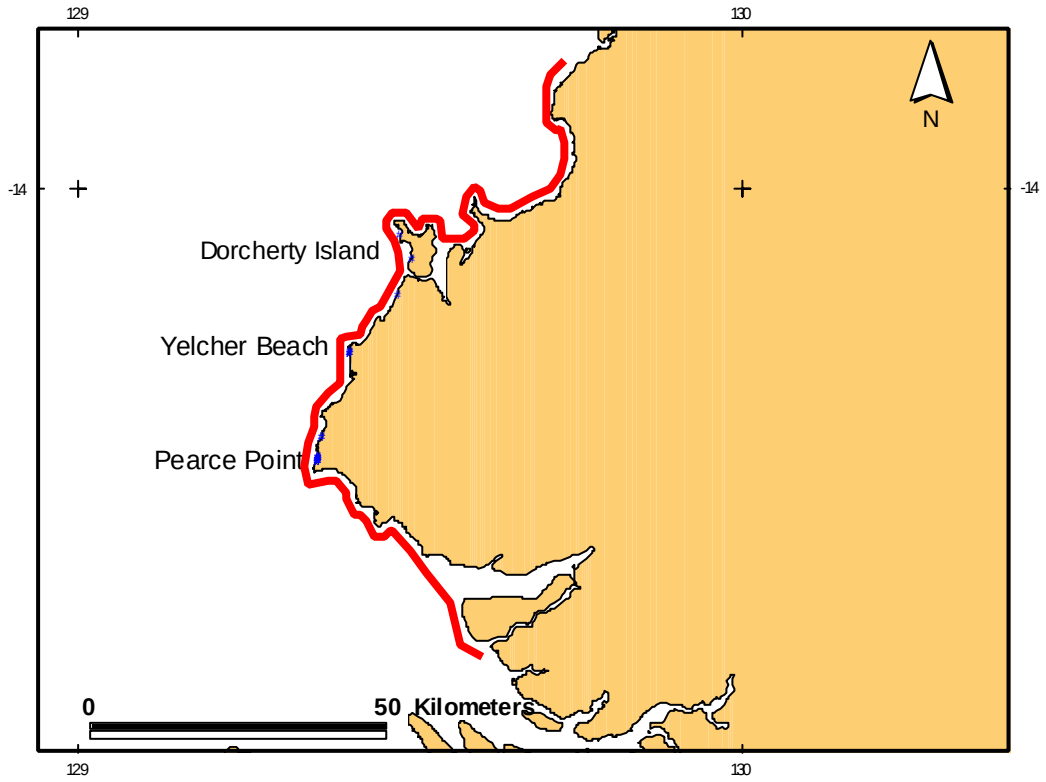


Figure 1 Nest locations along the coastline of Port Keats. Blue circles represent nest location. Red line indicates the path of the aerial survey.

Table 1 Localities of sea turtle nests seen on the preliminary survey of sea turtle resources near the Black Tip Project.

Nest Number	Latitude	Longitude
1	14º 24.262'S	129º 21.641'E
2	14º 24.306'S	129º 21.627'E
3	14º 24.313'S	129º 21.622'E
4	14º 24.327'S	129º 21.618'E
5	14º 24.327'S	129º 21.618'E
6	14º 24.327'S	129º 21.618'E
7	14º 24.37'S	129º 21.642'E
8	14º 24.38'S	129º 21.597'E
9	14º 24.395'S	129º 21.591'E
10	14º 24.438'S	129º 21.576'E
11	14º 24.438'S	129º 21.576'E
12	14º 24.238'S	129º 21.65'E
13	14º 24.236'S	129º 21.652'E
14	14º 24.229'S	129º 21.654'E
15	14º 9.601'S	129º 28.828'E
16	14º 22.244'S	129º 22.069'E
17	14º 22.298'S	129º 22.031'E
18	14º 14.743'S	129º 24.626'E
19	14º 14.728'S	129º 24.639'E
20	14º 14.477'S	129º 24.716'E
21	14º 14.779'S	129º 24.607'E
22	14º 6.2665'S	129º 30.1178'E
23	14º 4.109'S	129º 29.1781'E

Discussion

The six species of marine turtle occurring in Australian waters are listed marine species under Environmental Protection Biodiversity Conservation Act 1999 (EPBC) (Table 2). Internationally, the nesting species, Flatback and olive Ridley are considered Vulnerable and Endangered respectively. Their respective status is repeated at the National level. However, both species are listed as Data Deficient in the Northern Territory. The proposed pipeline project will contribute to rectifying the local lack of information about the nesting species of sea turtles through community involvement in the monitoring of any impacts resulting from the project.

Table 2. Conservation status at the International, National and Territory levels of the six species of sea turtles inhabiting Australian waters.

Names		Conservation Status		
Common	Scientific	International Red List 2000	National EPBC 1999	Northern Territory Threatened Species 2002
Flatback	*Natator depressus*	Vulnerable	Vulnerable	Data Deficient
Green	*Chelonia mydas*	Endangered	Vulnerable	Least Concern
Hawksbill	*Eretmochelys imbricata*	Critically Endangered	Vulnerable	Data Deficient
Leatherback	*Dermochelys olivacea*	Critically Endangered	Vulnerable	Vulnerable
Loggerhead	*Caretta caretta*	Endangered	Endangered	Endangered
Olive Ridley	*Lepidochelys olivacea*	Endangered	Endangered	Data Deficient

Pipeline Landfall

The pipeline project is going to cross the coast at the site of a sea turtle nesting beach that could support some tens of nests laid per year. There was no indication of other species such as Green sea turtles nesting on the beaches in the project area. This species causes a great deal of disturbance in the sand and the resulting depressions persist for some months. There as no local knowledge of species other than Flatback and Olive Ridley Sea turtles nesting in the area. The nesting season for these species in the Anson Beagle Bioregion starts in March and finishes in October each year. The peak of nesting activity is usually in July and August. Any risk of disturbance to the nesting beach associated with the pipeline landfall would be mitigated by the operations being conducted between October and March. The October to March construction period would have a low likelihood of impact. The March to October operation would have medium likelihood of impact, in that the disturbance would be over a medium scale and over several months.

Risk reduction measures should be viewed as an optimum given the time constraints of the pipeline installation being scheduled for the dry season, the need for operations to continue on a 24 hour basis, the need for the construction to be illuminated at night for safety reasons and the subsequent possibility of the light spill covering the entire beach. With the pipeline scheduled to cross Yelcher Beach in the dry season (March

to October), the risk of a negative impact on the nesting turtles increases from a low to medium level. Bearing in mind that there are an estimated 20 nests laid on Yelcher Beach each season and within the Anson Beagle Bioregion there is an estimated 2000 Flatback nests laid annually, approximately one percent of the nests risk direct negative impact. It is unlikely that a negative impact of this magnitude could be detected at a population level. However the impact would be detectable at the local level. This can be ameliorated by installing further safeguards.

As the pipeline landfall is towards the northern end to Yelcher Beach, it is recommended that the major source of illumination be from the southern side of the construction so that the spill of light onto the beach is reduced. The spill of light should be further reduced by placing shades on the southern (beach) sides of lights. This should place most of the beach in the shadow from the shades.

Female turtles will either nest on Yelcher Beach or move to a neighbouring beach to nest during the construction phase. Yelcher Beach and the neighbouring beaches to the north and south need to be monitored for sea turtle nesting activity to determine if turtles have been displaced by the construction activities. This monitoring should be conducted each morning from the start of the nesting season in March and continue for the entire season. Records should be kept on the number of turtle tracks and turtle nests on each of the beaches.

Even with the noise and lights of construction there is a high probability that turtles will nest on Yelcher Beach. On their return to the sea, the turtles will be attracted to the lights of construction. The equipment on the beach and the pit in which the pipe will be laid need to have a barrier in place to deflect the turtle down the beach towards the water. There needs to be a trained sea turtle handler on call from Wadeye during high tides, to coax nesting females away from construction lights and similarly to remove any hatchlings that may have emerged from nests that were missed by the beach monitors.

All nests laid on Yelcher Beach should be removed and transported with appropriate precautions to a hatchery on Kentjiptharra Beach at about 14° 15.276S 129° 24.641E or at another suitable location in the area. The removal and relocation of the nests should be completed by sunrise of the morning following laying. Precautions should be taken against vibrations and rotations. This removal of eggs should include all the nests for the season because eggs laid up to eight weeks prior to the construction will be affected by the vibrations. The embryos of sea turtles are particularly sensitive to vibrations and rotations during their development. For this reason during the construction of the pipeline landfall the nests should be collected by suitably trained community groups and removed to a hatchery on a neighbouring beach. Kentjiptharra Beach to the south would be a suitable location because the area has limited access to groups other than the traditional owners. The beach is of a suitable profile and aspect to support successful incubation of sea turtle eggs. The area can be monitored relatively easily. After incubation hatchlings should be collected in suitable corrals, held until darkness and released onto the beach to facilitate their imprinting to the area and its environmental and geomagnetic cues.

Hatching success of transplanted nests in the hatchery should be compared with hatching success from the control nests laid on the beaches to the north and south of Yelcher Beach. A complete report should be written on the number of turtles that

nested on Yelcher Beach during construction of the pipeline landfall, the numbers of eggs relocated to the hatchery, the hatching success of nests from within the hatchery and those nests left to hatch on the neighbouring beaches. From such a report the impact of the pipeline construction could be ascertained.

Lights

Beach Lighting

Sea turtles are sensitive to lights in the visible spectrum. There is no evidence that they can perceive light in the infrared or ultra violet wavelengths. Adult female sea turtles are photonegative as they approach the beach to nest. They can perceive and detect diffuse dark objects even in starlight. Having said that, they are subject to habituation and having nested in an area previously will return to the area even in the presence of light. Flatback sea turtles are extremely faithful in their nesting beaches and will return to the same island or beach having nested successfully there in previous years (Limpus *et al*. 1984). First time nesters are not so forgiving and are more sensitive to disturbance whilst on the nesting beach. Having finished nesting female turtles become photopositive and will move towards a lighted area that is at the lowest horizon. They are capable of detecting all wavelengths of visible light but respond less to red light.

Hatchling sea turtles are photopositive once they leave the nest. They move towards brighter regions and away from high beach silhouettes. The combination of light and low horizon usually leads the hatchlings to the open ocean (Limpus 1971, Bartol and Musick 2003). Unlike adults, hatchlings will climb uphill to a white light. Red light has a less effect but the hatchlings still respond to these wavelengths if sufficiently bright. Light of sufficient intensity can attract hatchlings from out of the water and entice them to climb the beach towards the light. This results in wasted energy and places the hatchlings in an illuminated area with greater risk of predation. Hatchings are attracted to the deck lights of boats at anchor and towards the “all round” white lights of yachts while anchored in the vicinity of nesting beaches. The best turtle friendly types of lights near nesting beaches include those light that emit a colour that has minimal effects on sea turtle adults and hatchlings. Luminaries that emit light in the shorter wavelengths of red and yellow have less attraction to hatchlings and adults than do other sources. Low pressure sodium vapour lamps are high in yellow wavelengths and are less disruptive near sea turtle nesting beaches (Witherington and Martin 1996).

Excess Gas and Flare

The flare system is designed to provide a safe means of disposing of pressurised gas in the event of an emergency and for proper maintenance of the plant. The frequency of accidental triggering of the flare system is expected to decrease after the commissioning phase and become an infrequent event. In emergencies, the flames may be up to 60 metres in height but with durations as short as 15 to 20 minutes. Given that the gas plant is approximately two kilometres from the shoreline, such an infrequent, short-lived flame is unlikely to have any impact on nesting sea turtles even if it occurred during their peak nesting period on a high tide at night during the dry season. The flame produced prior to scheduled maintenance is much smaller in size but may have a longer duration. The maintenance flares are scheduled at four times per year and may well occur during daylight hours. The pilot flame is of insufficient

size to impact on nesting turtles or their hatchlings. Should any impact from the flares be detectable then it would be classified as a minor and temporary disruption to a small portion of the population of nesting sea turtles and have no impact on critical habitat of activity.

Vibrations

Although lacking external ears sea turtles can hear by vibrations passing down the ear canals through a layer of fat. They respond mostly to low frequency sounds (Bartol and Musick 2003). Green turtles respond to sounds between 200 to 700Hz with best detection in the region of 400Hz (Bartol and Musick 2003). Pacific islanders noticed this behaviour and have a folk lore of the sound of the waves on the beach calling the nesting turtles. The sound of the waves crashing on the beach at high tide may be an important cue for nesting Flatback Sea Turtles to come ashore. Sea turtle embryos are particularly sensitive to vibrations. During the early phase of development vibrations and movement may dislodge the embryo from the egg membranes leading to the death of the embryo. In the later phases of development vibrations may cause the hatchlings to hatch prematurely leading to non-synchronous emergence from the nest and an increase in late development mortality (Andrea Koch, Personal Communication). As vibrations have the potential to cause negative impacts over several stages of embryonic development it is prudent to remove nests from the beach at the pipeline landfall where there is excessive noise and vibration to a safer hatchery area. This would provide a safeguard for the hatchlings during the construction phase of the pipeline.

Produced Water

Sea turtle are air breather and are therefore less susceptible to substances dissolved in the water than are fish. This is an area that has had little research and needs further literature searches particularly of the grey literature from the USA. It is noteworthy that having examined several thousand sea turtles in the northern regions of Joseph Bonaparte Gulf, there has not be a single case of fibropapillomastosis a debilitating condition of sea turtles that has been reported from more industrialised areas.

Community Involvement

This preliminary survey of the sea turtles in the region of the Black Tip Project wa to pave the way for follow up monitoring by a community group. The Wadeye community had started a Sea Ranger program which aims to be a marine counterpart to the “Caring for Country” initiative. This group appears to be an excellent organisation to conduct the ongoing monitoring of the sea turtles resources during the construction phase and after.

At the time of the survey the Sea Rangers had been in existence for at least twelve months and because they did not include members from all of the family groups, I detected an air of uncertainty regarding their role in my conversations with the Traditional Owners. I would encourage the Sea Rangers to get to know the coastal groups in whose land the sea turtles nest. This acceptance of the Sea Rangers is important in facilitating of ongoing monitoring. The monitoring should be inclusive of

the Traditional Owners, their understanding of what is going on and the benefits which can come from having a sea ranger program.

For the Sea Rangers to participate in the monitoring of the sea turtles and shifting nests to a safe hatchery, I recommend initiating a number of training sessions. This should include the Traditional Owners to provide the cultural aspects and consultants to provide the scientific and procedural aspects of the monitoring. In addition I support the sea Rangers at Wadeye forming links with Sea Rangers in other localities in the Northern Territory such a Borroloola and the Tiwi Islands to further facilitate the capacity building that grows from community conservation groups.

Training programs should be developed for:

1. Reading turtle tracks on nesting beaches.
2. Hatchery design and site location.
3. Hatchery management.
4. Safe methods of egg collection, transport and burial.
5. Detection of nests about to hatch.
6. Hatchling collection, care and release.
7. Record keeping, data collection and report writing.

The Sea Rangers under the guidance of Mr Scott McIntyre were an enthusiastic group who with appropriate training would make a positive contribution to monitoring the impacts of the Black Tip Project.

Acknowledgements

I thank Ms Una Phelan (SKM) and Ceri Morgan (Woodside) for the opportunity to participate in the project. Andrea Koch provided valuable photographs during the aerial survey. I thank the Traditional Owners Anthony, Cyril and Angus and their families for their guidance through their country and for the openness with which they participated in the discussions. I thank the Northern Land Council personnel for their attention to detail and for facilitating meetings with the Traditional Owners. I thank Scott McIntyre and the Sea Rangers of Wadeye for their hospitality and participation in the aerial surveys.

In addition to this report a full list of photographs and their captions will be presented in digital and hard copy form to SKM. Prints and captions will be presented to NLC, and the Traditional Owners.

References

Bartol, S. M. and Musick, J. A. (2003). Sensory Biology of Sea Turtles in Lutz, P. L. Musick, J. A. and Wyneken, J. (eds) The Biology of Sea turtles Volume II CRC Press Boca Raton pp79 -102.

Bayliss, P. (1986). Factors affecting aerial surveys of marine fauna and their relationship to a census of dugongs in the coastal waters of the Northern Territory. *Australian Wildlife Research* **13**: 27-37.

Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. *In* R. Kennett, A. Webb, G. Duff, M. Guinea and G. Hill (eds) Marine Turtle Conservation and Management in Northern Australia, Proceedings of Workshop held at the Northern Territory University, Darwin 3-4 June 1997, Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetland Management, Northern Territory University, Darwin pp 33-40.

ISOEA data base (no date). India Ocean South East Asian Sea Turtle Database. iosea.org.

King, P. P. (1827). Narrative of a survey of the Intertropical and Western Coasts of Australia. John Murray, London.

Limpus, c. J. (1971) Sea turtle ocean finding behaviour. *Search* **2(**10):385-387.

Limpus, C. J., A. Fleay, and V. Baker (1984). The flatback turtle, *Chelonia depressa* in Queensland: reproductive periodicity, philopatry and recruitment *Australian Wildlife Research* **11**: 579-87.

Prince, R. I. T. (1994). Status of Western Australian marine turtle populations: the Western Australian Marine Turtle Project 1986-1990. in James, R. (ed) Proceedings of Australian Marine Turtle Conservation Workshop Sea World Nara Resort Gold Coast 14-17 November 1990. pp 1-14.

Stokes J. L. (1846). Discoveries in Australia Vol 2 T and W. Boone: London.

Whiting, S. D. (2002) Rocky reefs provide foraging habitats for dugongs in the Darwin region of Northern Australia. Australian Mammalogy 24:147-150.

Whiting, S. D. (2004). Conserving Dugongs in Darwin Harbour. Coasts and Clean Seas Project #28491 Report.

Witherington, B. E. and Martin, R. E. (1996). Understanding, assessing and resolving light pollution problems on sea turtle nesting beaches. Florida Marine Research Technical Report TR–2 (http://www.turtletime.org/lighting/).

Diary of Events:

4 June 2004

Arrived at Pearl Aviation with CDU student Andrea Koch, for weigh in at 0830 and met Katie Tschia and Una Phelan and Scott McIntyre. Leon the Traditional Owner did not make it to the air port hence there may be a problem with Andrea leaving the aerodrome at Wadeye.

The aircraft was a Beachcraft Kingair seating 9 passengers and two pilots

Following the introductory video I spoke with the pilots about what we were looking for and enquired as to the best way for flying to provide a good coverage of the survey area.

Take off at 09.26 for a short flight to Bare Sand Island. Andrea and I were seated behind the wing so that from either side of the plane we had an unobstructed view of the survey. Survey height was 500 ft and air speed in excess of 140 knots (280 km/hr).

On Bare Sand Island there were 5 fresh turtle tracks from last night. This island supports up to about 500 nesting flatback sea turtles each year. This equates to about 1500 nests and 75,000 eggs. In addition there are about ten or so olive ridley sea turtles nesting on the island, but their tracks because of their small size are difficult to see from the air.

South of Dum in Mirrie Island, on the mainland there was one fresh sea turtle track on the most northern beach at Dundee Beach. This area supports some tens of nesting flatback sea turtles each year.

The aircraft kept a low altitude along the coast to the vicinity of Channel Point near the Perron Islands. There were no further sea turtle tracks on any of the beaches in the intervening 80 km.

From Channel Point the plane climbed to 2,000 ft to conserve fuel and to provide a more comfortable ride for those on board. We flew south over Cape Scott and Cape Hay on the way to Wadeye.

We landed at Wadeye and Scott McIntyre collected the Sea Rangers together, David Greg and Vincent were to accompany us on the aerial survey of the Port Keats Area. The traditional owners Anthony, Angus and Cyril also flew the survey as the plane was flying over their country.

As Andrea and Katie could not be accommodated under the existing permits they also joined the aerial survey.

Aerial Survey:4 June 2004

Take off at 11.57 and flew to the south over Whale Flat as one of the sea rangers indicated that at times locals collected turtle eggs from that area. The survey height was again about 500 ft and 200 m seaward of the shoreline and a speed of 140 knots.

The plane turned north-west after crossing Whale Flat (14°42.00'S 129° 37.00'E) and flew towards Fossil Head and Pearce Point and then turned north to follow the coast. The coastline was highly scenic with rocky laterite cliffs and protected beaches in between. In several places shoreline consisted of long sand beaches with well formed sand dunes and coastal swamps further inland. Almost the entire coastline was photographed for later ground surveys. The survey continued north to 13° 52.00'S and 129°43E where a road joins the beach north of Cape Dombey. At 12.47 the plane turned south and flew parallel to the coast about 1000m seaward of the shoreline to Pearce Point before heading north to Wadeye Aerodrome and landing at 13.13.

During the survey only two turtle tracks were seen and these were on the sandy dunes on the western side of Dorcherty Island. No other evidence of turtle nesting was seen. One green sea turtle was seen in the water off Pearce Point. There was no evidence of seagrass in the intertidal zone. No dugongs were seen. The speed and height of the survey was adequate to see large marine life in the water as evidenced by the single sea turtle and on the return southern leg of the trip a large salt water crocodile was seen in Treachery Bay to the south of Pearce Point.

Visit to Anthony's Country.

After the aerial survey I travelled with the NLC party to Anthony's outstation (14° 07.768S 129°29.866E) just south of Dorcherty Island. I opened my folder of sea turtle pictures and other information and conducted an informal interview that was mainly constructed around the interests of the traditional owners. Anthony and John Daly were eager to provide information about the types of sea turtle and the presence of dugongs in the area. The main nesting sea turtle was identified as the Greenback. Anthony identified a flatback (*Natator depressus*) from the photographs and particularly the diagrams of the turtle eggs. Anthony gave the name for the turtle in his language and indicated that this meant the turtle that lays eggs. This name may have referred to the activity as well as the species. The main nesting beaches in Anthony's country were on the western side of Dorcherty Island. Sea turtle nests were common on Dorcherty Island and fresh nests were found throughout the dry season. Goannas were common on the island. They raided many turtle nests and ate many of the turtle eggs.

Dugongs also occur along the coastline at Dorcherty Island. They inhabit the shallow reef to the north of Dorcherty Island and the vicinity of Cape Hay. Near Cape Hay there is a flat patch of reef and dugongs are commonly found on this patch. Melissa Byass (NLC) asked if seagrasses were found in this area near Cape Hay to which Anthony answered, "Yes" but did not elaborate and I was unsure if he understood the difference between seagrass and seaweed or his affirmative reply was out of courtesy. The region of Dorcherty Island and the surrounding reefs appears to be an important sea turtle nesting and dugong-feeding habitat.

John Daly indicated that he had seen large dugongs at the southern regions of the Joseph Bonaparte Gulf but did not give an exact locality. He did recall a large dugong surfacing beside his crabbing boat at the mouth of the Moyle River. This dugong had surfaced repeatedly beside the boat and had rubbed its back on the boat. The local people at Wadeye do not hunt the dugongs. Many people do not have boats and are therefore not in a position to engage in a hunt. Anthony indicated that he had taken a dugong some years ago but he did not hunt regularly. John Daly indicated that few people went turtle hunting as no body had turtle spears or harpoons and there were few boats and in large part the hunting skills had been lost by the people.

Few turtles nested on Anthony's front beach. Anthony indicated that whenever he went along the front beach there was sometimes one nest or maybe two nests but not any more. This was taken as a low level of sea turtle nesting. An inspection of the beach by 4wd vehicle revealed only two nests from with in the last two weeks in approximately 2 km. One nest was located at 14° 09.601S 129° 28.828E. It was that of a Flatback (Greenback to the locals). It had not been raided by goannas as there were few goannas on this coastline. Anthony was not interested in collecting the eggs either. On the beach there were dead shells of the auger shell mollusc (*Turritella terebra*) which indicate that there was a mud bank offshore that could be a feeding ground for loggerhead and olive ridley turtles as were found further north in Fog Bay.

Visit to Cyril's Country

Saturday 5 June 2004. I accompanied Anna and the NLC team to Wadeye and picked up Cyril and his family and headed south to the Pearce Point region. We arrived at the outstation and went onto the beach to find a Flatback turtle nest (14° 24.262S 129° 21.641 E) from last night. Cyril's family identified he turtle nest was that of a Greenback (Flatback *Natator depressus*). They located the eggs by probing for the soft eggs with pointed sticks. The identification was supported by there being 53 eggs in the nest. This is a typical clutch size for Flatback sea turtles. A table of the nests and their locations on this beach are presented in Table 3.

We had lunch at the outstation (14° 24.269S 129° 21.694E) and spoke about sea turtles. Cyril's family do not hunt turtles and have no harpoons. They collect some eggs at times. Similarly they do not hunt dugongs. They are familiar with dugongs and know they are in the area but seem to pass through rather than stay in a particular area.

After lunch Cyril took the party to the Sun Rock and the ochre cliffs. This was a sacred site and I was privileged to have been taken there.

We then went to another outstation and sacred site with Cyril. This site had been seen from the air and consisted of sand dunes that backed the beach at 14° 22.205S 129° 22.069E. We approached the dunes through the paperbark swamp and climbed the back of the dune that was about 30 m in height. Seaward of the dune that was a Python Dreaming Site, was a flatback nest (14° 22.244S 129° 22.069E) from which the group collected the eggs. Another nest (14° 22.298S 129°22.031E) had been raided by goannas. We walked southwards along the beach past a women's dreaming

site in which men were not permitted, to a rocky headland from which freshwater seeped from the rocks. Around the corner Cyril and Francis (Cyril's cousin) showed us the cave through which the sea turtles and the fresh water turtles changed over. The sea turtles found they were too large to live in the freshwater pools and the longneck turtles found they were too small to live in the sea. It was through this cave (14° 22.715S 129°21.782E) where the fresh water seeps into the sea that they changed places.

We walked back to the vehicle and left the area at 1525 to go to another beach. The ladies in the party were too tired to walk further so having got to the site we abandoned our plans and tried to contact the camp indicating we were dropping the group off in Wadeye before returning to the camp.

Table 3 Positions and fate of nests found on the beach at the out-station.

Number	Position	Comments
1	14° 24.262S 129° 21.641E	53 eggs collected as above
2	14° 24.306S 129° 21.627E	Raided by goannas
3	14° 24.313S 129° 21.622E	Raided by goannas
4	14° 24.327S 129° 21.618E	Raided by goannas
5	14° 24.327S 129° 21.618E	Raided by goannas
6	14° 24.327S 129° 21.618E	Raided by goannas
7	14° 24.370S 129° 21.642E	Raided by goannas
8	14° 24.380S 129° 21.597E	Eggs collected
9	14° 24.395S 129° 21.591E	Raided by goannas
10	14° 24.438S 129° 21.576E	Nest from last night there fore not present for aerial surveys. Eggs collected
11	14° 24.438S 129° 21.576E	Old (several weeks) nest opened by goannas
12	14° 24.238S 129° 21.650E	Left intact
13	14° 24.236S 129° 21.652E	Raided by goannas
14	14° 24.229S 129° 21.654E	Left intact

Visit to Angus's Country

Sunday 6 June 2004. We left the camp at 0830 to go to Yelcher Beach. Today's party consisted of Angus the Traditional Owner, Colin his brother-in-law, Anna, Melissa, David and others from NLC and other relatives and children. We reached Yelcher Beach (according to the locals) and the site of the pipeline landfall at 08.47.

A Flatback turtle had nested last night at 14° 14.743S 129°24.626E. The eggs were collected.

Last Wednesday (2 June 2004), this family group had collected the eggs from another Flatback nest on this beach. The nest was located at 14° 14.728S 129°24.639E. Further north along the beach another Flatback had come ashore last night at 14° 14.637S 129°24.679E but did not nest. The beach was inspected from the south to 14° 14.477S 129°24.716E for signs of nesting sea turtle activity. There was an old Flatback sea turtle nest at 14°14.779S 129° 24.607E.

We left the beach at 0925 and headed south to the neighbouring beach called Yelcher Beach on the maps but which the locals called Kentjiptharra Beach. The survey started at 14° 15.201S 129° 24.628E and continued to the point at 14° 15.517S 129° 24.548E. A stop was made at 14° 15.276S 129° 24.641E to photograph the beach. There was no sign of turtle nesting on this beach although Angus indicated that turtles nested further south around the point.

The party then proceeded to the beach north of the pipeline landfall. We drove along the beach to 14°12.935S 129° 26.400E. There was one old turtle nest that had been collected by a group in a four wheel drive some days before. We walked to the creek mouth and I photographed the hinterland and coastline from atop the dune at 14°12.815S 129°28.506. The beach continued on the northern side of the creek. It was on this northern part of the beach that the group collected the characteristically small eggs of the Olive Ridley Sea Turtle (*Lepidochelys olivacea*) last week.

We returned to the camp and packed for the drive to Darwin. Over lunch I spoke with Colin who said that there were dugongs in the area, but the people do not hunt them. Some years ago a fellow shot one and they cut it up and they ate it. They know the dugongs are in the area because on the lowest tides of the year he has walked out to the low tide mark and found seagrasses that were long and flat like a belt and also found the depressions in between clumps of this seagrass where dugongs had been feeding. The seagrass from its description is *Enhalus acoroides* that is relatively common in intertidal regions but to my knowledge is not a species of seagrass favoured by dugongs.

I left the camp at 13.05 with Melissa Byass (NLC) and drove to Darwin. We made the sat phone schedule calls as we crossed the Daly River and refuelled at Daly River and continued on to Darwin.

List of Photographs taken during this survey:

Photographs listed are the low resolution reference numbers.

Film Number	Caption
AA_0_001	Anthony's beach
AA_0_002	Anthony's beach
AA_0_003	Anthony's outstation
AA_0_004	Turtle tracks on Dorcherty Island
AA_0_005	Turtle tracks on Dorcherty Island
AA_0_006	Tree Point to Cape Dombey
AA_0_007	Tree Point to Cape Dombey
AA_0_008	Tree Point to Cape Dombey
AA_0_009	Melissa (NLC) with Anthony on Anthony's beach
AA_0_010	turtle nest at Anthony's beach 14deg 09.601minS: 129deg 28.828minE
AA_0_011	Anthony and Melissa (NLC) at turtle nest 14deg 09.601minS: 129deg 28.828minE
AA_0_012	General view of the low profile beach at Anthony's outstation
AA_0_013	General view of the low profile beach at Anthony's outstation
AA_0_014	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_015	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_016	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_017	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_018	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_019	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_020	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_021	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_022	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_023	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_024	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AA_0_025	Cyril and Francis with the ladies on Cyril's outstation beach14deg 24.262minS: 129deg 21.641minE
AB_0_001	Yelcher Beach (map) 14deg 15.201minS: 129deg 24.628E
AB_0_002	Proposed pipeline landfall
AB_0_003	Camp site on the headland at the site of the old nunnery
AB_0_004	Cyril, Francis and group entering the python dreaming site
AB_0_005	Python dreaming site
AB_0_006	Python dreaming site
AB_0_007	Cyril's group on top of the dune overlooking the wetlands
AB_0_008	David (NLC) on beach nort of camp 14deg 12.935min S: 129deg26.400min E
AB_0_009	Soft sand and nearly bogged troop carrier at 14deg 12.935min S: 129deg26.400min E
AB_0_010	Mellissa Byass (NLC) returning to Darwin by road
AB_0_011	Mellissa Byass (NLC) returning to Darwin by road
AC_0_001	Start of Aerial Survey. Departing Darwin Camera check on Darwin harbour Development
AC_0_002	Flight check, heading north over Darwin Harbour
AC_0_003	Approaching Bare Sand Island and Quail Island
AC_0_004	Bare Sand Island
AC_0_005	Bare Sand Island
AC_0_006	Bare Sand Island
AC_0_007	Bare Sand Island
AC_0_008	Bare Sand Island
AC_0_009	Dum in Mirrie Island
AC_0_010	Dum in Mirrie Island
AC_0_011	Bare Sand Island
AC_0_012	Bare Sand Island
AC_0_013	Bare Sand Island
AC_0_014	Bare Sand Island
AC_0_015	Bare Sand Island
AC_0_016	Bare Sand Island
AC_0_017	Bare Sand Island

AC_0_018	Dum in Mirrie Island
AC_0_019	Dum in Mirrie Island
AC_0_020	Dum in Mirrie Island
AC_0_021	Dum in Mirrie Island
AC_0_022	Dum in Mirrie Island
AD_0_001	Quail Island
AD_0_002	Quail Island
AD_0_003	North Perron Island
AD_0_004	North Perron Island
AD_0_005	Wetlands at New Moon Inlet
AD_0_006	Wetlands at New Moon Inlet
AD_0_007	Whale Flat
AD_0_008	Whale Flat
AD_0_009	Whale Flat
AD_0_010	Whale Flat
AD_0_011	Whale Flat
AD_0_012	Whale Flat
AD_0_013	Whale Flat
AD_0_014	Whale Flat
AD_0_015	Pearce Point
AD_0_016	Pearce Point
AD_0_017	Pearce Point
AD_0_018	Sand dunes at the Python Dreaming Beach
AD_0_019	headland to the south of the Turtle Sacred site
AD_0_020	Cyril's Python dreaming beach
AD_0_021	Cyril's Python dreaming beach
AD_0_022	Creek on Yelcher Beach on Cyril's beach with python Dreaming
AD_0_023	Creek on Yelcher Beach
AD_0_024	Yelcher Beach looking north
AD_0_025	Channel Island on the return flight to Darwin
AE_0_001	turtle nest opened by goannas at Cyril's outstation 14deg 24.262minS: 129deg 21.641minE
AE_0_002	turtle nest opened by goannas at Cyril's outstation 14deg 24.262minS: 129deg 21.641minE
AE_0_003	Cyril's beach at outstation
AE_0_004	Beach facing north at Cyril's outstation
AE_0_005	Anna (NLC) and children of the back of the dune at the Python dreaming site
AE_0_006	Beach facing south at Python dreaming site
AE_0_007	Beach facing north at Python dreaming site
AE_0_008	Francis and friend collecting eggs from the python dreaming site
AE_0_009	Cyril and Francis at the turtle sacred site 14deg 22.715minS129deg 21.782minE
AE_0_010	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_011	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_012	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_013	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_014	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_015	Angus, Colin and group with turtle nest at pipeline landfall beach 14deg 14.743minS: 129deg 24.626minE
AE_0_016	Flatback Turtle track at pipeline landfall beach14deg 14.637minS: 129deg 24.679minE
AE_0_017	Pipeline Landfall Beach (Yelcher beach to locals) 14deg 14.477minS: 129deg 24.716minE
AE_0_018	Kentjiptharra Beach south of Pipeline landfall Beach facing south at 14deg 15.276minS: 129deg 24.641minE
AE_0_019	Kentjiptharra Beach south of Pipeline landfall Beach facing north at 14deg 15.276minS: 129deg 24.641minE
AE_0_020	Kentjiptharra Beach south of Pipeline landfall Beach facing south at 14deg 15.517minS: 129deg 24.648minE
AE_0_021	Children playing with cuttlefish boats
AE_0_022	Beach north of Camp view southwest from 14deg 12.815minS:129deg 28.506minE
AE_0_023	Beach north of Camp view east from 14deg 12.815minS:129deg 28.506minE
AE_0_024	Beach north of Camp view north from 14deg 12.815minS:129deg 28.506minE
AE_0_025	David(NLC) and others at the creek north of the camp
AE_0_026	David (NLC) Anna (NLC) and Melissa (NLC)and Colin at northern end of beach before returning to camp.

AF_0_001	Cape Scott
AF_0_002	Dashwood Plains
AF_0_003	Dorcherty Island from East
AF_0_004	Port Keats
AF_0_005	Upstream of Port Keats
AF_0_006	Wetlands at New Moon Inlet
AF_0_007	Wetlands at New Moon Inlet
AF_0_008	Whale Flat
AF_0_009	Whale Flat
AF_0_010	Whale Flat
AF_0_011	Fossil Head
AF_0_012	Fossil Head
AF_0_013	Fossil Head
AF_0_014	Fossil Head
AF_0_015	Pearce Point
AF_0_016	Pearce Point
AF_0_017	Pearce Point
AF_0_018	Pearce Point
AF_0_019	Pearce Point
AF_0_020	Pearce Point
AF_0_021	Pearce Point
AF_0_022	Cyril's outstation 14deg 24.262min S: 129deg 21.641min E
AF_0_023	Cyril's coast
AF_0_024	Cyril's coast showing th python dreaming site being the sand dunes14deg 22.205minS: 129deg 22.069minE
AF_0_025	Cyril's coast
AF_0_026	Cyril's coast

Appendix D

Blacktip Development Onshore Plant Site and Gas Pipeline Route, Wadeye/Port Keats, Northern Territory: Desktop Assessment of Acid Sulfate Soils prepared by Sinclair Knight Merz






This page has been left intentionally blank

Blacktip Development Onshore Plant Site and Gas Pipeline Route, Wadeye/Port Keats, Northern Territory

DESKTOP ASSESSMENT OF ACID SULFATE SOILS

- Version 03
- 5/03/2004

Blacktip Development Onshore Plant Site and Gas Pipeline Route, Wadeye/Port Keats, Northern Territory

DESKTOP ASSESSMENT OF ACID SULFATE SOILS

- Version 03
- 5/03/2004

Sinclair Knight Merz
ABN 37 001 024 095
7th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia

Tel: +61 8 9268 4400
Fax: +61 8 9268 4488
Web: www.skmconsulting.com

COPYRIGHT: The concepts and information contained in this document are the property of Sinclair Knight Merz Pty Ltd. Use or copying of this document in whole or in part without the written permission of Sinclair Knight Merz constitutes an infringement of copyright.

Contents

1. Introduction 1

2. Background 1

3. Objective 2

4. Desktop Assessment 2

4.1 Land Systems of the Port Keats Area Map (1:250,000) 2
4.2 Australia Geological Survey of Northern Territory Sheet SD 52-11 (1:250,000) 2
4.3 Natural Heritage Trust – Australian Natural Resources Atlas from the Natural Land and Water Resources Audit 2001 2
4.4 Woodside Energy Limited Reports Provided to SKM 3

5. Assessment Criteria 4

5.1 West Australian Guidelines 4
5.2 Northern Territory Government – Risk Categories for Port Keats Land Resource Mapping 5

6. Potential Impacts 6

7. Conclusions 6

8. Recommendations 6

Document History and Status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
01	24/2/04	U. Phelan	NA	NA	1st Draft
02	5/3/04	D. Donovan	D. Donovan	5/3/04	2nd Draft
03	5/3/04	D. Donovan	U. Phelan	5/3/04	Final

Distribution of Copies

Revision	Copy No.	Quantity	Issued to
01	1	1	U. Phelan – Internal Review
02	1	1	U. Phelan – For
03	1 & 2	2	Timor Sea Gas Business Unit
03	1	1	SKM – File Copy

Printed:	18 October 2004
Last saved:	5 March 2004 02:44 a44/p44
File name:	I:\WVES\Projects\WV02540\Technical\ASS_Geology\R01dadUP.doc
Author:	David Donovan
Project manager:	Una Phelan
Name of organisation:	Timor Sea Gas Business Unit
Name of project:	Blacktip Development
Name of document:	Desktop Assessment of Acid Sulfate Soils
Document version:	03
Project number:	WV02540

1. Introduction

Sinclair Knight Merz (SKM) conducted a desktop assessment in order to determine the potential occurrence of Acid Sulfate Soils (ASS) at the proposed Blacktip Development Onshore Plant Site and approximately three kilometres of proposed incoming wet gas pipeline, located at Wadeye/Port Keats, Northern Territory.

The proposed incoming wet gas pipeline extends from the landfall on the northern end of Yelcher beach eastward to the proposed plant site.

2. Background

ASS are soils that contain iron sulfides which, when drained or disturbed, produce sulfuric acid and result in the release of soluble iron, sulfate, aluminium and other toxic metals. The early detection of ASS can provide a useful platform for developing and adopting effective measures to reduce the generation of acidic soils and water during the completion of bulk earth works.

The following guidelines have been used in completing this assessment:

- *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*, Department of Natural Resources, Indooroopilly, Queensland, Australia;
- *Identification and Investigation of Acid Sulfate Soils and Groundwater*, Draft 2003, Acid Sulfate Soils Guidelines Series, Department of Environmental Protection, Water and Rivers Commission, Western Australia.
- *Environmental Guidelines for Reclamation in Coastal Areas*, January 1999, Environmental and Heritage Division, Department of Lands, Planning and Environment, Northern Territory.
- Risk Categories for Port Keats Land Resource Mapping (November 2003) – provided by David Howe, Principal Scientist, Soil and Vegetation, Natural Systems Division of the Northern Territory Government.

It should be noted that the Queensland guideline does not provide guidance on the completion of ASS desktop assessments. The Queensland guideline does however provide information on ASS sampling and analysis procedures. In the absence of any Queensland guideline on the completion of ASS desktop assessments, SKM has adopted both the West Australian guideline and the information provided by the Northern Territory Government.

3. Objective

The objective of this desktop assessment is to conduct a preliminary appraisal of ASS risk associated with the soils in the areas of investigation.

4. Desktop Assessment

4.1 Land Systems of the Port Keats Area Map (1:250,000)

Proposed Plant Site:

According to the land systems map, the proposed plant site is located on the Moyle Land System. This system is described as gently undulating plains with slopes of less than 2.5%. The system consists of deeply weathered sandstone underlaying deep red earths and sandy red earths. The system supports an open forest vegetation type.

Proposed Pipeline Route and Landfall:

According to the land systems map, the proposed pipeline route crosses the Moyle Land System (as described above) and the Carpentaria Dune Land System. The Carpentaria Dune Land System is described as dunes and swales, beach deposits and sands supporting woodlands, monsoon thicket, grasslands or is bare of vegetation.

4.2 Australia Geological Survey of Northern Territory Sheet SD 52-11 (1:250,000)

Proposed Plant Site:

The geology map and representative cross section indicated that the proposed plant site is located on sand, soil, colluvium and black soil of tertiary age. This material is underlain by siltstone, silty sandstone, minor limestone, basal conglomerate and diamictite of Permian age.

Proposed Pipeline Route and Landfall:

The geology map and representative cross section indicated that the proposed pipeline route will cross the above material and the dune and beach alluvium formation, which is of Quaternary age. This alluvium is also underlain by the Permian age formation described above.

4.3 Natural Heritage Trust – Australian Natural Resources Atlas from the Natural Land and Water Resources Audit 2001

Several maps of the area were accessed through the Australian Natural Resources Atlas databases.

Proposed Plant Site:

Information collected for the proposed plant site is summarised below.

- Topsoil texture is described as sand, with pH ranges from 4.9 to 5.6.
- Subsoil texture is described as loam with pH ranges from 4.9 to 7.0.
- No data was available for vegetation groups.

Proposed Pipeline Route and Landfall:

There is no data available for the proposed pipeline route.

4.4 Woodside Energy Limited Reports Provided to SKM

Proposed Plant Site:

- The proposed plant site is located between 10 metres Australian Height Datum (mAHD) and 20 mAHD.
- Exploration for oil and coal has been conducted in the area to the east of the proposed site, between the proposed site and Wadeye/Port Keats.
- The following observations were made during limited soil profile investigations at the proposed plant site at the end of the dry season.
    - The soil profile consists of well-consolidated sandy clay to clayey sand.
    - Moisture was observed at 0.3 meters below grade (mbg).
    - Below 0.3 mbg, no free water was observed to the maximum depth of the investigation (9 mbg).
    - Anecdotal evidence suggests the area at and around the proposed plant site may become inundated with water during heavy rainfall events but drains quickly.

Proposed Pipeline Route and Landfall:

- The proposed pipeline route will range from 0 mAHD at the landfall location (ie. northern end of Yelcher beach) to 20 mAHD.
- Yelcher beach extends approximately 200 m from the dune system at low tide.
- Marine sediments associated with Yelcher beach and dune land system may be disturbed during excavation works conducted during construction of the proposed pipeline.
- The depth of marine sediments associated with Yelcher beach may be limited by shallow hard rock.
- The following observations made during limited soil profile investigations along the proposed pipeline route at the end of the dry season.
    - The soil profile along the proposed pipeline route becomes sandier as it approaches the beach and dune system.

- A laterite layer was observed at the surface underlain by sandy clay on the immediate landward side of the dune system.
- Plastic clay was observed at 1.2 mbg at the proposed pipeline beach crossing location.

5. Assessment Criteria

5.1 West Australian Guidelines

The West Australian guidelines recommends the use of 7 geomorphic or site description criteria to determine if ASS are likely to be present on a site. These criteria are detailed in the tables below including their association with the site.

Proposed Plant Site and Portions of the Proposed Pipeline Route (Moyle Land System)

Criteria		Association w/ Site
1	Land with an elevation less than 5 metres AHD.	NO
2	Soil and sediment of recent geological age (Holocene).	NO
3	Marine or estuarine sediments and tidal lakes.	UNLIKELY*
4	Low-lying coastal wetland or black swamp areas, waterlogged or scaled areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes.	NO
5	Coastal alluvial dunes.	NO
6	Areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging conditions (eg. mangroves, saltcouch, swamp-tolerant reeds, rushes, paperbarks (Melaleuca spp.) and swamp oak (Casuarina ssp)).	NO
7	Areas identified in geological description or in maps as: bearing sulfide minerals, coal deposits or marine shales/sediments, and deep older estuarine sediments below ground surface of either Holocene or pre-Holocene age.	UNLIKELY*

* The association of this criterion to the area is possible but unlikely. Limited information is currently available to confirm the association.

Landfall and Beach Crossing Portion of the Proposed Pipeline Route (Carpentaria Dune Land System)

Criteria		Association w/ Site
1	Land with an elevation less than 5 metres AHD.	YES
2	Soil and sediment of recent geological age (Holocene).	YES
3	Marine or estuarine sediments and tidal lakes.	YES
4	Low-lying coastal wetland or black swamp areas, waterlogged or scaled areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes.	YES
5	Coastal alluvial dunes.	YES
6	Areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging conditions (eg. mangroves, saltcouch, swamp-tolerant reeds, rushes, paperbarks (Melaleuca spp.) and swamp oak (Casuarina ssp)).	YES
7	Areas identified in geological description or in maps as: bearing sulfide minerals, coal deposits or marine shales/sediments, and deep older estuarine sediments below ground surface of either Holocene or pre-Holocene age.	YES

Based on the above criteria the proposed plant site and portions of the proposed pipeline route, associated with the Moyle Land System has a low potential for ASS. The landfall and beach crossing portion of the proposed pipeline route, associated with the Carpentaria Dune Land System, has a high potential for ASS.

5.2 Northern Territory Government – Risk Categories for Port Keats Land Resource Mapping

The Northern Territory government provided SKM with a list of map units and corresponding ASS risk categories based on land systems mapping for the Port Keats area.

The following risk categories apply to land systems mapping for the Port Keats area.

1) High risk of ASS conditions.
2) Moderate risk of ASS conditions.
3) Low to nil risk of ASS conditions.

Based on this information the proposed plant site and portions of the proposed pipeline route, associated with the Moyle Land System has a “low to nil risk of ASS conditions” and the landfall and beach crossing portion of the proposed pipeline route, associated with the Carpentaria Dune Land System has a “moderate risk of ASS conditions”.

6. Potential Impacts

ASS when drained or disturbed produce sulfuric acid that can result in adverse impacts to the environment and consequently human endeavours including fishing, recreation, tourism and human health. As defined in the above referenced guidelines, impacts that may occur include:

- soil acidification;
- adverse changes to the water quality of the soil, groundwater, surface water, wetlands, watercourses and estuaries;
- degradation of water dependant ecosystems and ecosystem services;
- loss of habitat and biodiversity;
- loss of plant yield;
- corrosion of metallic and concrete structures (concrete cancer) such as roads, bridges, pumps, pipes and foundations;
- invasion of and dominance of wetlands and waterways by acid tolerant water plants, plankton and pathogens; and
- increased human health risks associated with arsenic, aluminium and other heavy metal contamination of soil, groundwater and acid dust.

7. Conclusions

Based on the results of the desktop assessment, SKM conclude the following:

- There is a low to nil risk of ASS conditions in soils associated with the proposed plant site and portions of the proposed pipeline route.
- There is a moderate to high risk of ASS conditions in soils associated with the landfall and beach-crossing portion of the proposed pipeline route.

8. Recommendations

Based on the results of the desktop assessment and communications with David Howe, Principal Scientist, Soil and Vegetation, Natural Systems Division of the Northern Territory Government, soil investigations will be required for the proposed plant site and along the proposed pipeline route including the landfall. These investigations need to be conducted prior to bulk earthworks to ensure correct handling and treatment of soils disturbed during the construction works.

Discussions with personnel from the Department of Heritage and Environment - Northern Territory have confirmed that site investigations should be conducted in accordance with *Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland 1998.* However results of the desktop assessment indicate that the sampling of soils at the proposed plant site and portions of the proposed pipeline route can be completed at a reduced density than the sampling of soils at the landfall and beach crossing portion of the proposed pipeline route.

The sampling of soils at the landfall and beach crossing portion of the proposed pipeline route (identified as a moderate to high risk of ASS conditions associated with the Capentaira Dune Land System) should be conducted at 50 m intervals along the proposed pipeline route. The approximate extent of the Capentaira Dune Land System includes the beach from the low tide through the dunes to the tree line.

The sampling of soils at the proposed plant site and portions of the proposed pipeline route (identified as a low to nil risk of ASS conditions associated with the Moyle Land System) should be conducted in areas that will be disturbed as a result of the development and at a reduced sampling density of say 2 sample points per hectare.

As stated above, all sampling and analysis should be conducted in accordance with *Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland 1998*. A generalised work scope is summarised below.

- Field samples should be collected at 0.25m intervals or at a change in soil horizon, to depth of 1m below the maximum expected depth of the excavation or until hard rock is encountered.
- Samples should be collected for laboratory analysis at a minimum of 0.5m intervals or at a change in horizon to depth of 1m below the maximum expected depth of the excavation or until hard rock is encountered.
- Laboratory samples should be frozen immediately to prevent oxidation before being transported to the laboratory.
- Laboratory analysis should include Peroxide Oxidation Combined Acidity and Sulphate (POCAS), Total Oxidizable Sulphur (TOS) and grain size analysis.
- The results of the laboratory analysis should be compared to the action criteria included in the adopted guidelines.
- The action criteria are used to ascertain the need for a detailed management plan.
- All field-testing and laboratory analysis should be carried out by suitably qualified personnel.

Sampling for ASS could be completed in conjunction with the geotechnical survey provided a suitable sampling frequency could be established. SKM recommends that the appropriate NT authorities approve all proposed sampling regimes before site works commence.

Appendix E

Blacktip Project EIS: Hydrology and Water Quality prepared by EWL Sciences






This page has been left intentionally blank

Blacktip Project EIS: Hydrology & Water Quality

Prepared for: EcOz Environmental Services

Prepared by: EWL Sciences Pty Ltd

Authors: Ian Hollingsworth, Phillipe Puig, Michael Welch

July 2004

EWL Sciences Pty Ltd
Darwin Office 482 Stuart Highway, Winnellie NT 0820
PO Box 39443, Winnellie NT 0821
Tel: (08) 8922 5200 Fax (08) 8922 5260

ABN 12 000 955 171 Registered Research Agency No 31639

Blacktip Project EIS: Hydrology & Water Quality

for

EcOz Environmental Services

by

EWL Sciences Pty Ltd

Authors:

Ian Hollingsworth, Phillipe Puig, Michael Welch

July 2004

Project Manager: _____
Ian Hollingsworth

Reviewer: _____
Alan Puhalovich

General Manager: _____
Dr A R Milnes

Distribution: *Client* *2 Hardcopies and CD Rom*
EWL Sciences *Authors, Library, General Manager*

DISCLAIMER

EWL Sciences Pty Ltd ("EWLS") has had to rely on information from other persons in preparing this report (including the party for whom it is prepared) and is not in a position to, and has not, verified the accuracy or completeness of such information. Accordingly, EWLS takes no responsibility for, and assumes no liability in respect of, any information provided by others for the purpose of preparing this report, or any consequences from the use of such information.

This report is prepared only for the person to whom it is addressed and for the purpose for which it is stated to be prepared. This report and any information, statement or conclusion in it is not intended to be, and should not be, relied on or used by any other person or for any other purpose and EWLS accepts no liability for any such reliance or use.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1 INTRODUCTION **1**

1.1 Background 1

1.2 Project Objectives 1

2 BASELINE CONDITIONS **3**

2.1 Climate 3

2.2 Information Resources 3

2.3 Surface Water 3

2.4 Groundwater 7

3 IMPACTS FROM CONSTRUCTION AND OPERATION **9**

3.1 Project Components 9

3.2 Consultation 11

3.3 Impact Assessment 11

3.4 Construction 13

3.5 Operation 18

3.6 Risk Assessment & Safeguards 20

3.6.1 Conclusions 24

4 IMPACT MITIGATION RECOMMENDATIONS **27**

5 REFERENCES **31**

FIGURES

Figure 1 Surface water quality, general parameters 6

Figure 2 Monitoring bore data, Port Keats 8

TABLES

Table 1 Geographic information 4
Table 2 Key gauging stations 5
Table 3 Regional groundwater chemistry and groundwater investigation levels (GIL's) 8
Table 4 Project co-ordinates 9
Table 5 Key Blacktip development characteristics 10
Table 6 Wetland classification system 12
Table 7 Key physical and chemical water quality parameters 13
Table 8 Hydrological impact locations and areas 14
Table 9 Hydrological impacts 15
Table 10 Measures of consequence for environmental issues 21
Table 11 Likelihood of an environmental impact occurring 21
Table 12 Qualitative risk analysis matrix 21
Table 13 Risk assessment results 22

PLATES

Plate 1 Shore crossing 14
Plate 2 Gas processing plant location 18

MAPS

Map 1 Blacktip Project hydrology and infrastructure

APPENDICES

Appendix A Consultation

ACKNOWLEDGEMENTS:

- External document assistance, Kylie Harvey (EcOz),

EXECUTIVE SUMMARY

Background

A desktop survey was made to identify the potential wetland, riparian and groundwater impacts arising from the Blacktip Project. The locations of project components were overlaid on hydrogeological mapping (1:250 000), drainage (1:250 000) and raster topographic mapping (1:100 000). Intersections between project co-ordinates and high quality groundwater resources close to existing bore fields, drainage systems and wetlands were recorded as potential areas of hydrological impact. Standard methods for qualitative risk assessment were applied to rank the perceived impacts associated with the construction and operational activities of the project. A wetland classification and a matrix of water quality parameters was extracted from national guidelines for ecosystem protection. The guidelines were applied to assess surface and groundwater quality impacts. Statements of intent that we have made on behalf of the proponent are taken from the project design documentation provided to us.

Hydrology

The desktop study (using 1:100 000 scale mapping) did not identify any surface drainage in the immediate project area. Groundwater fed, near coastal wetlands occur 1 to 3 km away, down gradient to the north and south. The groundwater aquifer beneath the proposed Blacktip onshore project area is shallow, good quality and high yielding. It is a significant resource that supports nearby wetland ecosystems and will underpin agricultural and residential development in the Port Keats area into the future. The shallow depth to groundwater means that it is vulnerable to contamination through the land surface. Although the demands on the aquifer are currently minor and discharge from it supports near coastal wetlands, the high quality of the groundwater resource requires a high level of protection.

Impact Assessment & Recommendations

Potential hydrocarbon contamination of a relatively vulnerable and productive groundwater resource is the primary concern from the Blacktip project. This concern is moderate because most of the hydrocarbon at the site is volatile gas that will vent from buried infrastructure to the atmosphere. However, the condensate fraction and the fuel storage on site may potentially move directly to groundwater if a catastrophic rupture occurred. The project infrastructure and hydrological features upon which impacts were assessed are shown in Map 1.

There are knowledge gaps in understanding the risks to the groundwater resource in the vicinity of the gas plant and pipeline. Site-specific fate and transport modelling to identify potential flow paths and receptors of possible hydrocarbon contamination plumes arising from the project would help to address the risks and design an effective groundwater monitoring and spill response program. The groundwater monitoring system will need to be able to detect potential leakage of condensate and fuel hydrocarbons in particular from the Blacktip Project into the shallow groundwater system and assess impact on the receiving environment and municipal groundwater supplies. Monitoring and responding to groundwater impacts would pre-empt and reduce the risk of impact to near coastal wetlands, which are the local groundwater discharge areas. A site hydrogeological investigation is recommended once project planning is complete.

Detailed recommendations on crossing design, track construction, clearing and rehabilitation are provided in the body of this report to address potential impacts on surface water systems. Water extraction and disposal options need to be considered in consultation with landowners.

Marine or groundwaters are the preferred source for hydrotest water. The groundwater aquifer at the site could be used with a relatively low level of perceived environmental detriment for the volumes of water required for hydrotesting and ancillary services. If seawater is used, then disposal of the hydrotest water to the ocean outfall is recommended. If freshwater is used, then hydrotest water could be disposed of by land application to stable (rocky) vegetated areas. This approach would minimise impacts on surface and groundwater quality and the potential for introducing foreign plant and animals into local ecosystems.

1 INTRODUCTION

1.1 BACKGROUND

The desktop assessment of possible hydrological and water quality impacts associated with the onshore infrastructure of the Blacktip Gas Project were based on draft EIS guidelines (February 2004) that specify the documentation on baseline conditions, impact assessment and management that the proponent will need to consider.

1.2 PROJECT OBJECTIVES

The project objectives were to assess the potential environmental impacts of the Blacktip Project on surface and groundwater hydrology and recommend mitigation measures. The following assessment framework for onshore facilities from the EIS guidelines (Section 4.3 Draft EIS Guidelines February 2004) was used.

Baseline

- Provide a general description of the surface water systems that may be impacted by the onshore pipeline and gas processing facilities including storm water systems; natural and artificial catchment systems, drainage lines, wetlands and waterways; and the direction of overland flows.
- Describe the groundwater systems along the onshore pipeline route and facilities site.
- Provide details of the potential locations of pipeline waterway crossings including bed and bank profiles and describe selection criteria for determining the final crossing locations. Including information on the flow regime of the waterways in the vicinity of the pipeline, in particular the timing (and volume) of flows in relation to any construction work.

Impacts

- Describe how the pipeline and other components of the project might impact on the surface and groundwater features described above.
- Provide details of typical crossings that would be constructed at each water way crossing location and likely impacts associated with the crossing.
- Detail the options for the source and impact of water for hydrostatic testing and any other construction / operational water use, together with plans for its disposal after use.

Management

- Discuss measures to ensure the beds and banks of water courses remain stable and protected from the natural forces of erosion as required, incorporating preferred methodologies of relevant Advisory Agencies where practicable particularly where there has been any disturbance to the bank or bed.
- Discuss measures to safeguard downstream surface and ground water quality including appropriate management of any excavated acid sulfate soils and wetland crossings.

- Describe measures to address extraction and dewatering of groundwater from the trench including use of impoundment's.

Based on discussions with the proponent via EcOz, and our analysis of the available information, we understand that the onshore pipeline and gas plant will not intersect surface drainage systems. Consequently, field descriptions of bed and bank profiles have not been made. However, drainage depressions on the pipeline route not identified in the 1:100 000 scale base mapping provided to us will need to be considered during construction. The proposed scope of work was developed following consultation with *EcOz* and consideration of the draft EIS guidelines.

2 BASELINE CONDITIONS

2.1 CLIMATE

The climate is tropical monsoonal with a dry season which extends from May to September. This is followed by a wet season that typically lasts until the end of April. The mean annual rainfall in the region is about 1,400 mm, with a majority of the precipitation occurring during the wet season. Precipitation is negligible during the dry season.

2.2 INFORMATION RESOURCES

The groundwater and surface water data were obtained from the Wadeye / Nauiyu Water Study (Haig and Matsuyama 2003). Geographic information and documentation that was used is listed in Table 1. All map data is in geographic co-ordinates and WGS84 datum.

2.3 SURFACE WATER

The Blacktip onshore project area is wholly located within the Moyle River basin. The Moyle River basin (NLWRA 2000) comprises sub-catchments that are described as being unaffected by development. The average annual runoff is estimated to be around 600,000 ML / annum, with total diversions believed to be negligible. The Blacktip Gas Project is located within the southern sub-catchment of the Moyle River basin. The southern sub-catchment has an area of approximately 250 km^2. There is no well-defined surface drainage in the project area. Coastal inlets and associated mangroves with seasonally inundated inland swamps occur 2-3 km from the project area at Injin Beach to the north and around the inlet on Yelcher Beach to the south. These wetlands are down gradient of the Blacktip Project and the development activities may consequently have some impact on them via groundwater pathways in the future.

There are limited stream flow measurements. Stream gauging stations in the Moyle catchment (within 50 km of the project area) are listed in Table 2. Many of the creeks and streams have small flows at the end of the dry season. In most cases, the creeks dry up each year and do not flow again until the next wet season. There is no perennial stream network in the vicinity of the proposed development. The Port Keats gauge at Dee Creek (G8130003) is similar to that in the southern sub-catchment in which the proposed development is located.

Flows peak at the Port Keats tide gauge at the Dee River landing (G8130003) in December and January. Some of the largest flows in the region have been measured in the Daly River near Nauiyu, Tom Turners creek near Peppimenarti and the Moyle Rover between Peppimenarti and Nganmarriyang (Palumpa).

Table 1 Geographic information

Theme	File name	Source	Custodian
Outstations	Outstations.shp	(Haig and Matsuyama 2003)	Manager of Spatial Data and Mapping, Natural Systems, DIPE, NT Government ph) 08 89993603, fax)08 89993667 Address) 4th Floor Goyder Building, 25 Chung Wah Terrace, Palmerston, NT 0830, or PO Box 30, Palmerston, NT 0831
Stream gauges	All_stream_gauge_sites.shp	As above	As above
Rain gauges	All_rain_gauge.shp	As above	As above
Bores	All_keats_bores.shp	As above	As above
Evaporation gauges	All_evap_gauge.shp	As above	As above
Tracks	Tracks.shp	As above	As above
Minor roads	Roads_minor.shp	As above	As above
Major roads	Roads_major.shp	As above	As above
Catchments	Swma_geom_nat_polygons .shp	As above	As above
Hydrogeology	Keats_hydro_final	As above	As above
Sub-catchments	Sub_basins.shp	As above	As above
Seasonal wetlands	Seasonal_habitats.shp	(Gecoz 2001)	As above
Coastal wetlands	Nt wetlands.shp	(Gecoz 2001)	As above
Pipeline alignment	Pipeline_alignment_5_2004 0303_polyline.shp	Mipela (GIS) Pty Ltd	Hayden McDonald GPO Box 1152 Brisbane QLD 4001, p 07 32525589, f 07 32522477
Pipeline corridor	Pipeline_corridor_5_200402 24_region.shp	Mipela (GIS) Pty Ltd	Hayden McDonald
100K Topographic mapping	topo 100k raster mosaic	As above	As above
Project locations	Site_locations_040406.shp	Woodside	Ceri Morgan
Project Description	R11UMP_DraftA_Ch4.doc	SKM	C Morgan
10 km staging points	10k_Flags_5_20040303_poi nt.shp	Mipela	H McDonald
Drainage	Drainage_250k_polyline.sh p	Mipela	H McDonald
Roads	Roads_250k_polyline.shp	Mipela	H McDonald
Locality	Locality_250k_point.shp	Mipela	H McDonald
Hydrogeology	All_hydro_final.shp	DIPE	Lynton Fritz
Stream gauges	all_stream_gauge_sites.shp	DIPE	Lynton Fritz
Bores	all_keats_bores.shp	DIPE	Lynton Fritz

Table 2 Key gauging stations

Station	Name	Easting (AGD66)	Northing (AGD66)	Commenced	Ceased	Minimum flow (L/s)
G8130001	Moyle River at Port Keats Road Crossing	614400	8421500	8/08/66	19/07/86	5
G8130002	Tom Turners Creek at Tom Turners Crossing	623600	8431600	8/08/66	6/11/86	134
G8130003	Port Keats Tide Gauge at Dee Creek Landing	561151	8433761	6/09/79	6/11/86	NA
G8130004	Quins Creek at Road Crossing	582000	8418000	19/07/86	6/11/86	11
G8130010	Karrowa Creek at U/S Port Keats Road	617200	8428500	21/06/79	21/06/79	17

As part of the Wadeye/Nauiyu water study 108 surface water samples were collected from monitoring sites (Haig and Matsuyama 2003). About 20 samples were collected from small creeks and rivers between the Daly and Fitzmaurice rivers. Descriptive statistics for the general water quality parameters are shown in Figure 1.

The 95% Confidence Interval values from Figure 1 for pH (7.4-7.6), Electrical Conductivity (354-450 $\mu S.cm^{-1}$), temperature (21-30?C) and turbidity (73-92 NTU) are indicative of the range in baseline conditions. No permanent, fresh, surface water resources were identified in or adjacent to the proposed Blacktip gas processing facility. However, ephemeral runoff would appear to support near coastal wetland ecosystems. There is no evidence of contamination or acid generation.

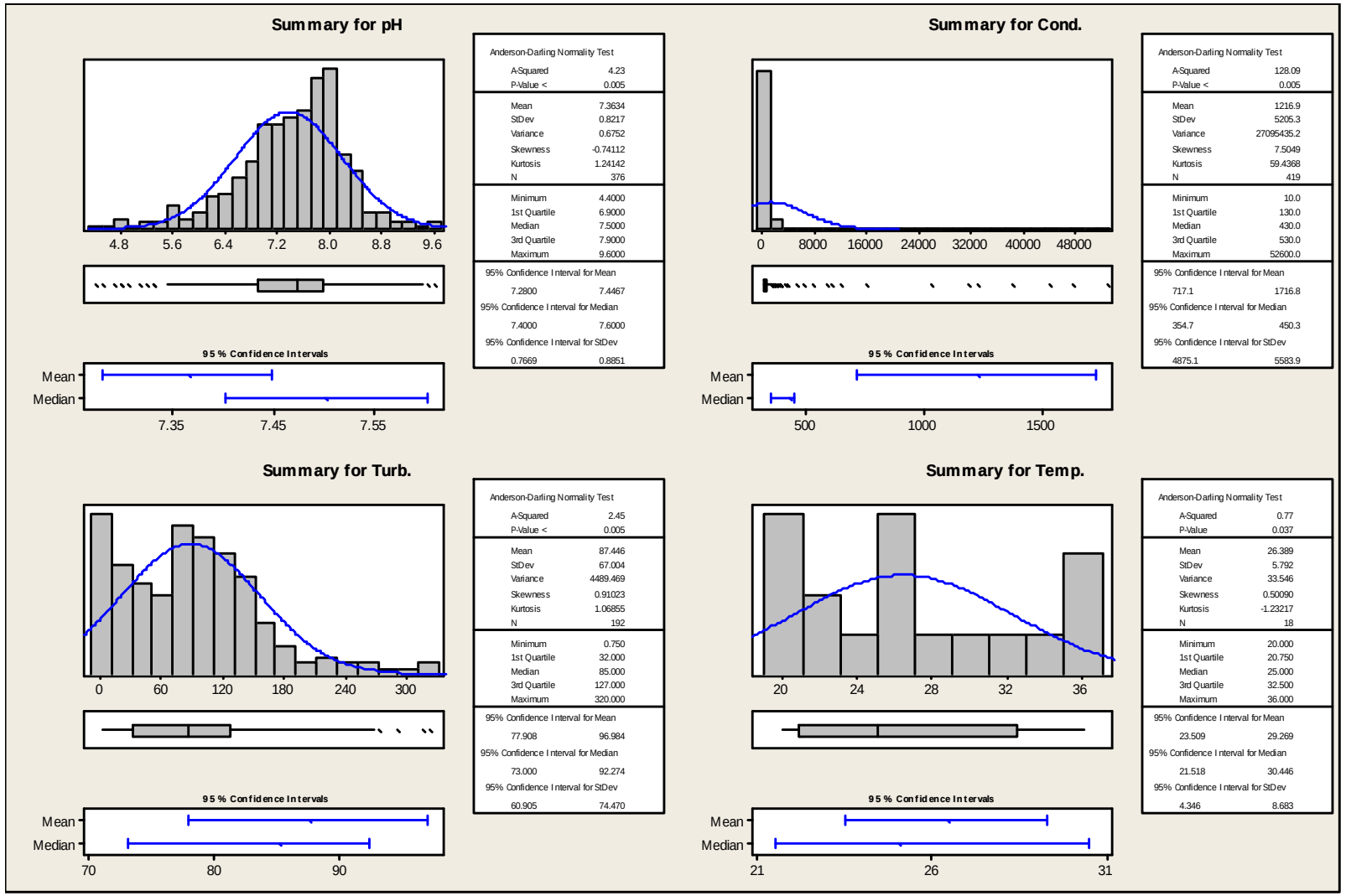


Figure 1 Surface water quality, general parameters

2.4 GROUNDWATER

Relatively shallow aquifers are present in sandstone, siltstone and claystone sediments of the Upper Permian Hyland Bay Formation. An impervious claystone at a depth of 50 to 100 metres marks the base of the aquifer. Shallow aquifers are the source of groundwater for the community of Wadeye and the outstations of Ditchi, Nangu, Kuduntiga, Ngardiniitchi, Old Mission, Kuy and Yedderr. Housing development is currently being extended along the road to the proposed development site. Shallow aquifers also have environmental beneficial uses - supporting wetlands and spring fed vegetation.

A high yielding, widespread shallow aquifer system underlies the Blacktip onshore project area. Water table depths at 10 to 15 m occur in the vicinity of the Blacktip Project. Pipeline trench excavation during the dry season is unlikely to intersect the water table. Yields commonly exceed 5 L/s and less often 10 L/s. In general, bore yields are very inconsistent and vary between 9.5 and 22 L/s. Higher yielding bores are associated with fracturing or a local source of recharge. This is a significant resource with potential to supply industrial or residential development in the future. In the view of the groundwater resources authority in the NT Government this is a community resource that requires a high level of protection.

The Wadeye community has a designated borefield for domestic water supply. The use of water from the reticulated water supply is allocated for drinking and the irrigation of lawns, community parks or football ovals. An essential service officer (ESO) with the Power Water Corporation maintains the community water supply. The Port Keats borefield has a number of monitoring bores where water levels are measured periodically. Monitoring bores were measured either monthly or once a year between 1985 and 1997. Between 1997 and 2002, there were no water level measurements made in monitoring bores.

The community production bores have production yields measured with a constant rate pump test. Community bores are usually not pumped at the maximum yield. The bores are pumped at rates that will meet community needs and storage restrictions. The bores are pumped at between 2 and 7 L/s at different times of the year. Wadeye has one high yielding bore that can be pumped at rates as high as 18 L/s if needed. Estimated daily water consumption for the Wadeye community is 1,295,000 L/day. This estimate is taken from Table 4 in the Wadeye Nauiyu water study report (Haig and Matsuyama 2003). It is based on records between 1999 – 2001, a population of 2,452 and usage of 528 L/person/day.

Certain plants, animals, and ecosystems rely on water from groundwater sources. Groundwater dependant ecosystems occur on Injin Beach to the north of the project area, and in the freshwater inlet to the south on Yelcher Beach. The Yelcher Beach inlet is the main catchment drainage system. The hyetograph of changing water levels in Port Keats (Figure 2) indicates stable groundwater levels over time. Presently the volume extracted from the municipal bore fields has not caused any noticeable impact on areas of environmental significance.

Water quality analyses from relevant outstation and community bores are summarised in Table 3, together with the groundwater investigation levels (GIL's). The GIL values, with consideration of ambient groundwater qualities, form the basis for the assessment of contaminated groundwater and associated risks and are taken from on the Australian Water Quality Guidelines (AWQG) and the Australian Drinking Water Guidelines (ADWG) as set out in Schedule B(1) Table 5-B (NEPC 1999a). The GIL values define acceptable water quality at the point of use and apply as investigation levels at the point of extraction and as

response levels at the point of use, or where there is likelihood of an adverse environmental effect at the point of discharge.

Water sampling of all outstations and community bores indicates that the water quality is generally within the *Water Quality and Monitoring Guidelines* (ANZECC 2000) as outlined by the *Australian and New Zealand; Guidelines for Fresh Water Quality*. Low ambient groundwater pH occurred at the Wadeye bore RN027211 and may indicate naturally acid conditions.

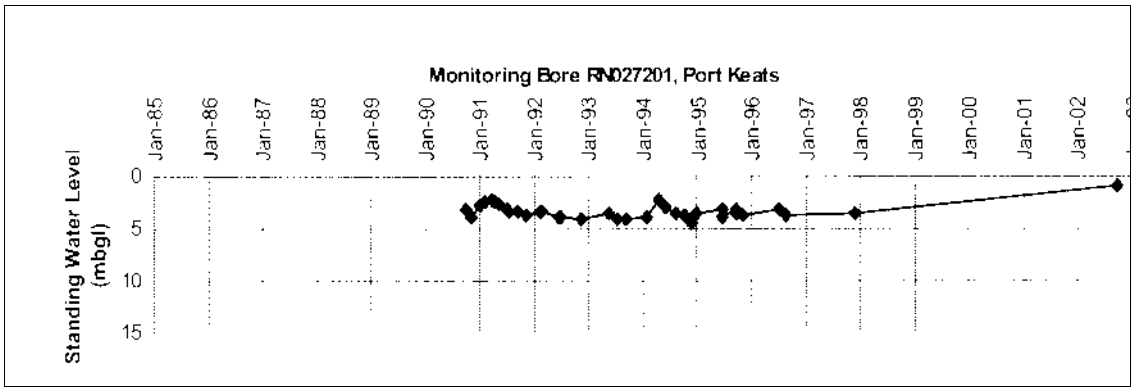


Figure 2 Monitoring bore data, Port Keats

Table 3 Regional groundwater chemistry and groundwater investigation levels (GIL's)

Bore RN	**RN025961**	**RN024308**	**RN027211**	
Outstation or community	Ditchi	Ngardinitchi	Wadeye	**GIL**
Bore yield (L/s)	10.0	5.0	22	na
pH	6.1	6.5	4.8	6.5-8
EC (µS/cm)	50	75	28	1500
Total Dissolved Solids (mg/L)	55	70	27	500
Sodium, Na (mg/L)	3	5	3	300
Potassium, K (mg/L)	4	4	1	na
Calcium, Ca (mg/L)	3	5	1	1000
Magnesium, Mg (mg/L)	1	1	1	<600
Iron (total), Fe (mg/L)	0.7	1.1	0.1	0.3
Total Hardness (mg/L)	8	17	4	na
Total Alkalinity (mg/L)	12	17	2	na
Bicarbonate, HCO3 (mg/L)	15	20	2	na
Silica, SiO2 (mg/L)	22	22	16	na
Chloride, Cl (mg/L)	6	10	6	250
Sulfate, SO4 (mg/L)	4	5	1	400
Nitrate, NO3 (mg/L)	1	1	1	na
Fluoride, F (mg/L)	0.1	0.1	0.1	na

3 IMPACTS FROM CONSTRUCTION AND OPERATION

The EIS guidelines require assessment of possible impacts from the construction and operation of the proposed development on surface and groundwater systems. Specifically in terms of:

- how components of the project might impact on the surface and groundwater features;
- details of typical crossings that would be constructed at each waterway crossing location and likely impacts associated with the crossing; and
- the options for resource use and impact of water for hydrostatic testing and any other construction / operational water use, together with plans for its disposal.

3.1 PROJECT COMPONENTS

Site location details have been taken from the project description document (Sinclair Knight Mertz 3/3/04). The co-ordinates of the project components identified in this draft document, and on which the assessment of hydrological impacts is based, are shown in Table 4. These co-ordinates represent the general location of the project and are likely to change in the final project plan. The onshore gas processing plant has a footprint of 750 by 750 m. Key project components that represent potential hydrological impact are listed in Table 5.

Table 4 Project co-ordinates

Project Component	Co-ordinates
Blacktip Reservoir	128° 27'E to 128° 30'E 13° 53'S to 13° 55'S
Export Pipeline Landfall	129°24'43"E 14°14'33"S
Onshore Gas Processing Plant	129°25'52.09"E 14°14'33.60"S 129°26'05.87"E 14°14'13.22"S 129°26'26.77"E 14°14'26.66"S 129°26'12.99"E 14°14'47.04"S
Spread Mooring for Condensate Export	129°23'27.77"E 14°14'27.65"S 129°23'19.10"E 14°14'36.58"S 129°23'10.44"E 14°14'45.52"S 129°23'01.78"E 14°14'54.46"S

Table 5 Key Blacktip development characteristics

Project element	Purpose	Characteristics
Condensate storage and export	Onshore condensate stabilisation and storage facilities	Approx. 6km pipeline for condensate export from onshore storage facilities to nearshore spread mooring. Spread mooring in 14 m water with condensate loading facilities onto tankers.
PW Facilities	Treatment of PW to remove condensate and contaminants Disposal of PW	PW treatment plant and settling ponds. Approx. 2 to 3 km pipeline (4 to 6" diameter) to ocean outfall for disposal of treated PW.
Gas Export Pipeline	Transport of reservoir fluids from wellhead platform to onshore facilities Includes shore crossing and onshore component of pipeline	Approx. 2 to 3 km from low water mark to onshore gas processing facility.
Laydown Areas	Beach storage area for pipeline sections during installation Onshore storage area for construction materials and vehicles	Pipe laydown area on the beach for pipeline construction materials 50 m x 50 m. Plant laydown area within 750 m x 750 m onshore footprint for materials, vehicles, construction camp, onshore facilities
Gas Processing Plant	Processing, compression and metering of gas	Within 750 m x 750 m footprint Slug catcher and primary liquids separation. Water and hydrocarbon dew-pointing Compressor including turbines (3 x 50%) and stacks to compress gas to 150 bar
Utilities	Support facilities for onshore processes	Power generation Firewater Instrument air, liquid and gaseous fuel systems
Accommodation	One accommodation camp will be used during all phases of the project	Within 750m x 750m onshore footprint for materials, vehicles, construction camp, onshore facilities. Up to 200 (peak) personnel during construction. The camp will be downsized following peak construction period to a capacity of approx. 40 personnel. Up to 4 operational personnel, with additional personnel as required for maintenance
Access and Haul Routes	Several options are being considered to transport provisions, equipment and personnel to and from the site during construction, operations and decommissioning	Dry season access via existing Wadeye airstrip or via road from Darwin. Wet season access via existing Wadeye airstrip or existing Wadeye barge landing. A road will need to be constructed from Wadeye to the onshore plant area.

3.2 CONSULTATION

The project officer from the supervising authority (Rod Johnson, NT Department of Environment & Heritage) and Principal Water Resources Engineer (Peter Jolly, NT Department of Infrastructure, Planning & Environment) were consulted. The scope of this discussion is given in Appendix A, with key issues identified as:

1. define the extent of disturbance associated with cathodic protection arrays (document 13832-7);
2. identify possible metal contaminants (extrusion treatments / surface coatings) associated with the pipe pressure testing using water;
3. identify possible contamination associated with epoxy mechanical / abrasion protection coatings;
4. hydrocarbon pipeline, storage and processing infrastructure in the vicinity of high quality groundwater resources, such as at Blacktip, will require detailed fate and transport assessment consistent with investigations for contaminated site risk assessment.

The proponent has provided the following information to address these issues:

Item 1. Cathodic protection (CP) arrays: shallow ground beds will probably be used in which case a trench will be dug 3 m deep, 600 mm wide and 25 m long. Eight anodes surrounded with petroleum coke (conductor) in a bag will be placed in the trenches, which will be backfilled to bury the anodes. Riser pipes will be inserted into the trenches to allow for watering if required. Beds can be up to 500m from the pipeline and are connected by a buried cable. Beds will usually be located at scraper facilities, as the CP system requires a source of power (solar).

Item 2. Potential contamination from linepipe coatings: linepipe is not coated internally and therefore will only contaminate the hydrotest water with rust. The pipe will be heated during the coating process so that any oil used in the forming of the pipe will likely have been removed. Note that the pipe is not extruded but is continuously formed from a flat strip and an Electric Resistance Weld (ERW) used to join the edges of the strip. An oxygen scavenger such as sodium sulphite may be used in the hydrotest water to minimise corrosion of the pipe. The joint coating is on the outside of the pipe and will not come in contact with the hydrotest water.

3.3 IMPACT ASSESSMENT

Assessment of surface water impact from project construction and operation was based on a national wetland classification and water quality criteria for ecosystem protection. The proposed wetland classification system in Table 6 follows that outlined in the Directory of Important Wetlands in Australia (Environment Australia 2001), which is based on the system used by the Ramsar Convention in describing Wetlands of International Importance. The proposed water quality criteria in Table 7 are based on national guidelines for environmental protection (ANZECC 2000).

Assessment of groundwater impact from project construction and operation follows the risk based approach recommended in national guidelines (NEPC 1999b). These guidelines

initially apply generic criteria (ADWG 1996; NHMRC and ARMCANZ 1996) to provide a system that responds appropriately as knowledge about the levels of protection required becomes available. Further investigations involving detailed fate and transport monitoring and modelling are triggered when and where generic criteria (NEPC 1999a) are exceeded or if there is a high level of environmental risk.

The locations of project components were overlaid on hydrogeological mapping (1:250 000), drainage (1:250 000) and raster topographic mapping (1:100 000). Intersections between project co-ordinates and high quality groundwater resources close to existing bore fields, drainage systems and wetlands were recorded as potential areas of hydrological impact.

Table 6 Wetland classification system

Wetland class	**Wetland class description**
A- Marine and Coastal Zone Wetlands (lowland river/creek)	
A5	Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets
A7	Intertidal mud, sand or salt flats
B- Inland wetlands (upland river/creek)	
B1	Permanent rivers and streams; includes waterfalls
B2	Seasonal and irregular rivers and streams
B4	Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
B10	Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes
B17 **(other wetlands)**	Freshwater springs, oases and rockpools

Table 7 Key physical and chemical water quality parameters

Water Quality Parameter	Upland river/creek	Lowland river/creek	Other wetlands	Notes
Dissolved oxygen (% saturation)	**B1, B2, B4, B10**	**A5, A7**	**B17**	
Lower Limit	90	85	90	Dissolved oxygen values derived from daytime measurements. Values may vary diurnally & with depth
Upper limit	120	120	120	
pH				
Lower Limit	6	6	6	pH's of lower than 6 are not unusual in poorly buffered upland streams (e.g. sandstone country), where respiration from decaying organic material produces CO_2, thereby lowering pH (S. Townsend, DIPE *pers. Comm.*)
Upper limit	7.5	8	8	
Salinity/Electrical Conductivity (mScm^{-1})	20-250	20-250	90-900	Conductivity in upland streams will vary depending on catchment geology. Values at the lower end of range typical of ephemeral flowing NT rivers. For other wetlands, values at lower end of range are found in permanent billabongs in the NT but generally increase in late dry season due to concentration effect of evaporation.
Turbidity (NTU)	2-15	2-15	2-200	For NT rivers, low values for base flow conditions. Wetlands vary greatly, depending on general condition of catchment or river draining into the wetland, recent flow events & water levels.
Temperature				
Lower limit	20th percentile	20th percentile	20th percentile	
Upper limit	80th percentile	80th percentile	80th percentile	

3.4 CONSTRUCTION

The project infrastructure, surface drainage, wetlands, bore locations, stream gauging locations and hydrogeological units are depicted in Map 1. Impacts to surface water drainage and freshwater aquatic life may arise in areas where sediment load into creeks is increased during the wet season as a result of land clearing and earthmoving without the establishment of sediment and erosion controls.

Project structures that will require construction on site will include the onshore gas processing plant and associated facilities, gas pipeline, access routes and a construction camp. The machinery and equipment will be brought onto the site to undertake the construction and installation activities, including compactors, welding machines, cranes and concrete trucks. The surface hydrological features that the project is likely to directly impact are identified in Table 8. Potential hydrological impacts during construction are listed in Table 9.

Table 8 Hydrological impact locations and areas

Project component	Wetland type	Code	Location
Shore crossing	Sand, shingle or pebble beaches; includes sand bars, spits	A5	*From*: Lat. -14.2425, Long. 129.412 *To*: Lat. -14.2426, Long. 129.413
Pipe Laydown Temporary: Storage of pipe lengths and other pipeline components during site preparation and construction / installation	Sand, shingle or pebble beaches; includes sand bars, spits	A5	Beach near shore crossing (area 100x100 m)

The Shore Crossing

The export pipeline crosses the shore on a beach 10km to the south-west of Wadeye. Co-ordinates of the shore crossing are provided in Table 4. The crossing site comprises sandy beach and dune facies. A photograph of the shore crossing site from the Blacktip Technical Overview presentation to the NT Office of Environment & Heritage (March 2004) is shown in Plate 1. A desktop study of acid sulfate soils in relation to the shore crossing (SKM 2004) concluded that there was a moderate to high risk of acid sulfate soils associated with the landfall and beach crossing portions of the proposed pipeline route.

The coastal and marine environment is the principal receptor of potential environmental impacts. Risks have been identified in Table 9 in relation to potential acid sulfate soils (acidity) and turbidity from disturbed soil material and hydrocarbon contamination from excavating equipment.



Plate 1 Shore crossing

Table 9 Hydrological impacts

Project Component	Receptor			Potential Impact type					
	Groundwater	Marine & coastal	Inland drainage	Chemical	Biological	Acidity	Salinity	Turbidity	Hydrocarbons
Construction									
Shore crossing									
nearshore dredging		X				X		X	X
beach / dune trench excavation		X				X		X	X
pipeline installation		X							X
backfilling		X						X	X
rehabilitation and pipeline marking		X						X	X
Onshore pipeline									
working width preparation	X		X					X	X
topsoil stripping and grading	X		X					X	X
trenching	X	X	X					X	X
stringing	X	X	X					X	X
line-up and welding	X	X	X					X	X
pipeline lowering	X	X	X					X	X
tie-in and testing	X	X	X				X		X
backfilling	X		X					X	X
rehabilitation and pipeline marking	X		X					X	X
Gas Processing Plant									
construction of access roads and an accommodation camp	X		X					X	X
vegetation clearing - lay down area	X		X					X	X
laying foundations and erecting facilities	X		X					X	X
installing equipment and systems	X			X				X	X
installing ancillaries	X			X				X	X
hydrostatic testing and pre-commissioning of systems and equipment	X	X		X	X		X		
clean up following construction	X							X	X
plant and pipeline access	X							X	X
Access & laydown areas									
Road access			X					X	X
Barge access		X						X	X
Pipe Laydown (temporary)		X						X	X
Plant Laydown (permanent)	X							X	X
Construction camp (temporary)	X		X		X			X	X
Construction material (off-site source)								X	X
Operational components									
Gas Processing Plant									
condensate storage	X								X
produced water	X	X					X		X
export Pipeline Landfall		X							X
Ancillary facilities									
Diesel & material storage	X								X
Gas flare	X								X
Water supply	X								
Drainage	X	X						X	
Accommodation	X	X						X	
Sewerage & putrescible waste	X	X		X	X				
Plant access			X					X	
Decommissioning									
Production shutdown	X	X	X					X	
Pipeline flushing	X	X						X	X
Removal of facilities	X	X	X					X	X

Onshore Gas and Condensate Pipelines

The onshore section of the export pipeline extends for approximately 2 to 3 km from the shore crossing to the gas processing plant. The onshore section of the pipeline will be designed and installed in accordance with Australian Standard AS2885, relevant legislation and licence requirements. Pipeline specifications will be similar to those of the shore crossing section. Cathodic protection via impressed current may be implemented to prevent corrosion. No significant quantity of powder over spray material would be left deposited on the 'right of way' during pipeline construction. The desktop study of acid sulfate soils (SKM 2004) concluded that there was a low to nil risk of potential acid sulfate soils associated with the proposed pipeline route.

The local groundwater system and near coastal ecosystems are the principal receptors of potential environmental impacts. Risks have been identified in Table 9 in relation to potential acid sulfate soils (acidity), turbidity from disturbed soil material and hydrocarbon contamination from excavating and pipe laying equipment.

Hydrostatic Testing

Project documentation (Morgan 2004) indicated that water for pressure testing could be extracted from surface water, groundwater or marine sources. Hydrostatic testing for the onshore pipeline and facilities will be separate from the offshore pipeline and hydrostatic test water is likely to be discharged offshore. Each 1 km section of pipe will require 1.25 ML of water for pressure testing with significantly larger volumes of water used if testing the Blacktip facility is linked to testing the Trans Territory Pipeline spreads connected to it. The water discharged from the pipeline will contain construction debris and mill scale. The water may contain residual oxygen scavenger, such as sodium sulphite, which is used to minimise corrosion of the pipe.

The local groundwater system and near coastal and marine ecosystems are the principal receptors of potential environmental impacts. Risks have been identified in Table 9 in relation to chemical, biological and saline water contamination arising from extracting and discharging possibly saline and chemically contaminated test water originating elsewhere into a local woodland, wetland or marine environment.

Plant Access and Laydown Areas

No road, river or stream crossings were identified between the shore crossing and the gas plant. However, the proponent is considering the following options for access to the onshore processing plant and pipeline during the construction phase:

- existing roads from Darwin to Wadeye and proposed road to plant
- use of existing boat ramp near Wadeye followed by road to facilities
- beach landing or prepared landing ramp in the vicinity of the pipeline landfall to bring in equipment and construction materials.

The crossing over the headwaters of Sandfly Creek on the unsealed access from Wadeye airport to the pipeline landfall represents a potential impact on surface water quality.

The proponent intends to transport large loads required during construction on trailers by barge (either landing barge or flat top) to the beach near the pipeline landfall. Either barge type would require some earthworks on the beach to support the trailers, and a dry weather, heavy duty access road would be required from the beach landing to the plant site. The temporary laydown area (100 x 100 m) for line pipe during construction is located on the beach near the shore crossing.

The inland and near coastal and surface drainage systems are the principal receptors of potential environmental impacts. Risks have been identified in Table 9 in relation to turbidity and hydrocarbons in runoff from roads, tracks and lay down areas discharging into drainage lines and coastal environments.

Gas Processing Plant

The location of the Gas Processing Plant is depicted in Plate 2. The receptors for impacts from gas plant construction are local groundwater systems and the near coastal wetlands that groundwater discharge supports. Inland drainage system receptors are remote from the site. Potential impacts from construction and operation are associated with turbidity from disturbed land, hydrocarbons and chemicals.

Construction Camp & Workforce

The temporary construction camp will cater for a maximum of 200 personnel within the 750x750m^2 onshore footprint. The majority of the camp will be removed once construction is complete, although facilities will remain on site for the life of the project to accommodate operations and maintenance personnel. The construction workforce will range from 60 to 130 personnel, operations will consist of approximately four staff and maintenance will peak at 20 to 40 personnel every three years. Water supply for the camp will be extracted from a bore within the onshore footprint. Wastewater disposal will incorporate sewage, septic, adsorption trenches or bio-filter treatment of effluent.

The local groundwater system and near coastal wetlands are the principal receptors of potential environmental impacts. Risks have been assessed in relation to biological and hydrocarbon contamination in recharge and turbidity in runoff.

Construction Material

Sources of sand and aggregate for construction have not been finalised. The project may make use of igneous rock sources of aggregate such as a dolerite from three small deposits adjacent to the Moyle River. Regardless of the sources used for sand and aggregate in construction they are unlikely to directly impact on the immediate project area. However, environmental guidelines for extractive industries in the Northern Territory would apply to any borrow areas that are developed.

The localised groundwater systems and inland drainage systems are the principal receptors of potential environmental impacts. Risks have been identified in Table 9 in relation to hydrocarbon contamination in recharge and turbidity in runoff.



Plate 2 Gas processing plant location

3.5 OPERATION

The Gas Plant, Condensate Storage and export

The gas processing plant consists of various systems to separate the reservoir fluids and produce dry gas suitable for export. The plant will be operated for 24 hours a day, seven days a week. The proponent envisages that two storage tanks will be required to store the condensate and these will be located within the onshore processing plant. Condensate will be pumped offsite, on a batch basis of up to 1000 bpd per day, via the condensate pipeline to a spread mooring. The volume of hydrocarbon being processed, stored and exported over the life of the project represents a significant environmental hazard.

The local groundwater system and near coastal and marine environments are the principal receptors of potential environmental impacts. Risks have been identified in Table 9 in relation to hydrocarbon contamination in recharge and subsequent discharge into receiving environments.

Rupture of buried liquid natural gas pipeline infrastructure will be a hazard to groundwater. Natural gas is lighter than air and in the event of a pipeline rupture, a considerable volume of gas could be released and vaporised. The potential impacts of a catastrophic rupture are therefore less than from an oil pipeline. The impacts of such an event could include freezing of soil in the vicinity of the rupture, vegetation dieback and impacts on soil dwelling animals caught in the upwelling zone and impacts on surface animals and birds in the immediate vicinity. The impacts would be localised.

Rupture of buried condensate export pipeline infrastructure will be a hazard to groundwater. Project documentation (Morgan 2004) indicates that the condensate will be lighter than gas after it is stabilised. However, in the event that liquid petroleum condensate is produced and piped or stored in buried infrastructure there is a risk that a catastrophic rupture could lead to groundwater contamination that may be extensive. In this respect, the

location of buried condensate storage and transport infrastructure in relation to water supply bores and groundwater discharge areas needs to be carefully considered.

Produced Water

Produced Water (PW) is potentially saline and will probably be discharged to the ocean outfall (Morgan 2004). Hydrocarbons and corrosion inhibitors may be removed in settling ponds prior to ocean outfall discharge. The produced water constitutes a slight hazard to the onshore environment in the event that buried infrastructure leaks PW to the groundwater system.

Groundwater and marine & coastal systems are the principal receptors from any Produced Water (PW) treatment and disposal system. Risks have been identified in Table 9 in relation to salinity, chemical and hydrocarbon contamination in recharge and subsequent discharge into receiving environments.

Ancillary Facilities

The level of activity at the site during the operational phase will influence the degree of environmental hazard. The following activities are described in the project description document (Morgan 2004). A workforce of two to four personnel will undertake daily maintenance of the facilities along with standard operations activities. The processing plant will be operated 24 hours a day, seven days a week throughout the year. The two to four personnel required to operate the plant will be accommodated on site and will operate on a shift basis. Activity will increase when full-scale maintenance operations are undertaken every three years for a period of three to five days during which operations will be shutdown. This will require 20 to 40 additional personnel. Accommodation facilities will be provided for the additional personnel in the plant, who will travel to the onshore facilities using established access routes. Testing of equipment and replacement of the silica used for gas processing will be undertaken. There will not be any silica disposed on site.

Diesel for power and equipment such as pumps, generators, compressors and machinery will be stored in drums during construction. Diesel will also be used to power fire pumps and to back-start the gas generator during processing plant operation. Diesel storage facilities during the operational phase of the project are located onshore, within the processing plant laydown area, and consist of bunded tanks or drums. A 1,000 to 2,000 L capacity tank will be used to store diesel for the emergency generator and firewater pumps.

There is a risk that wastewater, fuel and chemical storage systems could contaminate the shallow groundwater aquifer, with subsequent impacts on local wetlands. The risks associated with biological contamination from waste treatment and disposal systems could be exacerbated by ineffective site drainage. Groundwater is the principal receptor while hydrocarbons and biological contamination are the contaminants of concern identified in Table 9. A low level of risk exists of turbid runoff water in the site drainage system entering near coastal wetland environments.

Decommissioning

The decommissioning objective is to close down operations and abandon the development area leaving the environment as near as practicable to its original condition.

Decommissioning of the proposed Blacktip Development is expected to occur approximately 40 years after start-up and will most likely include:

- shutting down of production processes;
- flushing of pipelines and sub-sea facilities;
- plugging and abandonment of wells; and
- removal of onshore facilities.

Land disturbance and infrastructure flushing during decommissioning represent some hazard to receiving environments. Near coastal wetland and marine environments are the principal receptors. Turbidity in runoff and hydrocarbons in offshore disposal of pipe and plant flush water are the contaminants of concern identified in Table 9.

3.6 RISK ASSESSMENT & SAFEGUARDS

A qualitative risk assessment was conducted using the Australian Standard AS/NZS 4360:1999 *Risk Management*. The system of assessment combines *likelihood* of possible contaminants impacting on recognised receptors (and hence causing detriment) and the consequences of the event occurring.

The measures of *consequence* used in the detailed risk analysis are listed in Table 10. From the design documentation and baseline information we estimated *likelihood* of a failure occurring (Table 11). In particular, the likelihood that a failure occurs in the gas facility and onshore pipeline during the life of the project can be moderated based on design consideration. The consequence (Table 10) and likelihood (Table 11) allocations were multiplied to rank and prioritise the issues in a risk analysis matrix (Table 12).

Contaminant types from the project description (Morgan 2004) are listed in Table 13 with the consequence and likelihood allocations from the risk analysis (key provided in Table 12) to the public and/or the environment. A column headed "Residual Risk" has been included in Table 13 to identify where mitigation measures can be applied to high risk activities to reduce the incidence of failure and consequently reduce the residual risk ranking. Issues with a score of less than 6 are considered a moderate to low risk but further consideration in the design and/or incorporation into the Environmental Management Plan may be justified based on the precautionary principle.

The issues flagged as having moderate risk rankings in Table 13 were associated with:

- turbidity and acid sulfate soil risks at the shore crossing;
- discharge of poor quality water from hydrostatic testing of the onshore pipeline and gas plant;
- seepage and runoff contamination from laydown areas and construction camp facilities including waste treatment and fuel/chemical storage; and
- hydrocarbon contamination from condensate storage/transport facilities during project operation and decommissioning.

Table 10 Measures of consequence for environmental issues

Consequence		Description
1	Insignificant	Negligible impact remediated by site personnel using standard operating procedures.
2	Minor	Minor on-site surface contamination. Short-term environmental impact remediated by site personnel. Environmental consequences for <6 months.
3	Moderate	On-site surface and phreatic zone contamination. Medium-term environmental impact remediated by site personnel. Environmental consequences for 6<12 months.
4	Major	Off-site impact to external receptors via groundwater pathways. Medium to long term environmental and community health impacts remediated by specialised non-site personnel. Environmental consequences for 1-2 years.
5	Catastrophic	Off-site major deterioration in the water resource resulting in visible and/or severe contamination resulting in permanent or long-term loss of beneficial use. Environmental consequences for >2yrs.

Table 11 Likelihood of an environmental impact occurring

Occurrence		Description
1	Rare	Impact may occur in exceptional circumstances
2	Unlikely	Impact could occur based on design option used
3	Moderate	Impact could occur at some time in the life of the project based on the design option used
4	Likely	Impact will probably occur at some time in the life of the project based on the design option used
5	Almost certain/currently occurring	Impact expected to occur in most circumstances, including already occurring

Table 12 Qualitative risk analysis matrix

LIKELIHOOD	CONSEQUENCE				
	1 INSIGNIFICANT	**2 MINOR**	**3 MODERATE**	**4 MAJOR**	**5 CATASTROPHIC**
1. RARE	1	2	3	4	5
2. UNLIKELY	2	4	6	8	10
3. MODERATE	3	6	9	12	15
4. LIKELY	4	8	12	16	20
5. ALMOST CERTAIN	5	10	15	20	25

Key			
	LOW RISK	1 to 4 points	Low risk expected, apply precautionary principle
	MODERATE RISK	5 points	Moderate risk of low level, possibly chronic impacts (occur continually)
	HIGH RISK	6 to 9 points	High risk expected
	EXTREME RISK	10 to 25 points	Extreme risk expected

Table 13 Risk assessment results

	Impact type	Likelihood	Consequence	Risk ranking	Residual risk[1]
Construction					
shore crossing	Hydrocarbons	3	1	3	
	Turbidity	2	3	6	
	Acid drainage	2	3	6	
onshore pipeline	Hydrocarbons	3	1	3	
	Salinity	2	2	4	
	Chemical additives	3	2	6	
	Turbidity	2	2	4	
gas plant	Hydrocarbons	3	2	6	
	Turbidity	2	2	4	
plant access & laydown areas	Hydrocarbons	3	2	6	
	Turbidity	2	3	6	
construction camps	Hydrocarbons	2	3	6	
	Turbidity	2	3	6	
	Biological	2	3	6	
Operation					
gas processing	Hydrocarbons	2	3	6	
condensate	Hydrocarbons	2	4	8	6
produced water	Hydrocarbons	1	1	1	
	Turbidity	2	1	2	
	Salinity	2	2	4	
	Temperature	2	2	4	
Export pipeline landfall	Hydrocarbons	2	3	6	
ancillary systems	Hydrocarbons	2	4	8	6
	Chemicals	2	3	6	
	Turbidity	2	1	2	
	Biological	2	3	6	
Decommissioning					
gas plant	Hydrocarbons	2	3	6	
	Turbidity	3	2	6	
export pipeline	Hydrocarbons	2	3	6	

Fuel storage and condensate storage and transport during Blacktip operations were flagged as having a high risk ranking in Table 13. This ranking is based on the perceived potential for major off-site impact to external receptors via groundwater pathways; medium to long-term environmental and community health impacts; and the need for remediation by specialised non-site personnel with medium term environmental consequences (Table 10).

Moderate residual risk rankings for impacts from buried condensate and fuel storage and transport infrastructure in Table 13 indicate that hydrocarbon leakage to groundwater is unlikely during the life of the project if the following mitigation measures are considered in the design:

[1] Residual risk for high risk activities after mitigation measures or safeguards outlined in Section 3.6 have been applied

- storing hydrocarbons above ground;
- regular hydrocarbon inventory measurement and record reconciliation;
- leak detection systems and regular visual inspection for leaks; and
- underground tank designs incorporating a double wall with an interstitial space that can be monitored, corrosion protection, overfill protection and removal or transfer connections located within a spill containment device.

The potential impact from extraction and disposal of hydrotest water will depend on the chemistry of the source (marine or groundwater) and whether it is disposed of to surface streams, land application or ocean outfall. If surface water is extracted:

- aquatic biota may be physically removed from water bodies by pumping.
- substantial/complete abstraction of water from small water bodies may impact on aquatic ecosystems by removal of dry season refuges, therefore affecting species composition/abundance.
- translocation of water from one water body to another poses a risk of introducing non-endemic aquatic biota, therefore changing species composition and predator-prey relationships.
- change in physical/chemical properties (e.g. temperature, pH, salinity) of water may impact on aquatic biota by changing species composition/abundance.

If groundwater is used and discharged into inland or near coastal waterways, a change in the physical/chemical properties (e.g. temperature, pH, salinity, chemical additives) of water may impact on:

- aquatic biota by changing species composition/abundance; and
- drinking water quality.

Using groundwater or marine sources for hydrostatic testing and disposal by land application away from drainage lines or offshore will avoid impacts on inland and near coastal water bodies. Because the local aquifer has a potentially high yield, the impact of local groundwater extraction (of the volumes being considered for hydrotesting) on the local water table level should be slight. The offshore disposal option would remove any potential for impact to the onshore hydrological environment.

The risk of hydrocarbon spillage from excavation equipment is low, providing that effective safety and spillage response systems are in place. The risk of turbid runoff from disturbed land impacting on marine & coastal areas and inland drainage systems is also low, providing that standard sediment & erosion control planning measures will be implemented, as no surface drainage features were identified.

The construction camp and workforce facilities present risks to groundwater quality from fuel/oil spills and biological contamination from sewage and putrescible wastes generated from the accommodation camp. Wastes will need to be treated and/or disposed of in accordance with regulatory requirements. Vehicle maintenance and refuelling in contained areas will prevent ad hoc, localised contamination.

The perceived high risk from condensate and fuel contamination to groundwater via buried pipeline and storage infrastructure is due to:

- the long life of the project;
- the volumes of gas and condensate being processed and exported;
- historical problems with leakage from buried fuel storage tanks; and
- the high resource value of the underlying, shallow groundwater system.

Corrosion is a key risk management issue to be mitigated by cathodic protection and anti-corrosion treatment of the line pipe in particular. The large intertidal range at the landfall has warranted consideration of anti-corrosion coating design.

The standard risk management approach (NEPC 1999b) warrants site specific investigation into the fate and transport of contaminants that present a greater than moderate risk in the local hydrogeological environment. Also, a clear account of impacts from some of these contamination processes will be required at specific receptor sites during the life of the project.

Mitigation measures would reduce the likelihood of a hydrocarbon contamination, and consequently the overall risk ranking from high to moderate. However, the susceptibility of the local aquifer to contamination, the proximity of the Wadeye borefield and the proximity of groundwater discharge areas (wetlands) warrants site specific investigation into the fate and transport of heavier than air hydrocarbons in the gas condensate and fuel storage system.

The types and quantities of chemicals required for production, maintenance and operation are not yet known. However, chemicals that may be stored on site could include acids and solvents, glycol, surface active agents and detergents, defoamers, lubricating fluids and greases, hydraulic oils/fluids, paints, inhibitor chemicals (e.g. corrosion and scale inhibitors), specialised cleaning fluids, and cooling system treatment chemicals. Removing chemicals from site when not in use will reduce risks.

The settling ponds and piped discharge line in any Produced Water treatment and disposal system represent a low risk to the groundwater resource. The risk factors are principally hydrocarbons and salinity. The settling ponds may not be used. In this event there will be no risk to the local groundwater system from this source.

3.6.1 Conclusions

Construction

There is a low to moderate risk of hydrocarbon spillage, turbidity and acid sulfate soil impacts on surface water during construction. The unsealed road from the Wadeye airport to the project site will require upgrading and installation of culverts. A low risk of turbid runoff from land disturbed during clearing the pipeline corridor, access tracks and gas processing plant and laydown areas impacting on marine & coastal areas and inland drainage systems was assessed.

The receptors for impacts from gas plant construction are principally groundwater and near coastal wetland systems supported by groundwater discharge. The potential impact types include turbidity, hydrocarbons and chemicals used to hydrostatically test the gas plant. Extraction and disposal of the water used to test the integrity of pipeline, gas storage and processing equipment prior to commissioning presents a moderate risk of impact on groundwater and near coastal surface water systems.

Sources of sand and aggregate for construction have not been finalised. However, NT government environmental standards for extractive industries will need to be followed.

Operation

There is high level of risk over the long term to groundwater resources from hydrocarbon processing, storage and export and fuel storage and distribution. This can be mitigated by engineering design such that failure during the project life becomes highly unlikely. However, because the groundwater resource is shallow and high yielding, it is both susceptible to contamination and potentially an important resource for community development. Consequently, anti-corrosion coating design and cathodic protection systems are warranted.

The groundwater resource at the site has *realistic future* uses in support of industry and residential development. This potential, together with its shallow depth, making it vulnerable to contamination through the land surface, mean that site specific assessment of contaminant fate and transport is warranted. The NEPM guidelines for groundwater investigations and groundwater risk assessment on contaminated sites indicate that a simulation modelling approach to explore different exposure scenarios and several potential receptors (water supply and ecosystem). Modelling is a relatively cheap alternative to directly investigating all data gaps and is the primary method for identifying receptors. Groundwater can be considered to be contaminated whenever there is a change in water quality that produces a noticeable or detectable change in its characteristics (National Water Quality Management Strategy definition). Consequently, monitoring is needed to detect change in groundwater quality and the risk assessment process must consider any impact from site contamination on groundwater quality which causes groundwater parameters to differ from ambient quality..

A low to moderate risk of impacts was assessed on surface and groundwater quality from the construction camp and workforce and monitoring and maintenance operations. Surface drainage systems are remote from the immediate site and unlikely to be impacted upon. Potential impact types include turbidity, hydrocarbons and biological contamination. Corrosion will be a chronic risk management issue.

Baseline water quality information for groundwater at the Blacktip Project is incomplete and not a sufficiently reliable basis for a groundwater quality monitoring program. Tidal influence in the nearest surface drainage system, the tidal inlet on Yelcher Beach to the south of the project area would make surface water monitoring of project impacts problematic. However, monitoring groundwater beneath the site and in the groundwater flow field between the site and the receiving environment in near coastal water bodies and municipal bore fields would give pre-emptive advice of any likely impacts on surface water environments.

Decommissioning

Decommissioning of onshore facilities will involve the removal of the gas processing plant, condensate and PW treatment systems, and all associated utilities and infrastructure. The final decision in regard to best approach to the subsea and onshore components of the pipeline must minimise potential environmental impacts and comply with legislative requirements, relevant Australian Standards and industry practice in force at the time of abandonment. Consequently, the pipeline may remain intact after decommissioning.

4 IMPACT MITIGATION RECOMMENDATIONS

Recommendations and statements of intent from the proponent may need to be changed as particular aspects of the project design are completed. During the construction phase of the project, mitigation actions need to address the moderate risks of environmental impact that are associated land disturbance on the near coastal and marine environment and on ensuring a high level of environmental performance during the operational phase of the project. During the project operation, mitigation actions are focussed on addressing the moderate risks of environmental impact that are associated with the processing, storage and transport of hydrocarbons. Site security, maintenance and monitoring activities will be important components of the risk management system. During the decommissioning phase of the project, mitigation actions are focussed on minimising the risk of turbidity arising from land disturbance on receiving wetland and coastal environments, and meeting stakeholder expectations of the closure process.

Specific recommendations arising from our desktop review of risk the surface and groundwater hydrology follow.

1. As a general principle, confining construction and operational activities involving land disturbance in the second and third quarters (dry season months between May and September) will reduce environmental risks associated with the project.

2. At the shore crossing, effective safety and spillage response systems need to be implemented to minimise the risk of hydrocarbon spillage from excavation equipment.

    - Identify potential acid sulfate soils and if necessary implement an acid sulfate soil management plan in line with the recommendations in the main EIS report.

3. An effective sediment and erosion control program will minimise impacts from turbidity in runoff during construction and operation. We recommend the proponent develop and implement a sediment and erosion control plan that:

    - follows guidelines for the control of erosion and sedimentation at construction sites (Witheridge and Walker 1996) and NT soil conservation guidelines (Hadden 1993);
    - demonstrates control of all drainage onto, and leaving disturbed areas at all times;
    - includes prefabrication of onshore facilities, including the gas processing plant and ancillary systems, as far as practicable offsite, transporting to site, and constructing within the lay down area to minimise or control potential impacts on groundwater and surface water systems;
    - includes reinstating the ‘running track’ along the right of way (ROW) or working width by:
        - loosening excessively compacted soil by harrowing, ripping or equivalent;
        - reinstating sub-soil and topsoil layers over the cleared area;
        - respreading cleared vegetation leaving only a 4WD track with surface drainage;
        - disposing of any large rocks in an acceptable manner to landowners;
    - ensures that any quarrying or extraction complies with the appropriate NT Government regulations relating to extractive industries and borrow pit remediation;

- manages access route and laydown area construction to mitigate potential impacts from turbidity on surface water and hydrocarbons on groundwater resources by:
    - installing culverts on the unsealed access road from Wadeye;
    - restricting road access to the dry season;
    - specifying the precautions to be taken to minimise the potential impacts associated with land disturbance and road use in the sediment & erosion control plan;
    - restoring areas used for barge landings when construction is completed to mitigate ongoing risks to the coastal environment.
- takes precautions during access track construction and pipeline installation to contain sediment, minimise erosion and stabilise the work area when watercourses, drainage depressions and wetlands are crossed. The suggested design guidelines for crossings are:

A. Pipeline crossings

- construct pipeline crossings at right angles to the direction of water flow;
- clear felled trees from the floodplain if there is the potential for this material to cause damage downstream if they are carried away in flood waters;
- minimise clearing of riparian vegetation;
- maximum 6 m width of disturbance;
- maximum of 0.6 m of cut and fill;
- construct in a stable (straight) stream section;
- cross along the shortest possible route;
- prevent crossing from storing or diverting water;

B. Vehicle crossings

- gravel or rock cover the approaches, otherwise track layout and drainage design will be needed to prevent water from running down the approaches and into the stream;
- make service track approaches to water courses as level as practicable, otherwise gravel cover the wheel tracks on the approaches;
- protect access to a gully or water course with a diversion channel immediately above the access cut;
- avoid box cuttings in road construction as they present drainage problems, otherwise establish diversion drains to facilitate cross drainage;
- direct access down banks in the downstream direction;
- clear all fill material from the water course not used to backfill excavations;

C. Permanent crossings

- do not use fords where the stream has a deep cross-section requiring considerable excavation on the approach roads;
- consider the effects of debris blockages and erosive forces caused by overtopping flows in culvert design;

- make culverts 450 mm diameter or larger and discharge over stable surfaces (not fill);
- make the culvert flow area approximately equal to the in-bank area of the watercourse;

D. Temporary crossings

- locate crossings on sites with stable stream bed material where bank restoration will be possible;
- time construction activities to coincide with dry weather;
- restore bed and bank profiles to as near as possible to their original condition;
- drain approaches to prevent runoff flowing directly into the stream.

4. Implementing a water management plan with respect to hydrostatic testing, potable water supply and wastewater disposal will reduce the risk to receiving water bodies. We recommend that the proponent develops a water management plan:

- specifying consultation with landowners is made prior to hydrotesting to develop an agreed plan for extracting and disposing of test water;
- stipulating marine or groundwater sources are used for hydrotest water;
- if seawater is used, then disposal of the hydrotest water to the ocean outfall is recommended;
- if a groundwater source is used, then disposal of hydrotest water by land application to stable (rocky) vegetated areas could be considered;
- ensuring trench dewatering (if any) is disposed of by land application;
- ensuring the water quality criteria for receiving surface and groundwater systems are met (Table 7);

5. Design of condensate, chemical & fuel storage and waste water treatment facilities will reduce long term risks to the hydrological environment. We recommend that the proponent:

- stores hydrocarbons above ground;
- makes regular hydrocarbon inventory measurement and record reconciliation;
- implements leak detection systems and regular visual inspection for leaks; and
- designs underground storage tanks incorporating a double wall with an interstitial space that can be monitored, corrosion protection, overfill protection and removal or transfer connections located within a spill containment device.
- constructs bunds around condensate storage tanks as per legislative requirements such as the *Explosives and Dangerous goods Act 1961*, and the *Explosives and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations 1992*;
- designs fuel & chemical storage facilities and handling equipment according to legislation and Australian guidelines to prevent and contain any spills;

- designs drainage systems on based on:

- measured soil hydraulic properties, design storm intensities and the topography of the site providing drainage for storm water and process wastewater within the 750 m^2 footprint of the facility;
- controlling surface drainage and wastewater discharge from the site to minimise local flooding;
- capturing any contaminated water generated by equipment wash down during maintenance;
- providing bunded drains around equipment that could leak lubricant, diesel or other substances;
- directing any contaminated storm water or process wastewater to a treatment system and ultimate off-shore disposal via the PW system; and
- treats and disposes of sewage and putrescibles generated from the accommodation camp according to NT government codes of practice.

6. An effective groundwater monitoring program will assure stakeholders of environmental performance and identify any hydrological impacts in a timely way. We recommend that the proponent:

   - implements a fuel inventory and reconciliation procedure to identify leaks;
   - implements a site-specific groundwater modelling approach to assess the fate and extent of possible groundwater contamination plumes from fuel and condensate storage and transport facilities and assess possible impacts on environmental and drinking water uses;
   - ensures that values for hydraulic conductivity, contaminant load and degradation rates underpinning a modelling approach are accurate
   - monitors groundwater level and quality to identify leakage and potential impact from onshore pipeline, condensate storage & transport and diesel & chemical storage on the local groundwater system;
   - is able to use the groundwater monitoring data to support predictions of contaminant fate and transport made on the basis of site specific modelling.

7. A plan for decommissioning and rehabilitation developed in consultation with relevant authorities and stakeholders will help to ensure that the area is suitably rehabilitated with acceptable levels of risk and impact remaining to surface and groundwater beneficial uses at the end of the project. We recommend that the proponent:

   - determines and agrees on decommissioning activities and implementation with stakeholders in accordance with legislation, guidelines and industry best practicable technology; and
   - plans to flush residual hydrocarbons out of the onshore pipeline; and
   - makes a decision in regard to best approach to the onshore component of the pipeline that will minimise potential environmental impacts and comply with legislative requirements, relevant Australian Standards and industry practice.

5 REFERENCES

ADWG (1996) ' Australian Drinking Water Guidelines - Summary.' (Australian Wastewater Association PO Box 388 ARTAMON NSW 2064)

ANZECC (2000) 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality.' (Australian and New Zealand Environment and Conservation Council)

Gecoz (2001) Northern Territory Oil Spill Response Atlas: Estuaries / Rivers and Coastal Wetland Datasets. In. (NT DIPE: Darwin)

Hadden K (1993) 'Soil Conservation Handbook for Parks & Reserves in the Northern Territory.' Conservation Commission of the Northern Territory, Number 54, Darwin.

Haig T, Matsuyama A (2003) 'Water resources of Wadeye (Port Keats) and Nauyiu (Daly River) Region.' (NT Department of Infrastructure, Planning and Environment: Darwin)

Morgan C (2004) 'Blacktip Project Description.' Sinclair Knight Merz, WV02540.700.

NEPC (1999a) Schedule B (1) Guideline on the Investigation Levels for Soil and Groundwater. In 'Assessment of Site Contamination'. (National Environment Protection Council: Canberra)

NEPC (1999b) Schedule B(6) Guideline on Risk Based Assessment of Groundwater Contamination. In 'Assessment of Site Contamination'. (National Environment Protection Council: Canberra)

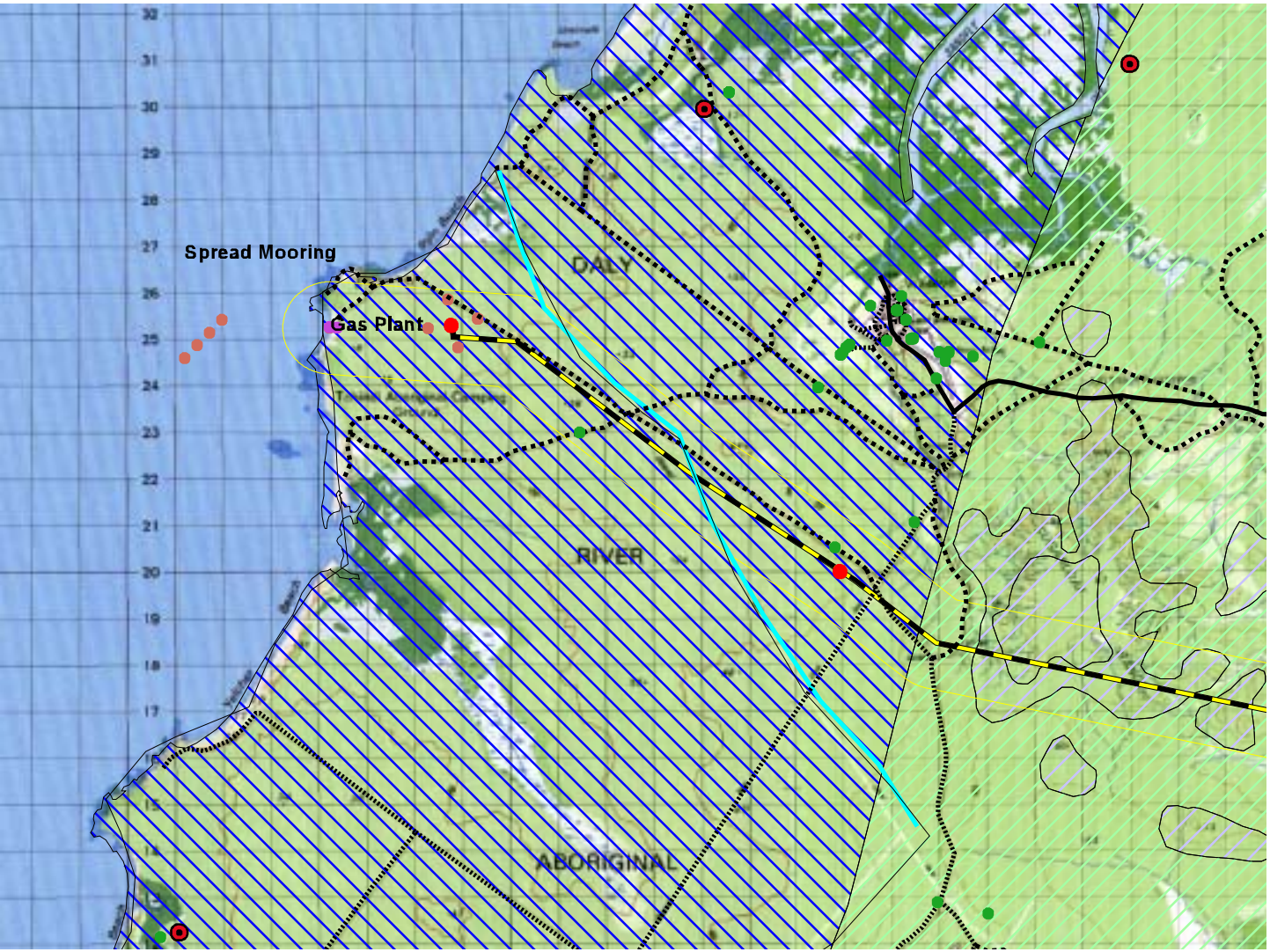
NHMRC, ARMCANZ (1996) 'Australian Drinking Water Guidelines.' (National Health and Medical Research Council & Agricultural and Resource Management Council of Australian and New Zealand, Australian Government Publishing Service)

NLWRA (2000) Australian Surface Water Management Areas. In. (National Land and Water Resources Audit)

SKM (2004) 'Blacktip development onshore plant site and gas pipeline route, Wadeye / Port Keats, Northern Territory
Desktop Assessment of Acid Sulfate Soils.' Sinclair Knight Mertz, Perth.

Witheridge G, Walker R (1996) 'Soil Erosion and Sediment Control Guidelines.' (Institution of Engineers, Queensland Division)

Map 1 Blacktip Hydrological Impacts



Legend

- Bores
- 10k flags
- Outstations
- tracks
- minor roads
- major roads
- wetland impacts
- Site locations
- Sub-basins
- Pipeline alignment (3 March 2004)
- Pipeline corridor (24 Feb 2004)

hydrogeology

- large supply
- sandstone plateau
- homeland supply (locally fractured aquifers)
- homeland supply (shallow aquifers)
- small homeland supply
- small homeland supply (locally fractured aquifers)
- no water

5 0 5 10 15 20 Kilometers

EWL Sciences

648_idh_01

APPENDICES

Appendix A
Consultation

Memo outline of consultation with DIPE – 7 April 04



memorandum

TO : Peter Jolly & Rod Johnson
COPIES :
FROM : Ian Hollingsworth
REF : 577, 648
SUBJECT : **Blacktip and TTP EIS – Hydrological Impacts consultation on approach**
DATE : 7 April 2004

Information sources for hydrological resources and beneficial uses

- Wadeye / Nauiyu Water Study (NT Gov. Sept 2003)
- Environmental Water Requirements of the Daly River (NT Gov. March 2003)
- West Arnhem Land Water Study (NT Gov.)
- East Arnhem Land Water Study (NT Gov.)
- 1:250 000 vector drainage and road data

Selection criteria for pipeline crossing location and design

- Crossing selection criteria:
- straight section of stream bank
- low bank profile

Crossing design:

- perennial watercourses – directional drilling
- intermittent water courses and wetlands – open trenching

Crossing construction:

- bank profile reinstatement
- reinstatement of bed material
- dry season operation (May – September)

Impact assessment criteria

- Wetland Classification – based on Directory of Important Wetlands in Australia
- Water quality criteria – pH, EC, temperature, turbidity, dissolved oxygen
- Assessment of risk to bore fields – flow path length criteria of 100 m

Advisory guidelines for waste water impoundments

- Volume
- Distance from water courses

Advisory guidelines for bed and bank stabilisation

- Timing
- Surface treatment
- Minimising impact

REPORT FOR REVIEW

REPORT TITLE:	Blacktip Project EIS
JOB NO:	Hydrology & Water Quality
SENIOR AUTHOR:	
TARGET DATE FOR SUBMISSION TO CLIENT:	

REPORT REVIEWER(s):_____

PLEASE COMMENT: - IMMEDIATELY/ASAP/WITHIN A WEEK

(circle appropriate time frame),

and make specific comments as appropriate directly on the report.

	Signature
GENERAL COMMENTS	
THE DATA PRESENTED ARE ACCURATE, COMPREHENSIVE AND RELEVANT TO THE SCOPE OF WORKS	
From the viewpoint of someone **not specialising in this technical area,** the report reads well and addresses the scope of work	
The methods used to present and analyse data, results/observations (statistical methods used, graphs, tables, diagrams etc) are appropriate to the type of data gathered	
The visual aids (photos, maps, boxes, figures etc) are of a high quality and facilitate comprehension	
The references are appropriate and match those in the text	

On completion of review return report to:_____

Appendix F

Environmental Impact Statement for the Proposed Blacktip Project Vegetation and Flora Study prepared by EcOz Environmental Services






This page has been left intentionally blank

Environmental Impact Statement for the proposed Blacktip Project

Vegetation and Flora Study

Prepared for: Woodside Energy Ltd.

Prepared by: EcOz Environmental Services

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

ABN 59 009 613 030

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

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

ABN 59 009 613 030

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

Environmental Impact Statement for the proposed Blacktip Project

Vegetation and Flora Study

Prepared for: Woodside Energy Ltd.

Prepared by: EcOz Environmental Services

DOCUMENT CONTROL INFORMATION

Project number:	Wood0303 Blacktip Project EIS
File ref:	Z:\OldServer\Documents\ecoz_projects\WOOD0303 - Blacktip\03 Flora & Fauna\Flora Report\Final\Blacktip Vegetation and Flora Report Final.doc
Report by:	Kylie Harvey
Reviewed by:	Noel Preece
Date:	18th October 2004
Document distribution:	Ceri Morgan (WEL) (1x soft copy, 2 x hardcopy)

Disclaimer:
This study, report and analyses have been based on the information available to EcOz at the time of the study. We take responsibility for the report and its conclusions to the extent that the information was sufficient. EcOz does not take responsibility for errors and omissions due to information not available to EcOz at the time of the study.

EXECUTIVE SUMMARY

This report is concerned with documenting baseline information on terrestrial vegetation and flora for the Blacktip Project area, and assessing the potential impacts associated with the following onshore project activities:

- *construction and operation of the onshore processing plant.*
- *construction and operation of a 3 km buried onshore pipeline.*
- *construction and operation of associated roads and access routes (land only).*
- *construction camps and laydown areas.*

Methodology
A vegetation map of the project area was derived from high resolution satellite imagery. Desktop reviews of relevant literature and databases, and consultations with regional flora experts from the NT Herbarium, and the Weeds Branch of DIPE, were undertaken to identify the range of flora species, vegetation types and other environmental constraints that may occur in the project area. Field surveys of vegetation and flora were undertaken in May 2002, August 2003 and December 2003 to supplement the information obtained during the desktop review. The surveys involved botanical assessment of the pipeline shore crossing, at locations in representative vegetation communities along the onshore pipeline route, and in the 750m by 750m gas plant footprint.

Statutory obligations
Statutory obligations in relation to the protection of vegetation and flora apply to the project under the following NT and Commonwealth legislation:

- *NT Planning Act 1999.*
- *Territory Parks and Wildlife Conservation Act 2000.*
- *Environment Protection and Biodiversity Conservation Act 1999.*
- *Weed Management Act 2001.*

Vegetation communities
Five vegetation communities, as listed below, have been described and mapped in the project area.

1. *Mixed species low open woodland.*

2. *Eucalyptus miniata and E. tetrodonta forest with mixed species tree\shrub layer and Sarga sp. tussock grasses.*

3. *Eucalyptus miniata and E. tetrodonta tall woodland to open woodland with mixed species tree\shrub layer and Sarga sp. and Heteropogon triticeus tussock grasses.*

4. *Coastal sand dune community.*

5. *Monsoon vine forest.*

*The **pipeline shore crossing** traverses a west facing coastal sand dune, which is sparsely vegetated with the grasses Sarga plumosum and Spinifex longifolius, and a number of herbaceous species including Fimbristylis sericea and Gomphrena sp.*

*The **onshore pipeline route** traverses a low open woodland community comprised of a mixture of tree and shrub species including, Red Bush Apple (Syzygium suborbiculare), Pandanus (Pandanus spiralis), Black Wattle (Acacia auriculiformis), Billy Goat Plum (Terminalia ferdinandiana), Corymbia confertiflora and the Cycad (Cycas maconochiei ssp. maconochieii). Further landward, the onshore pipeline route traverses forests to open woodlands dominated by Darwin Woollybutt (Eucalyptus miniata) and Darwin Stringybark (E. tetrodonta).*

*The vegetation within the 750m x 750m area proposed for the **onshore gas plant** is tall open forest to woodland dominated by Darwin Stringybark (Eucalyptus tetrodonta) and Darwin Woollybutt (E. miniata). The Cycad (Cycas maconochiei ssp. maconochiei) is a common feature of the understorey.*

Flora species
Surveys and NT Herbarium records for the project area document 90 flora species from 43 genera.

Weeds
Weeds are present in low numbers in the project area. Scattered Rubber Bush (Calotropis procera) plants occur on the beach dunes, and scattered infestations of Hyptis (Hyptis suaveolens) were observed in the hind dunes and in monsoon vine forests adjacent to the project area. Snake Vine (Stachytarpheta sp). and Wild Passionfruit (Passiflora foetida) were also observed in the near coastal areas. Other weed species are likely to be present, but in low numbers. The greatest potential for transfer of weeds during construction and operation of the project will be associated with the construction of access tracks and borrow pits, and the importation of fill material into the project area.

Communities of conservation significance

Monsoon vine forest communities *occur at the northern and southern ends of Yelcher Beach where the pipeline shore crossing is located. Outside the project area monsoon vine forest occurs in association with the estuarine systems at the southern end of Yelcher Beach, south of the project area and at Injin Beach, north of the project area. Research on rainforest patches in the Northern Territory has found that they are typically species rich and contain a high proportion of the NT's rare species (Palmer 2000; Dunlop et al. 1994; Russell-Smith & Bowman 1992), and all rainforest patches are significant in a regional context because of the high level of patch interdependence (Price et al. 1998). Field assessment revealed that the monsoon vine forest communities adjacent to the project area are relatively unaffected by weeds, fire and feral animals, although some Hyptis and Rubber Bush plants were observed during field surveys. The ecological integrity of the patches further contributes to their regional conservation significance. None of the patches identified during field surveys are directly impacted by the shore crossing, onshore pipeline and gas plant components of the proposed development. However, their position in close proximity to the project area creates potential for indirect impacts through weed invasion and increased fire frequency, the alteration of water supply and disturbance of rainforest fauna.*

The coastline at the Yelcher Beach shore crossing is dominated by a ***sandy beach backed by low dunes****. Extensive beach and sand dune environments also occur to the north (Injin Beach) and south (continuation of Yelcher Beach). The sand dunes are ecologically important through their role in protecting the coastline and landward vegetation communities. Sand dunes, especially foredunes, are highly susceptible to degradation when disturbed by natural and\or man-made forces. Open trenching through the sand dunes at Yelcher Beach to construct the pipeline shore crossing will cause substantial short-term physical disturbance to the beach and dune environments during construction. In the longer term, the dunes could be destabilised by the removal of vegetation and there is a high risk of erosion occurring, although this risk can be mitigated by the use of appropriate construction and rehabilitation techniques, and the implementation of a monitoring programme.*

Open grassland and Paperbark swamps *occur in association with the estuarine systems at Injin Beach and Yelcher Beach. These communities are at least 2-4 km away from the project area and for this reason have not been subject to field assessment. The Moyle River floodplain, which is a wetland of national importance (Environment Australia 2001), is located 50 km to the east of the project area. No wetland communities occur in areas identified for development of the shore crossing, onshore pipeline and gas plant. Wetlands that occur in other areas where other project related activities will take place i.e. along access routes and at borrow pits, will be determined when the locations and extent of these aspects has been finalised.*

Riparian *vegetation communities are of regional conservation significance through their role in maintaining the health of river and creek systems. These communities are typically floristically diverse, contain distinct flora species assemblages, and provide essential habitat for many species of fauna. The closest riparian communities to the project area are associated with the estuarine systems that occur on Injin Beach, 2 km north of the project area, and on Yelcher Beach, 3-4 km to the south. Access routes and areas for sourcing of construction materials will potentially impact on riparian communities. The locations and extent of impacts will be determined once the final project design is complete.*

Species of conservation significance
None of the plant species recorded during field surveys of the project area are declared 'threatened' species under NT or Commonwealth legislation. Furthermore, a review of the known distribution of all 'threatened' plant species that occur in the Northern Territory (NT Parks and Wildlife Service http://www.nt.gov.au/ipe/pwcnt/plants) did not reveal any species with a distribution in proximity to the project area. Overall, the project area is largely comprised of eucalyptus woodland communities, which typically do not contain a high proportion of rare species. Therefore, the likelihood of 'threatened' species occurring in the project area is considered to be low.

The Cycad Cycas maconochiei ssp. maconochiei, occurs in the project area where it forms a dominant understorey component of the eucalyptus woodland communities. The epiphytic orchids, Cymbidium canaliculatum and Dendrobium spp., are abundant throughout the project area. None of the cycad and orchid species identified in the project area are classified as 'threatened'.

Potential Environmental Effects

The majority of the potential environmental effects on flora associated with the Blacktip Project will be as a result of the disturbance and removal of native vegetation during the construction phase of the project. The main potential impacts of the project on vegetation and flora have been identified as:

- *Vegetation and habitat loss.*
- *Impacts on communities of conservation significance.*
- *Introduction of weeds and exotic species.*
- *Increased risk of fire.*

Other impacts, such as those associated with Acid Sulfate Soils, dust, visual amenity, effluent and waste discharge, and spills of hazardous substances, are considered to have a lower potential impact on flora, and therefore are not discussed in detail in this report.

There is significant scope for reducing the potential ecological impacts of the project by incorporating vegetation and flora considerations in the construction specifications. There are also opportunities to mitigate some of the potential adverse effects by management actions before, during and after construction.

TABLE OF CONTENTS

1. INTRODUCTION 1

2. STATUTORY OBLIGATIONS UNDER NT AND COMMONWEALTH LEGISLATION 2

2.1. Clearing native vegetation 2

2.2. Protected vegetation communities and flora species 2

2.3. Management of weeds 2

3. METHODOLOGY 3

3.1. Desktop studies 3

3.2. Field surveys 3

4. VEGETATION COMMUNITIES AND FLORA SPECIES 4

4.1. Regional context 4

4.2. Vegetation communities 4

4.3. Flora species 5

4.4. Weeds and exotic species 7

5. CONSERVATION SIGNIFICANCE OF VEGETATION AND FLORA 9

5.1. Vegetation communities of ecological conservation significance 9

5.2. Flora species of ecological conservation significance 11

6. POTENTIAL ENVIRONMENTAL EFFECTS AND MANAGEMENT RECOMMENDATIONS 13

6.1. Vegetation clearing and habitat loss 13

6.2. Impacts on vegetation communities and species of conservation significance 15

6.3. Introduction and spread of weeds and exotic species 16

6.4. Increased risk of fire 17

7. REFERENCES AND BIBLIOGRAPHY 19

TABLES

Table 1 Vegetation communities and survey sites.

Table 2 Weed species that occur in the project area and in regions to the east that will be used for access and sourcing of project materials.

Table 3 Summary of vegetation clearing dimensions and total area for each component of the proposed project.

FIGURES

Figure 1 Vegetation communities and survey sites.

PLATES

Plates 1-11 Photos of vegetation communities in the project area.

APPENDICES

Appendix 1 Botanical data collected in field surveys.

Appendix 2 Flora species lists.

Appendix 3 Declared weed species under *NT Weeds Management Act*.

ACKNOWLEDGEMENTS

We would like to thank Chris Brady, Daniel Banfai and Tom Vigilante for their contribution to botanical surveys, and, the NT Herbarium for their assistance in identification of voucher specimens. The Department of Infrastructure, Planning and Environment is acknowledged for the provision of data to the project. Specifically, Peter Krause is acknowledged for collating the data for us. Renee Bartolo and Josh Forner of Gecoz are acknowledged for their contribution to the development of a vegetation map for the project.

1. INTRODUCTION

EcOz Environmental Services has been contracted by Woodside Energy Ltd. (WEL) to undertake studies of the terrestrial vegetation and flora at the project area proposed for the Blacktip Project. A detailed overview of the proposed project is provided in the referral documents submitted to the NT and Commonwealth Governments and in preliminary drafts of the EIS documents. These documents form the current design specifications on which the assessment of terrestrial vegetation and flora is based.

The proposed project has both onshore and offshore components. Assessment of the potential environmental impacts of the project will therefore consider interactions with both the marine and terrestrial environments in, and surrounding, the project area. This report is concerned with documenting baseline information on terrestrial flora and vegetation, and assessing the potential impacts associated with the following onshore project activities:

- construction and operation of the onshore processing plant.
- construction and operation of a 3 km buried onshore pipeline.
- construction and operation of associated roads and access routes (land only).
- construction camps and laydown areas.

The last 2 points in the above list can only be partially assessed at this point in time as site selection and design specifications have not been finalised.

The marine environment in and surrounding the offshore project area is the subject of separate studies. For the purpose of this report, 'project area' refers to the onshore project area only.

The "Guidelines for Preparation of a Draft Environmental Impact Statement on the Proposed Blacktip Project (Department of Infrastructure, Planning and Environment, March 2004)" detail the specific requirements of the EIS document that is to be prepared for the Blacktip Project in accordance with Clause 8 of the Environmental Assessment Administrative Procedures of the *Environmental Assessment Act (1982)* and Chapter 4 Division 6 of the *Environment Protection and Biodiversity Conservation Act (1999)*. The terrestrial flora study was designed to satisfy the requirements of the Guidelines, and specifically to provide baseline information on which to base an assessment of potential impacts and development of appropriate mitigations measures for the project. This report documents the findings of field surveys, consultations and reviews of existing information undertaken to assess the potential impacts of the Blacktip Project on terrestrial vegetation and flora.

2. STATUTORY OBLIGATIONS UNDER NT AND COMMONWEALTH LEGISLATION

The main statutory requirements that apply to the potential impacts of the Blacktip Project on terrestrial vegetation and flora are discussed below.

2.1. Clearing native vegetation

Planning Act NT 1999

Interim Development Control Order No.12 declared under the *NT Planning Act 1999* prohibits clearing of more than 1 hectare of land without a Development Permit. These controls apply to all Freehold and Crown land of 2ha or more outside of existing towns and current Control Plan areas. In accordance with this legislation the proponents of the Blacktip Project should consult with Development Assessment Services (DIPE) regarding requirements for a development permit prior to any land clearing activities.

2.2. Protected vegetation communities and flora species

Territory Parks and Wildlife Conservation Act 2000 (TPWC Act)

The TPWC Act establishes lists of 'threatened wildlife' and 'areas of essential habitat' which are protected under the Act. There are currently no 'areas of essential habitat' declared in the Blacktip project area, and none of the flora species classified as 'threatened wildlife' under the Act are known to occur in the project area.

If it is intended to harvest species belonging to the Cycadaceae and Orchidaceae plant families in the project area for commercial purposes, a permit is required under section 55 of the Act.

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act establishes lists of nationally threatened species and ecological communities which are protected by the Act. None of the flora species or communities listed under the EPBC Act have a range that extends to the proposed onshore project area.

2.3. Management of weeds

Weeds Management Act 2001

Weed management in the Northern Territory is controlled under the *NT Weeds Management Act* (2001), which establishes lists of 'declared weeds' to which the Act applies. Weeds declared under the Act, that have been recorded in the project area or are known to occur in the region, are identified in Table 2. Section 9 of the Act establishes the responsibilities of land owners and occupiers for managing 'declared weeds'. The project proponent is responsible for the implementation of measures to ensure that 'declared weeds' are not introduced and\or spread by activities associated with the project, and that appropriate reporting strategies are in place.

3. METHODOLOGY

The methodologies adopted in undertaking the assessment of terrestrial vegetation and flora for the Blacktip Project were developed firstly to ensure that the range of potential issues are adequately covered, and secondly, to satisfy the requirements of the Draft EIS Guidelines. The methodologies were developed in consultation with the NT Parks and Wildlife Service and were provided to the NT Office of Environment and Heritage for comment. This section describes the methodologies employed in conducting desktop reviews and field surveys, and the key data sources utilised.

3.1. Desktop studies

To identify the range of flora species, vegetation types and other environmental constraints that may occur in the project area, reviews of relevant literature and databases, and consultations with regional flora experts from the NT Herbarium, and the Weeds Branch of DIPE, were undertaken.

The main data sources utilised in the desktop review were:

- *NT Herbarium database* – documents specimens previously identified and collected in the area.
- *Commonwealth Department of Environment and Heritage EPBC Act (1999) database (www.environment.gov.au)* – predicts species listed under the provisions of the EPBC Act that occur, or are likely to occur, in the area.
- *NT Parks and Wildlife Service Threatened Species Information* http://www.nt.gov.au/ipe/pwcnt/plants.
- *NT Rainforest Database* (Parks and Wildlife Service NT) – maps the boundaries of rainforest patches in the area.
- *Various scientific publications relating to NT flora.*
- *Environmental Legislation (species listed under the EPBC Act (Cth) (1999) and Territory Parks and Wildlife Conservation Act (NT) (2000).*

Vegetation communities and flora species of conservation significance identified from these data sources are discussed in section 5 of this report.

3.2. Field surveys

Field surveys of vegetation and flora in the project area were undertaken in May 2002, August 2003 and December 2003. These surveys involved botanical assessment of the pipeline shore crossing, and of locations in representative vegetation communities along the onshore pipeline route, and in the 750m by 750m gas plant footprint. During the surveys the project area was traversed on quad bikes, by 4WD vehicle and on foot.

Flora survey plots were established in representative vegetation communities. The following data were collected at each of the sample plots:

- GPS Coordinates.
- Community description.
- Dominant flora species in each stratum - where species could not be identified in the field, specimens were collected, pressed and dried, and were later verified by the NT Herbarium.
- Site photo.
- Weed species present.
- Locations of potential sensitivity such as riparian habitats, wetlands, rainforest patches etc.

In addition, foot searches for species of conservation significance and weed species were undertaken whilst traversing through the project area during the three survey periods.

The botanical surveys focussed on the description of structural characteristics and identification of species within each stratum of the community. The structural classification used in the surveys generally follows the Australian Soil and Land Survey Field Handbook (McDonald *et al.* 1998).

4. VEGETATION COMMUNITIES AND FLORA SPECIES

4.1. Regional context

The project area is located in the Darwin Coastal bioregion identified in the Interim Biogeographic Regionalisation of Australia (Environment Australia 2000). The summary of the attributes of the Darwin Coastal bioregion presented in this section is largely taken from Woinarski (2002).

The Darwin Coastal bioregion comprises gently undulating plains on lateritised Cretaceous sandstones and siltstones; sandy and loamy red and yellow earths and siliceous sands from near the mouth of the Victoria River to just west of Cobourg Peninsula. The most notable vegetation feature is the extensive and diverse floodplain environment associated with the lower reaches of the many large river systems. Floodplain environments associated with the Moyle River system occur 50km to the north-east of the project area. There are also substantial areas of mangroves, rainforest and other riparian vegetation fringing the rivers in the bioregion. Inland from the coast, the dominant vegetation type is eucalypt tall open forest, typically dominated by Darwin Woollybutt *Eucalyptus miniata* and Darwin Stringybark *E. tetrodonta*. This bioregional pattern holds true for the project area, where variations of the eucalyptus woodland to forest community are dominant.

4.2. Vegetation communities

Five vegetation communities, as listed below, have been described in the project area based on field surveys (Table 1). An additional 4 communities, namely mangrove forest, saline flats, Melaleuca swamp and Melaleuca woodland have been mapped in proximity to the project area. A map of the vegetation communities that occur in and surrounding the project area is included as Figure 1, along with the locations of sites surveyed during the field studies.

Table 1 Vegetation communities and survey sites in the onshore project area.

Vegetation community	Survey sites
Mixed species low open woodland.	OSP6, OSP1
Eucalyptus miniata and *E. tetrodonta* forest with mixed species tree\shrub layer and *Sarga sp*. tussock grasses.	OSP2, GP1, GP2, GP3
Eucalyptus miniata and *E. tetrodonta* tall woodland to open woodland with mixed species tree\shrub layer and *Sarga sp.* and *Heteropogon triticeus* tussock grasses.	OSP3, OSP4, OSP5, OUT1
Sand dune community.	SC1, SC2
Monsoon vine forest.	MVF1

The vegetation communities that occur at the pipeline shore crossing, along the onshore pipeline route and at the proposed gas plant site are described below, and botanical data collected during field surveys are collated in Appendix 1. Mangroves occur in association with rocky headlands that define the northern and southern ends of the beach where the pipeline will come onshore. Mangroves are being assessed as part of separate studies of the intertidal zone and therefore are not assessed in this report.

Shore crossing

The pipeline shore crossing traverses a west facing coastal sand dune, which is sparsely vegetated with the grasses *Sarga plumosum* and *Spinifex longifolius*, and a number of herbaceous species including *Fimbristylis sericea* and *Gomphrena sp.*(Plates 1 and 2). Patches of monsoon vine forest occur on the

hind dunes at the northern and southern ends of the beach. These patches are dominated by the trees Tamarind *Tamarindus indica,* Red Bush Apple *Syzygium suborbiculare* and Billy Goat Plum *Terminalia ferdinandiana,* and have a dense and diverse understorey of trees, shrubs and vines. Further discussion of monsoon vine forests is provided in section 5.1.3.





Plates 1 and 2 Sand dunes near shore crossing

Onshore pipeline route

The onshore pipeline route traverses a low open woodland community that occurs on damp sandy soils in the hind dunes (Plate 3). This community is comprised of a mixture of tree and shrub species including, Red Bush Apple *Syzygium suborbiculare,* Pandanus *Pandanus spiralis,* Black Wattle *Acacia auriculiformis,* Billy Goat Plum *Terminalia ferdinandiana, Corymbia confertiflora* and the Cycad *Cycas maconochiei ssp. maconochiei.* The ground layer is comprised of *Heteropogon contortus* and *H. triticeus* tussock grasses.

Further landward, the onshore pipeline route traverses forests to open woodlands dominated by Darwin Woollybutt *Eucalyptus miniata* and Darwin Stringybark *E. tetrodonta.* Seasonal variations in these communities are illustrated in Plates 4-7. Species that are common in the mid-storey of these communities include, Billy Goat Plum *Terminalia ferdinandiana,* Red-flowered Kurrajong *Brachychiton megaphyllus,* Cocky Apple *Planchonia careya* and *Cycas maconochiei ssp. maconochiei*. The ground layer is typically comprised of *Sarga sp.* and *Heteropogon sp.* tussock grasses.

Gas Plant

The vegetation within the 750m x 750m area proposed for the onshore gas plant is tall open forest to woodland dominated by Darwin Stringybark *Eucalyptus tetrodonta* and Darwin Woollybutt *E. miniata*. Other species that typically occur in the canopy include Ironwood *Erythrophleum chlorostachys* and *Terminalia ferdinandiana*. The mid-storey of this community is typically sparse and comprised of a mixture of tree and shrub species. The Cycad *Cycas maconochiei ssp. maconochiei* is a common feature of the understorey. The ground layer is mainly comprised of *Heteropogon triticeus* and *Sarga sp.* tussock grasses.

4.3. Flora species

Surveys and NT Herbarium records for the project area document 90 flora species from 43 genera. Lists of species recorded at the shore crossing, pipeline, gas plant site and in the rainforest patch at the southern end of the shore crossing beach, are provided at Appendix 2.



Plate 3 Low open woodland landward of sand dunes.



Plate 4 Eucalyptus forest traversed by the onshore pipeline – photo taken early dry season (May).



Plate 5 Eucalyptus forest traversed by the onshore pipeline – photo taken late dry season (Oct).



Plate 6 Eucalyptus forest at gas plant site – photo taken early dry season (May).



Plate 7 Eucalyptus forest at gas plant site – photo taken late dry season (Oct).

4.4. Weeds and exotic species

Weed species recorded in the project area and in regions to the east that may be used for access routes and sourcing of project materials are listed in Table 2. These species were identified in previous surveys, NT Herbarium records and in consultations with the Weeds Branch of the Department of Infrastructure, Planning and Environment.

Weeds are present in low numbers in the project area. Scattered Rubber Bush *Calotropis procera* plants occur on the beach dunes, and scattered infestations of Hyptis *Hyptis suaveolens* were observed in the hind dunes and in monsoon vine forests adjacent to the project area. Snake Vine *Stachytarpheta sp.* and Wild Passionfruit *Passiflora foetida* were also observed in the near coastal areas. Other weed species are likely to be present, but in low numbers.

The areas that will be used for access routes and sourcing of project materials had not been identified at the time of this study. The greatest potential for transfer of weeds during construction and operation of the project will be associated with these areas. The key bioregional weed management issues in, and surrounding the project area, as described by Woinarski (2002), are summarised below.

The floodplains across the Darwin Coastal bioregion face a range of serious threats from weed incursion notably by *Mimosa pigra*, which completely re-models their composition and structure, but also by Olive Hymenachne *Hymenachne amplexicaulis* and Para Grass *Brachiaria mutica.* There are no floodplain environments in the project area, however, the weed species identified may be present at river and creek crossings along the access routes and at locations where construction material will be sourced for the project. The extensive eucalypt forests in this region are affected by the rapid spread to dominance in the understorey of the exotic pasture grasses Gamba Grass *Andropogon gayanus* and Mission Grasses *Pennisetum pedicellatum* and *P. polystachion,* which exacerbate the detrimental impacts of an increasing frequency of extensive hot late dry season fires. These species are common along the highways between Darwin and the project area. Heavy infestations of weeds (such as Noogoora Burr, Parkinsonia, and Castor-oil plant) are a feature of most riparian systems in the Ord-Bonaparte bioregion. Once again, these species may be present along access routes and at locations where construction material will be sourced for the project.

Table 2 Weed species that occur in the project area and in regions to the east that will be used for access and sourcing of project materials. Notes taken from Smith (2002) and Parsons and Cuthbertson (2001).

Weed species		Classification in project area	Notes
Species name	**Common name**		
Andropogon gayanus	Gamba Grass	A, except in Finniss River, Adelaide River, Mary River and Daly River catchments where D	A highly productive annual grass that increases fuel loads, cures later than the native annual grasses and produces intense late dry season fires which seriously damage native woody species.
Bidens pilosa	Cobblers Peg	Not declared.	A nuisance weed.
Brachiaria mutica	Para Grass	Not declared.	Environmental weed that grows in wet or seasonally flooded areas. Spreads quickly choking out native species and hindering the re-establishment of more desirable species.
Calotropis procera	Rubber Bush	C	Forms dense thickets, which compete with native plant species and transform the appearance of the savanna. Hinders pastoralism by degrading pastoral lands and making mustering difficult.
Cascabela thevetia	Yellow Oleander	Potential weed	

Weed species		Classification in project area	Notes
Species name	**Common name**		
Hyptis suaveolens	Hyptis	D & C	Forms dense thickets rendering infested areas unproductive.
Hymenachne amplexicaulis	Olive Hymenachne	A except in Finniss River, Adelaide River, Mary River and Daly River catchments where D	Has the ability to smother native vegetation and form dense monospecific stands on floodplains
Jatropha gossypifolia	Bellyache Bush	C	Competes with native species and is toxic to humans and animals.
Mimosa pigra	Mimosa, Giant Sensitive Plant	C	Forms dense impenetrable thickets which exclude native plants and animals, transforming sedgeland and grassland on floodplains into monotonous tall shrublands.
Parkinsonia aculeata	Parkinsonia	C	Forms impenetrable thickets that compete with and exclude native species. Thickets block access to creek lines and rivers.
Passiflora foetida	Wild Passionfruit	Not declared.	A fast growing species that spreads, choking native vegetation.
Pennisetum pedicellatum	Annual Mission Grass	D & C	Competes with and displaces native species. Remains green until late in the dry season and provides fuel for very hot fires. Late burning is seriously changing fire regimes.
Pennisetum polystachion	Mission Grass	C	Competes with and displaces native species. Remains green until late in the dry season and provides fuel for very hot fires. Late burning is seriously changing fire regimes.
Senna obtusifolia	Sicklepod	D & C	Competes with and excludes native species. Degrades pastures and toxic to stock.
Senna occidentalis	Coffee Senna	D & C	Competes with and excludes native species. Degrades pastures and toxic to stock.
Sida acuta	Spiny Head Sida	D & C	Competes with and excludes more desirable species. Competes strongly with crops and pastures and is one of the most serious weeds of crops and pastures in the Top End of the NT.
Sida cordifolia	Flannel Weed	D & C	Competes with and excludes more desirable species. Competes strongly with crops and pastures and is one of the most serious weeds of crops and pastures in the Top End of the NT.
Sida rhombifolia	Paddy's Lucerne	D & C	Competes with and excludes more desirable species. Competes strongly with crops and pastures.
Stachytarpheta sp.	Snake Weed	C	Invades disturbed areas and monsoon vine forests. Dominates and excludes native species.
Tribulus terrestris	Caltrop	Not declared	Competes with and excludes native species.
Xanthium strumarium	Noogoora Burr	B	Thickets are quick to establish and difficult to eradicate. Exclude native shrub species and inhibits ground layers. Spines hinder pastoralism and can cause discomfort in stock and are reported to be poisonous.

Key:
Class A – to be eradicated. **Class B** – growth and spread to be controlled. **Class C** – not to be introduced. **Class D** – not to be spread by human means. **Class E** – species under an approved strategy. Note: No strategies are currently in place for the project lease area.

5. CONSERVATION SIGNIFICANCE OF VEGETATION AND FLORA

5.1. Vegetation communities of ecological conservation significance

Vegetation communities of conservation significance are those that have unique ecological attributes and perform important ecological functions. These communities are typically rare, or restricted in distribution, and are often highly susceptible to degradation through disturbance. Communities of conservation significance that occur in and around the project area include monsoon vine forests, coastal sand dune communities, mangrove forests, wetlands (swamps and floodplains), and riparian communities. The locations, attributes and significance of these communities are discussed in this section.

Monsoon vine forests

Monsoon vine forest communities occur at the northern and southern ends of Yelcher Beach where the pipeline shore crossing will be located (Figure 1). The largest monsoon vine forest patch, which covers an area of approximately 49 ha, lies to the east of a rocky headland at the southern end of the beach and continues south along the coast for approximately 3 km (Plate 8). A smaller patch of vine forest, covering an area of about 1 ha lies 50 m north of this main patch (Plate 9). The monsoon vine forest that dominates the hind dunes at the northern end of the beach is smaller in size, covering approximately 14 ha (aerial extent derived from PWCNT database). Monsoon vine forest also occurs in association with the estuarine systems at the southern end of Yelcher Beach and at Injin Beach (Figure 1).

Rainforests in northern Australia occur as scattered patches in a landscape dominated by Eucalypt savannas (Bach *et al.* 1999). Although not uncommon, rainforest patches are generally small in area and contain distinct plant species assemblages which warrant conservation measures (PWCNT 2000b). They are typically extremely species rich, containing 13% of the total known NT flora (Dunlop *et al.* 1994), yet only occupy 0.2% of the land area of the Northern Territory (Price *et al.* 1995). Many rainforest species are rare, with thirty percent of rainforest flora species having been recorded from fewer than 10 patches (Palmer 2000; Russell-Smith & Bowman 1992). Rainforests also provide fruit resources required by frugivorous birds and bats, which in turn assist in the dispersal of seed between monsoon rainforest patches to maintain gene flow (Price *et al.* 1999). All rainforest patches are significant in a regional context because of the high level of patch interdependence (Price *et al.* 1998). All of these factors contribute to the conservation significance of this vegetation community.

The monsoon vine forest communities adjacent to the project area are relatively unaffected by weeds, fire and feral animals, although some Hyptis and Rubber Bush plants were observed during field surveys. The ecological integrity of the patches further contributes to their regional conservation significance. None of the patches identified during field surveys are directly impacted by the shore crossing, onshore pipeline and gas plant components of the proposed development. However, their position in close proximity to the project area creates potential for indirect impacts through weed invasion and increased fire frequency, the alteration of water supply and disturbance of rainforest fauna.



Plate 8 Monsoon vine forest at the southern end of beach. A Rubber Bush plant can be seen in the foreground.



Plate 9 One-hectare patch of monsoon vine forest at the southern end of the beach.

Sand dunes

The pipeline comes onshore at the northern end of an area that local people identify as Yelcher Beach. The coastline here is dominated by a sandy beach backed by low dunes. Extensive beach and sand dune environments also occur to the north (Injin Beach) and south (continuation of Yelcher Beach). The sand dunes are ecologically important through their role in protecting the coastline. They act as a buffer against wave damage during storms and cyclones, protecting the land behind from salt water intrusion and allowing the development of more complex plant communities in areas protected from salt water inundation, sea spray and strong winds. The dunes also act as a reservoir of sand, to replenish and maintain the beach at times of erosion. Erosion is a natural part of coastal processes and anecdotal evidence from Traditional Owners suggests that Yelcher Beach has in the past been some distance seaward. One estimate from an Aboriginal resident from the area was that it has receded some 50 m.

Sand dunes, especially foredunes, are highly susceptible to degradation when disturbed by natural and\or man-made forces. Open trenching through the sand dunes at Yelcher Beach to construct the pipeline shore crossing will cause substantial short-term physical disturbance to the beach and dune environments during construction. In the longer term, the dunes could be destabilised by the removal of vegetation and there is a high risk of erosion occurring, although this risk can be mitigated by the use of appropriate construction and rehabilitation techniques, and the implementation of a monitoring programme.

Wetlands

Open grassland and Paperbark swamps occur in association with the estuarine systems at Injin Beach to the north of the project area, and Yelcher Beach to the south of the project area (Figure 1). These communities are at least 2-4 km away from the project area and for this reason have not been subject to field assessment. The Moyle River floodplain, which is a wetland of national importance (Environment Australia 2001), is located 50 km to the east of the project area. The wetland is considered to be a good example, and one of the least disturbed, of a Top End floodplain system associated with a small river and a mudflat-fringed bay. The Moyle floodplain has high conservation value due to its vegetation being relatively weed-free and undisturbed (Whitehead and Chatto 2001). No wetland communities occur in areas identified for development of the shore crossing, onshore pipeline and gas plant. Wetlands that occur in other areas where other project related activities will

take place i.e. along access routes and at borrow pits, can only be determined when the locations and extent of these aspects has been finalised.

Riparian

Riparian vegetation communities are of regional conservation significance through their role in maintaining the health of river and creek systems. These communities are typically floristically diverse, contain distinct flora species assemblages, and provide essential habitat for many species of fauna. The closest riparian communities to the project area are associated with the estuarine systems that occur on Injin Beach, 2 km north of the project area, and on Yelcher Beach, 3-4 km to the south. Access routes and areas for sourcing of construction materials will potentially impact on riparian communities. The locations and extent of impacts can only be determined once the final routes are chosen.

5.2. Flora species of ecological conservation significance

Flora species of conservation significance include those species that are classified as 'threatened' and\or protected under NT and Commonwealth legislation, and species that are regionally restricted in their distribution. The locations, attributes and significance of flora species in relation to the project area are discussed in the following sections.

Many of the species that occur in and around the project area will also be of conservation significance to local Aboriginal people. Local people use parts of plants for a variety of purposes and some may also have spiritual significance. There has been no systematic documentation of flora species that are of significance to the local people, however, the existence of these values is acknowledged.

'Threatened' species

None of the plant species recorded during field surveys of the project area are declared 'threatened' species under NT or Commonwealth legislation. Furthermore, a review of the known distribution of all 'threatened' plant species that occur in the Northern Territory (NT Parks and Wildlife Service http://www.nt.gov.au/ipe/pwcnt/plants) did not reveal any species with a distribution in proximity to the project area.

Zeuxine oblonga and *Schoutenia ovata* are the 'threatened' species with the closest known distribution to the project area. *Z. oblonga* is known from a wet rainforest site on the Daly River (Kerrigan, Cowie and Baker 2002a). This vegetation type does not occur in the project area. *Schoutenia ovata* is known from monsoon vine thickets on granite and limestone outcrops near Tipperary Station (Kerrigan, Cowie and Baker 2002a). The monsoon vine forest patches in close proximity to the project area have been surveyed in both the early and late dry season. No species of significance were identified during these surveys.

Overall, the project area is largely comprised of eucalyptus woodland communities, which typically do not contain a high proportion of rare species. Therefore, the likelihood of 'threatened' species occurring in the project area is considered to be low.

Other species of conservation significance

Plant species belonging to the families Cycadaceae and Orchidaceae are typically regionally restricted in distribution and are of conservation significance for this reason, but none of the cycads and orchids in the project area are declared 'threatened' species. Only 'threatened' species are declared 'Protected Wildlife' under section 3 of the *Territory Wildlife Regulations.*

One species of Cycad, *Cycas maconochiei ssp. maconochiei*, occurs in the project area (Plate 10) where it forms a dominant understorey component of the eucalyptus woodland communities (Plate 11). The epiphytic orchids, *Cymbidium canaliculatum* and *Dendrobium spp.*, are abundant throughout the project area where they have been observed growing on the trunks of Cycads and eucalyptus trees.

The Draft NT Cycad Management Plan (Parks and Wildlife Service of the Northern Territory 2003, 3.1.4) states that where land clearing has been approved under the procedures of the Northern Territory Government, no permit will be required to take unprotected cycads for non-commercial purposes on areas designated to be cleared. If commercial harvesting is intended, a permit will be required.

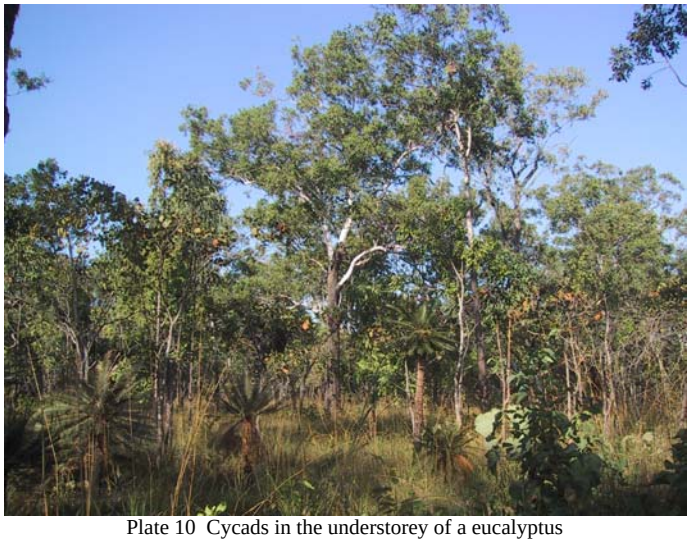


Plate 10 Cycads in the understorey of a eucalyptus woodland community in the project area.



Plate 11 Cycas maconochiei ssp. maconochiei

6. POTENTIAL ENVIRONMENTAL EFFECTS AND MANAGEMENT RECOMMENDATIONS

The majority of the potential environmental effects on flora associated with the Blacktip Project will be associated with the disturbance and removal of native vegetation during the construction phase of the project. The main potential impacts of the project on vegetation and flora have been identified as:

1. Vegetation and habitat loss.
2. Impacts on communities of conservation significance.
3. Introduction of weeds and exotic species.
4. Increased risk of fire.

Other impacts, such as those associated with Acid Sulfate Soils, dust, visual amenity, effluent and waste discharge, and spills of hazardous substances, are considered to have a lower potential impact on flora, and therefore are not discussed in detail in this report.

There is significant scope for reducing the potential ecological impacts of the project by incorporating flora considerations in the construction specifications. There are also opportunities to mitigate some of the potential adverse effects by management actions before, during and after construction. Recommendations on management measures to minimise impacts on flora are identified in this section. Additional measures for minimisation of site specific impacts should be developed following determination of the final design specifications.

6.1. Vegetation clearing and habitat loss

Potential effects

Construction in areas of intact native vegetation may cause a decline in the physical condition of vegetation and habitats beyond the actual zone of disturbance, or create other changes that reduce the suitability of surrounding habitat. The extent and nature of such effects is influenced by the initial condition of the habitats affected, the width of the area disturbed (i.e. the wider the easement the greater the potential impact), the management of construction operations, and the context of the development zone (fragmentation and isolation of habitat). A summary of vegetation clearing that will be associated with the project proposal as it currently stands is provided in Table 3, and the potential effects on native vegetation and flora are discussed below.

Table 3 Summary of vegetation clearing dimensions and total area for each component of the proposed project.

Project component	**Area to be cleared**	
	Dimensions	**Area**
Shore crossing	40m x 2.2km	8.8ha
Onshore pipeline		
Onshore lay-down near shore crossing	100m x 100m	1ha
Gas plant	750m x 750m	56.25ha
Access route from shore crossing to gas plant	To be determined	To be determined
Onshore lay-down at gas plant	Within gas plant footprint	
Access route from Wadeye to plant site	To be determined	To be determined
Project component	**Area to be cleared**	
	Dimensions	**Area**
Construction materials sources	To be determined	To be determined
Accommodation (construction and operation)	Within gas plant footprint	

Construction of the shore crossing and onshore pipeline will be via an 'open cut' technique, which will result in the clearing of 6.6 ha of native vegetation within a 40 m working width. The pipeline shore crossing traverses sand dunes, which are sparsely vegetated with grasses and herbs. Removal and\or disturbance of the vegetation cover on the dunes has the potential to destabilise the dune system and subsequently to cause erosion, which due to coastal sediment transportation processes may have impacts beyond the shore crossing site.

The vegetation traversed by the 2 km onshore pipeline route is characterised by eucalyptus woodland communities dominated by *Eucalyptus miniata* and *E. tetrodonta* (Appendix 1). The 750 m x 750 m site proposed for the gas plant is also dominated by this community. A laydown area and construction camp will be sited within the gas plant footprint. Eucalyptus woodlands dominated by *E.miniata* and *E. tetrodonta* are well represented in the Darwin Coastal bioregion (Woinarski 2002) and is the most common eucalyptus community in the Top End (Brock 1993). Given that the community is well represented and largely undisturbed by development in the region, the extent of clearing that will be associated with the project is unlikely to have a significant impact on habitat availability for flora and fauna.

Additional vegetation clearing will be associated with the:

- construction of an access route from Wadeye to the onshore plant site;
- construction of a lay-down area for storage of pipe lengths and other pipeline components during site preparation and construction/installation;
- construction of a beach barge landing and heavy vehicle access road from the beach landing to the plant site; and
- potentially other project aspects not finalised at this point in time.

The details of these aspects of the project are yet to be finalised, however, it can be established at this stage that there is potential for adverse effects on sensitive vegetation types, especially riparian zones crossed by access routes.

There is also high potential for weeds to be introduced and spread, especially in uninspected construction materials, although this potential will be greatly reduced by the implementation of weed inspections as part of a weed management plan.

Management recommendations

The following management measures should be considered to minimise the effects of vegetation clearing activities associated with the project:

1. Keep the extent of the planned working width to the minimum area necessary for construction activities. This is particularly important at the shore crossing and where the sand dune landforms and vegetation communities are sensitive to disturbance.

2. Clearly mark the working width using construction pegs or other temporary measures.

3. Stage clearing of vegetation in accordance with the construction schedule to minimise the time between clearing and rehabilitation.

4. Develop a rehabilitation plan prior to construction. Include a rehabilitation schedule, proposed techniques, species proposed for use, and the following general principles:

    a. Stockpile top soil and suitable vegetative matter near to the area from which it was taken so that it can be respread over the area during rehabilitation.

    b. Locate stockpiles within the marked working width.

c. Store excavated soil on-site in an area previously cleared of vegetation, or remove to an appropriate area off-site. Any on-site or off-site location will be approved by DIPE prior to dumping.

d. Clearly mark appropriate locations for dumping of spoil.

5. Design additional project infrastructure, including access routes, vehicle and plant storage and turn-around areas, borrow pits etc. so that:

   a. previously disturbed areas are used where possible;

   b. areas of sensitive vegetation are avoided; and

   c. low impact construction techniques are used in environmentally sensitive areas.

6. Assess the environment and heritage values of routes chosen for access roads, and locations where other project related activities will take place i.e. sourcing of construction materials.

7. Brief all construction staff about the importance of vegetation protection.

6.2. Impacts on vegetation communities and species of conservation significance

Potential effects

None of the vegetation communities that will be directly affected by clearing activities associated with construction of the shore crossing, onshore pipeline and gas plant are of notable conservation significance, and no threatened flora species have been identified in these areas.

The construction of access routes and borrow pits has the potential to directly impact on communities of conservation significance, especially riparian habitats. Two of the current access routes being considered make use of existing dirt tracks from Wadeye to the plant site, which will minimise the amount of vegetation clearing required to that needed to sufficiently upgrade the tracks to handle construction traffic. The third access route is via a barge landing at the shore crossing, which would require earthworks at the shore crossing beach to construct a landing, and the construction of a heavy vehicle access road from the shore crossing to the plant site. This option would result in high levels of disturbance through the sand dune communities, which may cause dune destabilisation and erosion.

Three small deposits of dolerite located adjacent to the Moyle River, have been identified as the most likely sources of construction materials. Development of these resources may result in disturbance or removal of riparian vegetation, which can cause destabilisation of banks and erosion and siltation of rivers and creeks, and may also disturb fauna utilising riparian areas as habitat. Disturbance of riparian areas creates potential for a decline in ecosystem condition and impacts often extend beyond the immediate site of disturbance.

Vegetation clearing and excavations will potentially alter natural drainage patterns, which is of concern for the maintenance of the monsoon vine forest patches that occur adjacent to the project area (see section 5.1.1) and for water dependent communities that may occur in areas chosen for siting of additional project infrastructure. A hydrological study is being undertaken separately, which will identify more specifically the potential effects of the project on hydrology and the ecological implications.

Weed incursion and fire are possibly the greatest threats to communities of conservation significance, especially monsoon vine forests, riparian communities and freshwater wetlands. Woinarski (2002) observes that the monsoon rainforest patch network in the Darwin Coastal bioregion is being degraded by incursion of weeds and the impacts of more frequent hot late dry season fires. The project, if not

properly managed, has the potential to create conditions for weed invasion and increased fire frequency. These issues are discussed in sections 6.3 and 6.4.

Management recommendations

The following management measures should be considered, in addition to measures 1-7, to minimise impacts on communities and species of conservation significance:

8. Investigate the feasibility of using directional drilling as a potential way to minimise impacts associated with the construction of the pipeline shore crossing.

9. Clearly mark sensitive vegetation communities that occur in the vicinity of areas where construction activities will take place, and ensure that these areas are avoided by a sufficient distance to minimise disturbance.

10. Maintain a vegetated buffer zone around any monsoon vine forest communities that occur in proximity to locations where project related activities will take place.

11. Minimise impacts on natural drainage patterns where possible.

12. Brief all construction staff on recognising and protecting sensitive vegetation communities, specifically, monsoon vine forests, wetlands and riparian forests.

13. Seek advice from the Northern Territory Parks and Wildlife Service on permit requirements for vegetation clearing activities that will impact on cycads and orchids.

6.3. Introduction and spread of weeds and exotic species

Potential effects

Activities associated with the construction and operation of the project have a high potential to introduce weeds into remote areas, which are currently relatively weed free. The greatest risk of weeds being introduced and spread will occur during the construction phase of the project when vehicles, plant and construction materials are being transported on and off the project area. Activities that involve disturbance of native vegetation create suitable conditions for weeds to rapidly establish and displace native species. Once weeds become established they compete with native vegetation, and in the case of the grassy weeds, can create conditions for hot, intense fires that adversely impact on native vegetation.

The *Weeds Management Act 2001* places obligations on land owners and occupiers to manage the introduction and spread of weeds declared under the Act, and to comply with approved weed management plans relating to declared weeds that occur on their land. The proponent of the project must take all reasonable measures to prevent the spread of Class D weeds, and to ensure that declared weeds of any class are not introduced into the project area during construction and operation of the project. Management of weed species not declared under the *Weeds Management Act 2001* is also encouraged in order to minimise the potential impacts of these species on the environment. Management of the grass weeds, Gamba Grass *Andropogon gayanus* and Mission Grasses *Pennisetum polystachion* and *P. pedicellatum,* is especially recommended, as these species provide fuel for hot, late season fires, which have the potential to negatively impact on the environment and to place project personnel and infrastructure at risk. A list of weeds declared under the *Weeds Management Act 2001* is included at Appendix 3.

Management recommendations

The following management measures should be considered to minimise the introduction and spread of weeds during project construction and operation:

14. Identify and treat existing weed infestations at the project area, along access routes and at borrow pits, prior to construction activities.

15. Develop a weed management programme for construction and operation, incorporating the following elements:
    a. Wash-down and inspection of vehicles and plant prior to moving off main roads.
    b. Inspection of construction materials sourced outside the project lease area.
    c. Requirements for providers of construction materials to certify their 'weed free' status.
    d. Weed awareness training and inductions.
    e. A weed monitoring and treatment programme that commences immediately following construction and continues throughout the operation stage of the project.

16. Only use species native to the area in rehabilitation and landscaping.

17. Determine species suitability for use in consultation with experts in rehabilitation techniques in tropical environments.

6.4. Increased risk of fire

Bushfires are frequent and widespread throughout the savannas of northern Australia. In the Wadeye area they occur throughout the dry seasons from March or April each year to the end of the dry season in about November or December. The area experiences fires on an annual basis, and half the natural vegetation may burn each year. Fire history maps indicate that the frequency and scale of fires in the Wadeye area may be less than in other areas (Allan *et al.* 2001; Russell-Smith 2001). Most fires are lit by people, although lightning has been suggested as a source of ignition in the late dry season ('build-up') when lighting storms are common, but there are no data on the frequency and occurrence of such fires (Preece 2002). Observations of Aboriginal fire practices in the area (Preece *pers. obs*. 2002, 2003) suggest that fires are lit at any time of the year, and that the fire patches are generally smaller than those occurring in other landscapes of the northern savannas. Early dry season fires are usually of less intensity than the later fires when the conditions are hotter and drier, and winds are stronger. The scale and intensity of fires can be reduced if many small patches are lit throughout the dry season.

Potential effects

There will be an increased risk of fire during the construction phase, and to a lesser extent, operational phase of the project. During the construction phase, potential fire ignition sources will include:

- vehicle and plant exhausts;
- sparks from contact with rock;
- cooking or camp fires and cigarettes; and
- deliberate ignition.

During the operational phase of the project, the risk of ignition from the above sources will be greatly reduced by decreased numbers or vehicles and workers at the site, and maintenance of vegetation in the project area. Fire could also occur as a result of plant malfunction or pipeline rupture although the risks of these occurring are negligible.

The integrity of the vegetation in and surrounding the project area would be diminished by more frequent fires. This is particularly an issue for monsoon vine forest communities and riparian areas, the edges of which may become more susceptible to fires as a result of clearing of adjacent vegetation communities. Long-term, repeated high intensity fires cause the erosion of rainforest boundaries and habitat decline (Russell-Smith and Bowman 1992). One of the most significant threats to the integrity of these communities is the combined threat of fire and weeds, which dictates the need to coordinate weed and fire management activities.

Management recommendations

The following management measures should be considered to minimise the impacts of fire on project infrastructure and the surrounding environment:

18. Develop a fire management programme for the construction phase of the project that incorporates the following elements:

    a. A fire-fighting unit and persons trained in fire fighting will be readily available at all times to extinguish fires.
    b. Spark arrestors fitted to all earthmoving equipment.
    c. Fire awareness and prevention training and induction for the construction workforce.
    d. No cooking or camp fires permitted.

19. Develop a fire management programme for the operation phase of the project that incorporates the following elements:

    a. Maintenance of fire breaks around the project area.
    b. Maintenance of vegetation in the project area.
    c. Maintenance of vegetation along road verges.
    d. An Emergency Response Plan that incorporates protection of nearby sensitive vegetation.

20. Implement a weed management plan and control programme to reduce fuel loads.

7. REFERENCES AND BIBLIOGRAPHY

Allan G., Dyer R., Johnson A., Russell-Smith J. & Yates C. (2001) 7. Monitoring Fire Regimes. In: *Savanna Burning - Understanding and using fire in northern Australia* (eds. R. Dyer, P. Jacklyn, I. Partridge, J. Russell-Smith & D. Williams) pp. 102-121. Tropical Savannas Cooperative Research Centre, Darwin.

Bach C., Price O., Shapcott A. & Palmer C. (1999) Fruit resources, frugivore movements and landscape scale conservation in monsoon rainforests of northern Australia. In: *Australian Wildlife Management Society Conference*, Darwin, Australia.

Brock, J. (1993) *Native Plants of Northern Australia*. Reed Books, Chatswood.

Commonwealth Department of Environment and Heritage, EPBC Act (1999) database [online] www.environment.gov.au.

Dunlop C., Leach G., Latz P., Barritt M., Cowie I. & Albrecht D. (1994) Checklist of the Vascular Plants of the Northern Territory, Australia, Genus Ordered. Conservation Commission of the Northern Territory.

Environment Australia (2000) Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1 - Summary Report.

Environment Australia (2001) *A Directory of Important Wetlands in Australia 3rd Edition* [online] www.deh.gov.au/cgi-bin/wetlands [Accessed 22 April 2004].

Kerrigan R., Cowie I. and Baker B. (2002a) Threatened Species Information Sheet - *Zeuxine oblonga*. Parks and Wildlife Service Northern Territory, Palmerston.

Kerrigan R., Cowie I. & Baker B. (2002b) Threatened Species Information Sheet - *Schoutenia ovata*. Parks and Wildlife Service Northern Territory, Palmerston.

McDonald R., Isbell R., Speight J., Walker J. & Hopkins M. (1998) *Australian Soil and Land Survey - Field Handbook.* CSIRO.

Palmer C., Price, O., & Bach, C (2000) Foraging ecology of the black flying fox (Pteropus alecto) in the seasonal tropics of the Northern Territory. *Wildl. Res* 27: 169-178.

Parks and Wildlife Service Northern Territory (2003) *Draft Management Programme for Cycads in the Northern Territory*. Northern Territory Government, Palmerston.

Parks and Wildlife Service Northern Territory, Threatened Species Information Sheets [online] http://www.nt.gov.au/ipe/pwcnt/plants [Accessed April 20 2004].

Parsons W.T. and Cuthbertson E.G. (2001) *Noxious weeds of Australia*. CSIRO Publishing.

Preece N. D. (2002) Aboriginal fires in monsoonal Australia from historical accounts. *Journal of Biogeography* 29: 321-336.

Price O., Woinarski J. & Robinson D. (1999) Very large area requirements for frugivorous birds in monsoon rainforests of the Northern Territory , Australia. *Biological Conservation* 91: 169-180.

Price O., Bach C., Shapcott A. & Palmer C. (1998) *Design of Reserves for Mobile Species in Monsoon Rainforests.* Parks and Wildlife Commission of the Northern Territory, Darwin.

Price O., Woinarski J., Liddle D. & Russell-Smith J. (1995) Patterns of species composition and reserve design for a fragmented estate: monsoon rainforests in the Northern Territory, Australia. *Biological Conservation* 74: 9-20.

Russell-Smith J. (2001) Pre-contact Aboriginal, and contemporary fire regimes of the savanna landscapes of Northern Australia; patterns, changes and ecological responses. *Ngoonjook* 20: 6-32.

Russell-Smith J. & Bowman D. (1992) Conservation of monsoon rainforest isolates in the Northern Territory, Australia. *Biological Conservation* 59: 51-63

Smith, N. (2002) *Weeds of the wet\dry tropics of Australia – A field guide*. Environment Centre NT, Darwin, 2002.

Whitehead P. & Chatto R. (2001) Chapter 7 Northern Territory. In: Environment Australia (eds) *A Directory of Important Wetlands in Australia* Third Edition. Environment Australia, Canberra.

Woinarski, J. (2002) Biodiversity Audit Bioregional Summaries - Compilation of individual summaries (NT) for the National Land and Water Resources Audit [online] http://www.nt.gov.au/ipe/pwcnt/index.cfm?attributes.fuseaction=open_page&page_id=266.

Figure 1

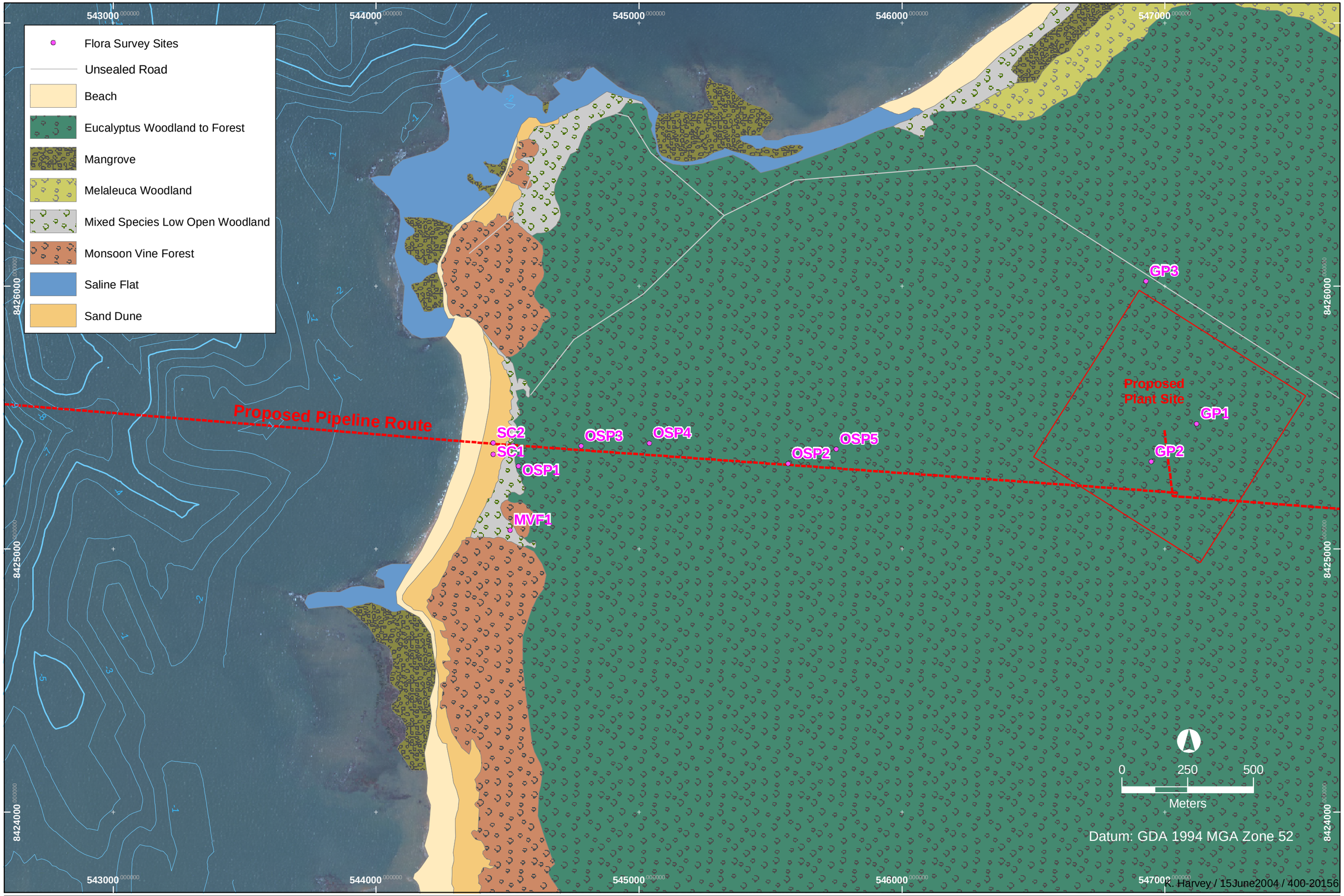


FIGURE 1: VEGETATION COMMUNITIES AND FLORA SURVEY SITES

WOODSIDE
AUSTRALIAN ENERGY

Appendix 1

Appendix 1
Vegetation survey data

SITE ID	SITE NO.	DATE	LAT	LONG	PHOTO	WEEDS	COMMUNITY	SPECIES IN CANOPY	SPECIES IN MID-STOREY	SPECIES IN GROUND LAYER
SHORE CROSSING										
SC1	100	Oct-03	-14.2430	129.4120	120-2007	Calotropis procera	Sarga plumosum and Spinifex longifolius grassland	*Sarga plumosum, Spinifex longifolius, Ipomoea pes-caprae*		
SC2	C97	May-02	-14.2426	129.4120	1038	Calotropis procera	Sarga plumosum and Spinifex longifolius grassland	*Sarga plumosum, Spinifex longifolius*		*Sparse herbs and forbs (including Fimbristylis sericea, Gomphrena sp., Asteraceae, Cyperaceae)*
MVF1	104	May-02	-14.2456	129.4126	2012, 1043, 1044	Hyptis suaveolens	Monsoon vine forest dominated by Syzygium suborbiculare, Terminalia ferdinandiana, Tamarindus indica. Approximately 200m south of the pipeline land fall site.	*Syzygium suborbiculare, Terminalia ferdinandiana, Tamarindus indica, Brachychiton diversifolius, Corymbia porrecta, Buchanania obovata, Erythrophleum chlorostachys, Bombax ceiba, Litsea glutinosa, Milletia pinnata*	*Flagellaria indica, Grewia retusifolia, Exocarpos latifolius, Carissa lanceolata, Hyptis suaveolens*, Canarium australianum, Acacia auriculiformis, Brachychiton megaphyllus, Syzygium eucalyptoides ssp. bleeseri, Strychnos lucida, Gardenia megasperma, Sterculia quadrifida, Breynia cernua, Planchonia careya, Grevillea angulata, Petalostigma pubescens, Persoonia falcata, Livistona humilis, Cupaniopsis anacardioides, Ficus scobina, Pouteria sericea, Vitex glabrata, Bridelia tomentosum, Celtis philippensis, Diospyros calcycantha, Aidia racemosa, Murraya paniculata, Micromelum minutum, Cryptocarya cunninghamii, Syzygium nervosum, Helicia australasica*	*Smilax australis, Abrus precatorius, Crinum angustifolium, Protoasparagus racemosus, Ampelocissus acetosa, Trema aspera, Opilia amentacea, Grewia multiflora, Pachygone ovata, Cassytha filiformis, Cymbopogon sp.*
ONSHORE PIPELINE										
OSP1	101	Oct-03	-14.2434	129.4129	2008	Hyptis suaveolens	Corymbia porrecta & Corrymbia grandifolia forest with mixed species tree\shrub understorey.	*Corymbia porrecta, Corymbia grandifolia, Syzygium suborbiculare, Brachychiton diversifolius*	*Terminalia ferdinandiana, Erythrophleum chlorostachys, Grevillea heliosperma, Brachychiton megasperma, Planchonia careya, Persoonia falcata, Ficus aculeata, Acacia auriculiformis, Livistona humilis, Pandanus spiralis, Trema aspera, Tinospora smilacina*	*Hyptis suaveolens**
OSP2	103	Oct-03	-14.2433	129.4224	2011	nil	Eucalyptus miniata & Eucalyptus tetrodonta forest with mixed species tree\shrub mid-storey and Sarga sp. tussock grass.	*Eucalyptus miniata, Eucalyptus tetrodonta, Terminalia ferdinandiana, Erythrophleum chlorostachys, Corymbia porrecta, Brachychiton diversifolius*	*Cycas maconochiei, Planchonia careya, Brachychiton megaphyllus, Buchanania obovata, Grevillea angulata*	*Juv Erythrophleum chlorostachys, juv Terminalia ferdinandiana, Sarga plumosum, Heteropogon contortus, Grewia retusifolia, Persoonia falcata, Ampelocissus acetosa*
OSP3	C99	May-02	-14.2427	129.4151	1042		Eucalyptus tetrodonta open woodland with mixed species dense tree\shrub mid-storey and Heteropogon triticeus tussock grass.	*Eucalyptus tetrodonta, Brachychiton diversifolius, Erythrophleum chlorostachys*	*Planchonia careya, Terminalia ferdinandiana, Persoonia falcata, Cycas maconochiei subsp. maconochiei*	*Heteropogon triticeus, Grewia retusifolia*
OSP4	C101	May-02	-14.2426	129.4175	1045		Eucalyptus tetrodonta and E. miniata tall open woodland with mixed species dense tree\shrub mid-storey and Heteropogon triticeus and Sarga sp. tussock grasses	*Eucalyptus tetrodonta, E. miniata*	*Buchanania obovata, Brachychiton diversifolius, Corymbia porrecta, Petalostigma pubescens, Terminalia ferdinandiana, Cycas maconochiei subsp. Maconochiei, Grevillea heliosperma, Acacia sp., Brachychiton tuberculatus*	*Sarga plumosum, Heteropogon triticeus*
OSP5	C102	May-02	-14.2428	129.4241	1046		Eucalyptus tetrodonta and E. miniata tall woodland with Heteropogon triticeus and Sorghum sp. tussock grasses	*Eucalyptus tetrodonta, E. miniata*	*Erythrophleum chlorostachys, Livistona humilis, Terminalia ferdinandiana, Pandanus spiralis, Cycas maconochiei subsp. maconochiei*	*Sarga plumosum, Heteropogon triticeus, Brachychiton tuberculatus, Grevillea pluricaulis and suppressed eucalypt and tree suckers*
OSP6	C98	May-02	-14.2427	129.4127	1039, 1040		Mixed species low open woodland. Community occurs on damp sandy soils behind coastal dunes. Cycas maconochiei common.	*nil*	*Syzygium suborbiculare, Pandanus spiralis, Acacia auriculifomis, Terminalia ferdinandiana, Eucalyptus confertiflora, Cycas maconochiei subsp. viridis*	*Heteropogon contortus, Heteropogon triticeus*

Appendix 1
Vegetation survey data

SITE ID	SITE NO.	DATE	LAT	LONG	PHOTO	WEEDS	COMMUNITY	SPECIES IN CANOPY	SPECIES IN MID-STOREY	SPECIES IN GROUND LAYER
GAS PLANT										
GP1	102	Oct-03	-14.2419	129.4368	2009, 2010	nil	Eucalyptus miniata & Eucalyptus tetrodonta forest with open mixed species tree\shrub mid-storey and Sarga sp. tussock grass	*Eucalyptus miniata, Eucalyptus tetrodonta, Terminalia ferdinandiana, Erythrophleum chlorostachys*	*Brachychiton diversifolius, Livistona humilis, Cycas maconochiei*	*Erythrophleum chlorostachys, Brachychiton megaphyllus, Sarga plumosum*
GP2	C103	May-02	-14.2432	129.4352	1050		Eucalyptus tetrodonta and E. miniata tall woodland with open tree\shrub midstorey and Heteropogon triticeus and Sarga plumosum tussock grasses	*Eucalyptus tetrodonta, E. miniata*	*Erythrophleum chlorostachys, Livistona humilis, Pandanus spiralis, Terminalia ferdinandiana*	*Sarga plumosum, Heteropogon triticeus and suppressed woody suckers*
GP3	99	Oct-03	-14.2370	129.4350	1992, 1997	nil	Eucalyptus miniata & Eucalyptus tetrodonta forest with open mixed species tree\shrub mid-storey and Sarga sp. tussock grass.	*Syzygium suborbiculare, Terminalia ferdinandiana, Tamarindus indica, Brachychiton diversifolius, Corymbia porrecta, Buchanania obovata, Erythrophleum chlorostachys, Bombax ceiba, Litsea glutinosa*	*Flagellaria indica, Grewia retusifolia, Exocarpos latifolius, Carissa lanceolata, Hyptis suaveolens*, Canarium australianum, Acacia auriculiformis, Brachychiton megaphylus, Syzgium eucalyptoides ssp bleeseri, Strychnos lucida, Gardenia megasperma, Sterculia quadrifida, Breynia cernua, Planchonia careya, Grevillea angulata, Petalostigma pubescens, Persoonia falcata, Livistona humilis, Cupaniopsis anacardioides, Ficus scobina*	*Smilax australis, Abrus precatorius, Crinum angustifolium, Protoasparagus racemosus, Ampelocissus acetosa, Trema aspera, Opilia amentacea, Grewia breviflora, Pachygone ovata, Cassytha filiformis*
OUTSIDE PROJECT AREA										
OUT1	105	Oct-03	-14.2451	129.4480		nil	Eucalyptus miniata & Eucalyptus tetrodonta forest with open mixed species tree\shrub mid-storey and Sarga sp. tussock grass	*Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia polycarpa, Corymbia porrecta, Erythrophleum chlorostachys*	*Acacia auriculiformis, Acacia dimidiata, Brachychiton megaphyllus, Brachychiton diversifolius, Buchanania obovata, Croton arnhemicus, Cycas maconochiei, Denhamia obscura, Distichostemon hispidulus, Helicteres sp., Grevillea pluricaulis, Livistona humilis, Persoonia falcata, Planchonia careya, Petalostigma quadriloculare, Terminalia ferdinandiana, Tinospora smilacina*	*Crinum angustifolium, Ampelocissus acetosa, Plectranthus scutellarioides, Eriosema chinense, Haemodorum coccineum, Heteropogon sp, Sarga plumosum*

SC = Shore crossing

MVF = Monsoon vine forest

OSP = Onshore pipeline
OUT=Outside project area.
GP = Gas plant

Appendix 2

Appendix 2
Species list

Family	*Taxa*	Shore crossing	Onshore pipeline	Gas Plant	Other	Herbarium records
AMARANTHACEAE	*Gomphrena sp*	x				
ANACARDIACEAE	*Buchanania obovata*		x	x	MVF	
APOCYNACEAE	*Carissa lanceolata*		x		MVF	
ARECACEAE	*Livistona humilis*		x	x	MVF	x
ASCLEPIADACEAE	*Calotropis procera**	x			MVF	
BOMBACACEAE	*Bombax ceiba*		x		MVF	
BURSERACEAE	*Canarium australianum*		x		MVF	
CAESALPINIACEAE	*Erythrophleum chlorostachys*		x	x	MVF	x
CAESALPINIACEAE	*Tamarindus indica*		x		MVF	
CELASTRACEAE	*Denhamia obscura*			x		x
COMBRETACEAE	*Terminalia ferdinandiana*		x	x	MVF	
CONVOLVULACEAE	*Ipomoea pes-caprae*	x				
CONVOLVULACEAE	*Polymeria ambigua*		x			
CYCADACEAE	*Cycas maconochiei ssp maconochiei*		x	x		
CYPERACEAE	*Fimbristylis sericea*	x				
EBENACEAE	*Diospyros calcycantha*				MVF	
EUPHORBIACEAE	*Breynia cernua*		x		MVF	
EUPHORBIACEAE	*Bridelia tomentosum*				MVF	
EUPHORBIACEAE	*Croton arnhemicus*			x		
EUPHORBIACEAE	*Petalostigma pubescens*		x			
EUPHORBIACEAE	*Petalostigma quadriloculare*			x		
FABACEAE	*Abrus precatorius*		x		MVF	
FABACEAE	*Eriosema chinense*			x		
FABACEAE	*Milletia pinnata*				MVF	
FABACEAE	*Plagiocarpus axillarus*					x
FLAGELLARIACEAE	*Flagellaria indica*		x		MVF	
HAEMODORACEAE	*Haemodorum coccineum*			x		
LAMIACEAE	*Hyptis suaveolens**		x		MVF	
LAMIACEAE	*Plectranthus scutellarioides*			x		
LAURACEAE	*Cassytha filiformis*		x		MVF	
LAURACEAE	*Cryptocarya cunninghamii*				MVF	
LAURACEAE	*Litsea glutinosa*		x		MVF	
LECYTHIDACEAE	*Planchonia careya*		x	x	MVF	x
LILIACEAE	*Crinum angustifolium*		x	x	MVF	
LILIACEAE	*Protasparagus racemosus*		x		MVF	
LOGANIACEAE	*Strychnos lucida*		x		MVF	
MENISPERMACEAE	*Pachygone ovata*		x		MVF	
MENISPERMACEAE	*Tinospora smilacina*		x	x		
MIMOSACEAE	*Acacia auriculiformis*		x	x	MVF	
MIMOSACEAE	*Acacia dimidiata*			x		
MIMOSACEAE	*Acacia oncinocarpa*					x
MORACEAE	*Ficus aculeata*		x			
MORACEAE	*Ficus scobina*		x		MVF	
MYRTACEAE	*Corymbia confertiflora*		x			
MYRTACEAE	*Corymbia grandifolia*		x			
MYRTACEAE	*Corymbia polycarpa*			x		
MYRTACEAE	*Corymbia porrecta*		x	x	MVF	x
MYRTACEAE	*Eucalyptus miniata*		x	x		x
MYRTACEAE	*Eucalyptus tetrodonta*		x	x		x
MYRTACEAE	*Syzygium nervosum*				MVF	
MYRTACEAE	*Syzygium suborbiculare*		x		MVF	
MYRTACEAE	*Syzygium eucalyptoides ssp. bleeseri*		x		MVF	
OPILIACEAE	*Opilia amentacea*		x		MVF	
PANDANACEAE	*Pandanus spiralis*		x	x		x
PASSIFLORACEAE	*Passiflora foetida**	x				
POACEAE	*Cymbopogon sp*				MVF	
POACEAE	*Aristida inaequiglumis*					x
POACEAE	*Chrysopogon latifolius*					x
POACEAE	*Heteropogon contortus*		x	x		
POACEAE	*Heteropogon triticeus*		x	x		

Appendix 2
Species list

Family	*Taxa*	Shore crossing	Onshore pipeline	Gas Plant	Other	Herbarium records
POACEAE	*Sarga intrans*		x	x		
POACEAE	*Sarga plumosum*	x	x	x		
POACEAE	*Spinifex longifolius*	x				
PROTEACEAE	*Grevillea angulata*		x		MVF	
PROTEACEAE	*Grevillea goodii*			x		x
PROTEACEAE	*Grevillea heliosperma*		x			
PROTEACEAE	*Grevillea pluricaulis*		x			
PROTEACEAE	*Helicia australasica*				MVF	
PROTEACEAE	*Persoonia falcata*		x	x	MVF	x
RUBIACEAE	*Aidia racemosa*				MVF	
RUBIACEAE	*Gardenia megasperma*		x		MVF	
RUTACEAE	*Micromelum minutum*				MVF	
RUTACEAE	*Murraya paniculata*				MVF	
SANTALACEAE	*Exocarpos latifolius*		x		MVF	
SAPINDACEAE	*Cupaniopsis anacardioides*		x		MVF	
SAPINDACEAE	*Distichostemon hispidulus*			x		
SAPOTACEAE	*Pouteria sericea*				MVF	
SMILACACEAE	*Smilax australis*		x		MVF	
STERCULIACEAE	*Brachychiton diversifolius*		x	x	MVF	
STERCULIACEAE	*Brachychiton megaphyllus*		x	x	MVF	
STERCULIACEAE	*Brachychiton tuberculatus*		x			
STERCULIACEAE	*Helicteres sp*			x		
STERCULIACEAE	*Sterculia quadrifida*		x		MVF	
TILIACEAE	*Grewia breviflora*		x		MVF	
TILIACEAE	*Grewia retusifolia*		x		MVF	
ULMACEAE	*Celtis philippensis*				MVF	
ULMACEAE	*Trema aspera*		x		MVF	
VERBENACEAE	*Vitex glabrata*				MVF	
VERBENACEAE	*Stachytarpheta sp.**	x				
VITACEAE	*Ampelocissus acetosa*		x	x	MVF	
* denotes weed species						
MVF = Monsoon vine forest						

Appendix 3

NORTHERN TERRITORY *WEEDS MANAGEMENT ACT 2001*

DECLARED WEEDS OF THE NORTHERN TERRITORY

CLASS A WEEDS - to be eradicated

BOTANICAL NAME	**COMMON NAME**	**PART OF THE TERRITORY**
Acacia catechu	Cutch tree	All of the Territory
Acacia nilotica	Prickly acacia	" "
Alternanthera philoxeroides	Alligator weed	" "
Asphodelus fistulosus	Onion weed	" "
Barleria prionitis	Barleria	" "
Cabomba spp	Fanwort	" "
Cryptostegia madagascariensis	Ornamental rubber vine	" "
Dalbergia sissoo	Dalbergia	N of 18^{o} S latitude
Datura ferox	Longspine thornapple	All of the Territory
Echium plantagineum	Paterson's curse	" "
Eichhornia crassipes	Water hyacinth	" "
Jatropha curcas	Physic nut	" "
Lycium ferocissimum	African boxthorn	
Martynia annua	Devil's claw	" "
Mimosa pigra	Mimosa, giant sensitive plant	S of 14^{o} S latitude
Parthenium hysterophorus	Parthenium weed	All of the Territory
Salvinia molesta	Salvinia	" "
Ziziphus mauritiana	Chinee apple, Indian jujube	Outside Darwin city, Palmerston, Litchfield Shire, Alice Springs Region

CLASS B WEEDS - growth and spread to be controlled

BOTANICAL NAME	**COMMON NAME**	**PART OF THE TERRITORY**
Acanthospermum hispidum	Star burr, goat's head	All of the Territory
Alternanthera pungens	Khaki weed	" "
Argemone ochroleuca	Mexican poppy	" "
Calotropis procera	Rubber bush	S of 16^{o}30' S latitude
Carthamus lanatus	Saffron thistle	All of the Territory
Cenchrus echinatus	Mossman River grass	" "
Emex australis	Spiny emex	" "
Hyptis suaveolens	Hyptis	" "
Jatropha gossypifolia	Bellyache bush	" "
Lantana camara	Common lantana	Outside town areas
Lantana montevidensis	Creeping lantana	Outside town areas
Leonotis nepetifolia	Lion's tail	All of the Territory
Mimosa pigra	Mimosa, giant sensitive plant	N of 14^{o} S latitude
Mimosa pudica	Common sensitive plant	All of the Territory
Opuntia spp.	Prickly pears	S of 18^{o} S latitude, outside town areas
Pennisetum polystachion	Mission grass	All of the Territory
Pistia stratiotes	Water lettuce	" "
Parkinsonia aculeata	Parkinsonia	" "
Prosopis limensis	Mesquite, algaroba	" "
Ricinus communis	Castor oil plant	" "
Salvinia molesta	Salvinia	" "
Senna alata	Candle bush	Outside town areas
Senna obtusifolia	Sicklepod	All of the Territory
Senna occidentalis	Coffee senna	" "
Sida acuta	Spinyhead sida	" "
Sida cordifolia	Flannel weed	" "
Sida rhombifolia	Paddy's lucerne	" "
Stachytarpheta spp.	Snake weeds	Outside town areas
Tamarix aphylla	Tamarisk, Athel pine	Alice Springs Region outside of home gardens
Themeda quadrivalvis	Grader grass	All of the Territory
Tribulus cistoides	Caltrop	" "
Tribulus terrestris	Caltrop	" "
Xanthium occidentale	Noogoora burr	" "
Xanthium spinosum	Bathurst burr	" "

CLASS C WEEDS - not to be introduced to the Territory

Includes ALL Class A and Class B Noxious Weeds

BOTANICAL NAME	**COMMON NAME**
Acroptilon repens	Creeping knapweed
Ageratina riparia	Mistflower
Ambrosia artemisiifolia	Annual ragweed
Ambrosia psilostachya	Perennial ragweed
Baccharis halimifolia	Groundsel bush
Cabomba spp	Fanwort
Chromolaena odorata	Siam weed
Cryptostegia grandiflora	Rubber vine
Datura spp.	Thornapples
Egeria densa	Dense waterweed
Elodea canadensis	Canadian pondweed
Eriocereus martinii	Harrisia cactus
Hyptis capitata	Knobweed
Lagarosiphon major	Lagarosiphon
Mimosa invisa	Giant sensitive plant
Prosopis spp.	Mesquite
Sorghum halepense	Johnson grass
Xanthium spp.	Burrs

Appendix G

Biting Insect Survey and Assessment Blacktip Project June 2004 prepared by Northern Territory Medical Entomology






This page has been left intentionally blank

Northern Territory Government

Department of Health and Community Services

Biting Insect Survey and Assessment

BlacktipProject

June 2004

13 July 2001

Study undertaken on behalf of EcOZ Environmental Services
for
Woodside Energy Ltd

Allan Warchot, Peter Whelan and Jane Carter

For further information contact:

Allan Warchot
Medical Entomology Branch
Centre for Disease Control
Department of Health and Community Services
PO Box 40596
Casuarina NT 0811

Telephone: (08) 8922 8337
Fax: (08) 8922 8820
E-mail: allan.warchot@nt.gov.au

Synopsis

Background

The Blacktip Project consists of both offshore and onshore components. The onshore components include the construction and operation of an onshore processing plant, construction and operation of 3km of buried onshore pipeline, and the construction of access roads and construction camp. There were potential biting insect concerns associated with these onshore components of the Blacktip Project.

EcOZ Environmental Services was commissioned by Woodside Energy Limited (Woodside) to assist in the preparation of a Draft Environmental Impact Statement (EIS) for the Blacktip Project. EcOZ Environmental Services then commissioned the Medical Entomology Branch of the Department of Health and Community Services to provide information on biting insects likely to affect the Blacktip Project.

The Medical Entomology Branch (MEB) of the Department of Health and Community Services (DHCS) was commissioned to;

- Conduct field surveys to locate actual and potential freshwater, brackish and salt marsh water mosquito breeding sites likely to affect the development area.

- Conduct adult biting insect trapping to indicate species and relative numbers of biting insects likely to affect the development area.

- Conduct a desktop study to indicate potential pest *Culicoides ornatus* biting midge breeding sites.

- Identify any risk areas where the construction of the gas pipeline and onshore gas processing facility may lead to the creation of mosquito breeding sites.

- Provide information on mitigation measures to ensure the construction of the gas pipeline and onshore gas processing facility does not lead to the creation of new mosquito breeding sites and to prevent the importation of exotic mosquito species.

- Provide information on mitigation measures to reduce the negative health impacts associated with biting insects.

Survey and report

A field survey was conducted in June 2004 to locate actual and potential freshwater and brackish water mosquito breeding sites. Adult biting insect trapping was conducted one night before the full moon in June 2004 to indicate the post wet season relative numbers of *Anopheles, Culex, Coquillettidia* and *Mansonia* mosquito species, and the monthly peak of the human pest mangrove biting midge species *Culicoides ornatus.* The following report outlines the findings of the June 2004 adult biting insect trapping and field survey. Further biting insect trapping will be conducted in September 2004 to indicate peak season pest biting midge numbers, and in November 2004 to indicate peak season salt marsh mosquito numbers, with additional field surveys to locate further potential mosquito breeding sites.

A desktop assessment was made using aerial photography to indicate potential human pest biting midge breeding sites.

Findings

The major findings from the June 2004 survey and assessment were:

Biting midges

a) Species

- *Culicoides ornatus* was the principal species of biting midge collected, representing 87.4% of all biting midges recovered

b) Source

- The largest biting midge breeding sites likely to affect the Blacktip Project area are the upper tidal creek mangrove areas associated with Swamp 2, which is located approximately 3km south-west of the onshore gas processing plant. Minor breeding sites may be the *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing. Minor breeding sites may also be located in the small mangrove tidal creek area associated with Swamp 1, approximately 2km north of the onshore gas processing plant.

c) Pest problem

- *Culicoides ornatus* will be the principal biting midge pest species in the Blacktip Project development area.

- *Culicoides ornatus* may cause minor pest problems in the Blacktip Project development area in the months of August to November. It is unlikely that pest numbers of this species will affect the development area during other periods of the year.

- Highest numbers will be present in those areas of the development nearest to Swamp 2.

- Pest problems, when they occur, will be greatest for three or four days around the full moon and new moon periods in the months of August to November, with numbers being greater during full moon periods. Pest problems are likely to be greatest one hour either side of sunset, and one hour either side of sunrise.

- Adult biting midge trapping in September 2004 around the time of the full moon will be conducted to indicate actual peak season numbers of *C. ornatus* affecting the Blacktip Project area.

d) Mitigation measures

- The development will not reduce or affect the *C. ornatus* breeding sites likely to affect the Blacktip Project area.

- High use personnel areas such as accommodation, mess and recreation areas should be screened and landscaped to allow effective insecticide barrier control of midges. Yellow or red lights should be used in outdoor personnel areas, as well a light proof curtains for personnel buildings, to prevent attracting biting midges.

- The use of white or UV lights in non-personnel areas can be used to divert biting midges away from personnel areas.

- It is unlikely that *C. ornatus* will reach numbers sufficient to warrant fogging with insecticides in the development area, due to the considerable buffer distance of the development area from Swamp 2.

- The elimination of biting midge breeding sites is not feasible. It would require the filling of a considerable portion of the upper tidal creek mangrove areas in Swamp 1 and 2, and the filling of the entire *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing.

- The workforce and visitors should be notified of a potential minor biting midge pest problem in the months of August to November, and they need to take appropriate personal protection precautions.

- The NT Government will not be responsible for any biting midge monitoring or control operations at the development site and within the vicinity of the development.

Mosquitoes

a) Species

- The species occurring in highest numbers during June 2004 were, in decreasing order of prevalence, *An. farauti s.l.* (the Australian malaria mosquito), *Cx. annulirostris* (the common banded mosquito), *Cq. xanthogaster* (the golden mosquito), *Cx. sitiens* (the salt water *Culex* mosquito) and *Oc. vigilax* (the salt marsh mosquito).

- *Anopheles farauti s.l., Cx. annulirostris* and *Oc. vigilax* will be the most important mosquito species affecting the Blacktip Project development area.

b) Source

- By far the major source of mosquitoes to the Blacktip Project area will be Swamp 1, a tidal and rainwater influenced swamp located approximately 1.5km north of the onshore gas processing plant. This swamp will be a breeding ground for extreme numbers of *Oc. vigilax*, very high numbers of *An. farauti s.l.* and high to very high numbers of *Cx. annulirostris.* This swamp will also be a breeding ground for non-disease transmitting pest mosquito species such as *Cq. xanthogaster, An. bancroftii* and *Ma. uniformis.*

- Swamp 2, a tidal and rainwater influenced swamp located approximately 3km south-west of the onshore gas processing plant, will also provide pest numbers of *Oc. vigilax* to the development sites. The interdunal areas adjacent to the coastal vine thicket to the south (referred to as 'Southern Coastal Vine Thicket') of the onshore gas pipeline crossing is also a likely significant *Oc. vigilax* breeding site.

c) Pest and potential disease problem

- *Ochlerotatus vigilax* will pose the greatest pest problem. Severe pest problems may occur for up to 10 days per month from September to January inclusive. Low to moderate pest problems may occur in February. Pest numbers will appear from 9 days after significant rainfall or monthly high tides in the months of September to February.

- *Ochlerotatus vigilax* will pose a high risk for Ross River Virus (RRV) and Barmah Forest Virus (BFV) transmission in the October to January period.

- *Culex annulirostris* were trapped in moderate pest numbers. A moderate pest problem from this species is likely to occur in the mid to late wet season months of January, February and March, with high to very high pest problems in the post wet season months of April, May and June. This species will pose a high risk for RRV and BFV transmission in January to March and a high risk for MVEV transmission from January to June.

- *Anopheles farauti s.l.* will pose a very high risk of local malaria transmission at the Blacktip Project development site, should a person with the infective stages of malaria be present in the

development area from April to June. High risk areas are located near Swamp 1 and the northern section of the onshore gas processing plant.

- Other mosquito species including *Cq. xanthogater* and *An. bancroftii* will cause pest problems only, mainly in the post wet season months of April, May and June.

d) Mitigation measures

- Advice should be given to all employees and visitors by the Blacktip Project Environmental Officer on the need for periodic personal protection measures against mosquitoes at the Blacktip Project area, to reduce pest problems and reduce exposure to mosquito borne diseases. Potential problem areas and problem periods should be pointed out to workers.

- Any mosquito complaint should be forwarded to the Blacktip Project Environmental Officer, who can then take remedial action by advising appropriate personal protection and advising other workers or visitors of problem periods or areas during the construction phase.

- Possible malaria cases should be reported as soon as possible to a doctor and health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes. This is to prevent the infection of local populations of *Anopheles* mosquitoes and subsequent local transmission. Employees recently arrived or returning from overseas should receive malaria awareness material.

- During the construction phase, any vessels and cargo capable of holding small amounts of water, such as machinery, used tyres etc from overseas or North Queensland should be inspected as per DHCS guidelines (Appendix 8) by the Blacktip Project Environmental Officer. This is to prevent the introduction of exotic dengue transmitting mosquitoes (*Ae. aegypti* and *Ae. albopictus*). Any road transport and cargo from North Queensland and Tennant Creek should also be inspected by the Blacktip Project Environmental Officer as per DHCS guidelines (Appendix 8), to prevent the introduction of *Ae. aegypti*. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.

- Artificial receptacles such as tyres, drums etc should be disposed of by landfill, holed or stored away from rainfall. If this is not possible, ongoing sanitation measures such as treatment with a chlorine solution or residual insecticide would be required to prevent mosquito breeding. Monthly inspections of artificial receptacles holding rainwater by the Blacktip Project Environmental Officer for mosquito breeding should be conducted during the construction phase, and a final inspection should be conducted upon the completion of construction, with appropriate treatment applied when necessary. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised by MEB.

- Swamps 1 & 2 should be burned annually as soon as possible after the swamps dry out each wet season. Burning reduces shelter for mosquito larvae, which allows predator access to larvae. The Blacktip Project Environmental officer should conduct inspections in late June or July to observe if the swamps are dry enough to burn.

- A mosquito larval control program for Swamp 1 should be established and conducted by the proponents and under the duties of the Blacktip Project Environmental Officer, to detect and control salt marsh mosquitoes during the construction phase. Helicopter larval control should be carried out at least in the productive reed areas of the swamp. The MEB will delineate the potentially most productive salt marsh mosquito breeding areas in September 2004 and provide this information to the proponents. The larvicide of choice would be a methoprene 30 day residual pellet formulation. The residual pellets should be applied at Swamp 1 before the October monthly high tide, and reapplied after every 30 days of water inundation in the breeding site until the end

of January. The Medical Entomology Branch should be consulted on any mosquito larval survey and control program.

- Stormwater drains throughout the development should have erosion control structures where appropriate. Drains with the likelihood of dry season low flows should be formalised with impervious linings and low flow facilities. All drains would need to be maintained annually to remove excess silt and vegetation. Drains should discharge to a suitable end point where water can not pool in downstream areas and cause mosquito breeding. Drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this swamp. Drains should be monitored monthly for mosquito breeding during the construction phase by the Blacktip Project Environmental Officer, with samples sent to the MEB laboratory in Darwin for analysis and advice on rectification measures.

- The processed water settling ponds should be deep and constructed with steep sides (1:2, 1:3 or 1:4 slope) to discourage marginal vegetation growth. A slightly sloping floor should be constructed so that during low water periods all of the water is contained in one area. Provisions should be allowed to ensure overflow water does not pool in any downstream areas, which could exacerbate mosquito breeding. The processed water ponds should be checked monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis and control recommendations.

- The bunded drains, washdown area, condensate and fuel bunded areas, as well as any other bunded area should contain provisions that ensures that water does not pool for more than five days in these structures, to prevent mosquito breeding. It may be necessary to drain these areas into the processed water settling ponds on a weekly basis in the wet season, and whenever necessary to prevent mosquito breeding in the dry season. These areas should be formalised to prevent the establishment of vegetation and consequent mosquito breeding. These areas should be monitored monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis advice.

- Construction activities should be monitored by the Blacktip Project Environmental Officer, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites. This would include monthly inspections for mosquito breeding during the wet season, with samples sent to the MEB laboratory in Darwin for analysis and advice.

- Sewage treatment facilities should dispose of effluent through sprinkler irrigation to designated areas or dispose of effluent to regularly flushed tidal areas. Disposal to regularly flushed tidal areas is the preferred option in regard to preventing mosquito breeding.

- Any high use personnel area for the onshore gas processing plant should be sited on the southern section of the onshore gas processing plant, as far away from Swamp 1 as possible. This is to create a greater buffer distance between personnel areas and the extensive mosquito breeding sources of Swamp 1.

- White or UV lights should be sited away from personnel areas, to divert mosquitoes to some extent away from personnel areas. Outdoor personnel areas should be fitted with yellow or red lights, and have light proof curtains fitted to prevent inside lights from attracting mosquitoes.

- The barrier spray bifenthrin should be utilised around personnel areas, to control adult mosquito numbers. The benefits of this product will be enhanced by planting shrub type vegetation or constructing a fence with dark shade matting around personnel areas, which can then be treated with the product. The shrub type vegetation or dark fencing will be attractive resting places for

mosquitoes (as well as biting midges), and they will receive a dose of the chemical when they rest on the treated surface. Bifenthrin can also be sprayed on insect screens and any other likely mosquito resting place.

- The laying of the underground pipeline must not result in the impediment of the natural flow of surface water. The finished surface must be level with the surrounding land. Any upstream embankment of water could lead to the creation of mosquito breeding sites. Any leftover spoil should not result in the embankment of water.

- Soil erosion, silt deposition and pooling of rain in excavations will need to be prevented to reduce the potential to create new mosquito breeding sites. Any disturbance caused by machinery should be rectified as soon as possible.

- Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent new surface water features.

- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

Recommendations

The major recommendations arising from the findings of the study are:

Biting midges

- The use of bifenthrin barrier treatments around personnel areas should be implemented to reduce adult biting midge numbers that could affect the workforce.

- The workforce and visitors should be notified of a potential minor biting midge pest problem in the development area in the months of August to November.

Mosquitoes

- There will be a requirement for periodic personal protection against mosquitoes at the Blacktip Project area to reduce pest problems and exposure to mosquito borne disease.

- Possible malaria cases should be reported as soon as possible to health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes.

- High use personnel areas should be sites as far away as possible from Swamp 1.

- Any vessels and cargo such as machinery or other receptacles capable of holding small amounts of water from overseas or Queensland, and road transport cargo from Queensland or Tennant Creek should be inspected as per DHCS guidelines to prevent the introduction of the dengue mosquito.

- Mosquito larval control with methoprene 30 day residual pellets is recommended for Swamp 1, to control salt marsh mosquitoes. This is recommended for the construction phase.

- Swamps 1 & 2 should be burned annually during the construction phase when the swamps dry after the wet season.

- Stormwater drains should be constructed in a manner that does not lead to the creation of new mosquito breeding sites.

- The processed water settling ponds should be constructed in a manner that does not lead to the creation of mosquito breeding sites. Hardy native fish species should be stocked in the settling ponds.

- Bunded areas should be managed to prevent mosquito breeding.

- Artificial receptacles should be managed to prevent mosquito breeding.

- Sewage treatment facilities should dispose of effluent through sprinkler irrigation or disposal to a regularly flushed tidal area. Disposal to a regularly flushed tidal area is the preferred option.

- Bifenthrin barrier treatment should be used around high use personnel areas, to reduce adult mosquito populations in these areas.

- The laying of the underground pipeline must not result in the ponding of water or impediment of the natural flow of surface water.

- Construction activities should be monitored, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites.

- The construction of borrow pits must not lead to the creation of mosquito breeding sites, and should be avoided within 1.5km of personnel areas and 1.5km of Port Keats residential areas.

- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

Contents

CONTENTS **1**

LIST OF FIGURES **4**

LIST OF TABLES **4**

LIST OF APPENDICES **4**

1.0 INTRODUCTION **6**

1.1 BACKGROUND **6**

1.2 SURVEY AND REPORT **6**

1.3 ACKNOWLEDGMENTS **7**

2. PROJECT AIMS **8**

2.1 AIMS **8**

2.2 SIGNIFICANCE AND SCOPE OF THE PROJECT **8**

2.3 STUDY SITE **9**

3. METHODS **10**

3.1 FIELD INSPECTION **10**

3.1.1 HABITAT INSPECTION 10
3.1.2 TRAP SITE SELECTION 10

3.2 SURVEY DATES AND SEASONAL TIMING **10**

3.3 BITING MIDGE TRAPPING **11**

3.4 BITING MIDGE POPULATION AND SEASONAL TRENDS **11**

3.5 MOSQUITO TRAPPING **11**

3.6 MOSQUITO POPULATION AND SEASONAL TRENDS **12**

4. RESULTS **13**

4.1 HABITAT SURVEY 13

4.1.1 FIELD SURVEY 2 AND 3 JUNE 2004 13
4.1.1.1 Swamp 1 13
4.1.1.2 Swamp 2 14
4.1.1.3 Southern coastal vine thicket 14

4.2 BITING MIDGE TRAPPING 15

4.2.1 SPECIES PRESENT 15
4.2.2 SPATIAL ABUNDANCE 15
4.2.3 SEASONAL ABUNDANCE 16
4.2.4 BITING MIDGE BREEDING SITES 16

4.3 MOSQUITO TRAPPING 16

4.3.1 SPECIES PRESENT 16
4.3.2 SPATIAL ABUNDANCE 17
4.3.3 SEASONAL ABUNDANCE 17

4.4 LOCATION OF VARIOUS DEVELOPMENT ELEMENTS 18

4.4.1 SHORE CROSSING 18
4.4.2 ONSHORE GAS PROCESSING PLANT AND ANCILLARY FACILITIES 19

5.0 DISCUSSION 20

5.1 BITING MIDGES 20

5.1.1 SPECIES PRESENT 20
5.1.2 PROBABLE BREEDING SITES 20
5.1.3 SPATIAL ABUNDANCE AND DISPERSAL 21
5.1.4 SEASONAL FLUCTUATIONS 22
5.1.5 LIMITATIONS 22
5.1.6 PEST PROBLEMS AND PUBLIC HEALTH 22
5.1.7 MEASURES TO REDUCE BITING MIDGE PEST PROBLEMS 23
5.1.7.1 Alteration or removal of breeding habitat 23
5.1.7.2 Biting midge buffer zones 23
5.1.7.3 Biting midge larval control by insecticides 23
5.1.7.4 Biting midge adult control 23
5.1.7.5 Personal protection and avoidance 24

5.2 MOSQUITOES 24

5.2.1 SPECIES PRESENT 24
5.2.2 MOSQUITO BREEDING SITES 24
5.2.2.1 Swamp 1 25
5.2.2.2 Swamp 2 25
5.2.2.3 Southern coastal vine thicket 26
5.2.2.4 Northern coastal vine thicket 26
5.2.3 SPATIAL ABUNDANCE AND DISPERSAL 26
5.2.4 SEASONAL FLUCTUATIONS 27
5.2.5 PEST PROBLEMS AND PUBLIC HEALTH 27

5.3 POTENTIAL MOSQUITO BORNE DISEASES 28

5.3.1 ARBOVIRUSES 28
5.3.2 MALARIA 29

5.4 EVALUATION OF DEVELOPMENT PLANS AND SUGGESTED MOSQUITO CONTROL MEASURES 30

5.4.1 GENERAL CONSIDERATIONS 30
5.4.1.1 Internal drainage 30
5.4.1.2 Containment bunding 30
5.4.1.3 Water storage features 30
5.4.1.4 Borrow pits or depressions 31
5.4.1.5 Artificial receptacles 31
5.4.2 DEVELOPMENT ELEMENTS 31
5.4.2.1 Onshore gas pipeline 31
5.4.2.2 Onshore gas processing plant 31
5.4.2.3 Access roads 32
5.4.3 MAJOR MOSQUITO BREEDING SITE CONTROL 32
5.4.3.1 Swamp 1 32
5.4.3.2 Swamp 2 33
5.4.3.3 Southern coastal vine thicket 33

5.5 PERSONAL PROTECTION MEASURES 34

5.6 MOSQUITO CONTROL 34

5.7 MOSQUITO MONITORING AND REPORTING 35

5.8 LIMITATIONS 36

6. CONCLUSIONS 37

6.1 BITING MIDGES 37

6.2 MOSQUITOES 38

7.0 RECOMMENDATIONS 42

7.1 BITING MIDGES 42

7.2 MOSQUITOES 42

8.0 REFERENCES 44

List of Figures

Figure 1: Blacktip Project site location.

Figure 2: Spatial abundance of selected mosquito species

Figure 3: Spatial abundance of *Culicoides ornatus*

Figure 4a: Larval mosquito sampling sites Swamp 1

Figure 4b. Larval mosquito sampling sites Swamp 2 and southern coastal vine thicket

Figure 5a: Potential mosquito breeding and biting midge breeding sites near Swamp 1

Figure 5b: Potential mosquito breeding and biting midge breeding sites near Swamp 2 and the coastal vine thickets

Figure 6: Darwin weekly mosquito monitoring program – CO2 traps. Holmes Jungle 1996 to 2002.

Figure 7: Biting midge investigations "Fairway Waters" Palmerston May 1996 to April 1997. Seasonal trend of *C. ornatus* collected form all sites on all monthly trap nights, and total monthly rainfall.

List of Tables

Table 1: Blacktip Project. Total number of female biting midges collected in CO2 baited EVS traps set on the afternoon on June 2, 2004 (one night before the full moon).

Table 2: Blacktip Project. Total number of female mosquitoes collected in CO2 baited EVS traps set on the afternoon on June 2, 2004 (one night before the full moon).

Table 3: Larval mosquito survey results. Blacktip Project Biting Insect Study June 2004. (refer to Figures 4a & 4b for site locations).

List of Appendices

Appendix 1: Adult mosquito trap location photos.

Appendix 2: Laval mosquito sampling site photos

Appendix 3: Table 1 – Summary of the Biology of Selected *Culicoides* Species in the Top End of the Northern Territory.
Table 2 – Seasonal Prevalence of Selected *Culicoides* Species in the Top End of the NT.

Appendix 4: Problem Mosquito Species in the Top End of the NT. Pest and Vector Status Habitats and Breeding Sites.

Appendix 5: Personal Protection from Mosquitoes and Biting Midges in the NT.

Appendix 6: Biting Midges or "Sandflies" in the NT.

Appendix 7: Field Evaluation of Bistar 80SC as an Effective Insecticide Harbourage Treatment for Biting Midges (*Culicoides*) and Mosquitoes Infesting Peridomestic Situations in an Urban Environment.

Appendix 8: Exotic Mosquitoes Arriving on Seagoing Vessels. Recommended Inspection and Eradication Procedures.

1.0 Introduction

1.1 Background

The Blacktip Project consists of both offshore and onshore components. The onshore components include the construction and operation of an onshore processing plant, construction and operation of 3km of buried onshore pipeline, and the construction of access roads and construction camp. There were potential biting insect concerns associated with these onshore components of the Blacktip Project.

EcOZ Environmental Services was commissioned by Woodside Energy Limited (Woodside) to assist in the preparation of a Draft Environmental Impact Statement (EIS) for the Blacktip Project. EcOZ Environmental Services then commissioned the Medical Entomology Branch of the Department of Health and Community Services to provide information on biting insects likely to affect the Blacktip Project.

The Medical Entomology Branch (MEB) of the Department of Health and Community Services (DHCS) was commissioned to;

- Conduct field surveys to locate actual and potential freshwater, brackish and salt marsh water mosquito breeding sites likely to affect the development area.

- Conduct adult biting insect trapping to indicate species and relative numbers of biting insects likely to affect the development area.

- Conduct a desktop study to indicate potential pest *Culicoides ornatus* biting midge breeding sites.

- Identify any risk areas where the construction of the gas pipeline and onshore gas processing facility may lead to the creation of mosquito breeding sites.

- Provide information on mitigation measures to ensure the construction of the gas pipeline and onshore gas processing facility does not lead to the creation of new mosquito breeding sites and to prevent the importation of exotic mosquito species.

- Provide information on mitigation measures to reduce the negative health impacts associated with biting insects.

1.2 Survey and report

A field survey was conducted in June 2004 to locate actual and potential freshwater and brackish water mosquito breeding sites. Adult biting insect trapping was conducted one night before the full moon in June 2004 to indicate the post wet season relative numbers in *Anopheles, Culex, Coquillettidia* and *Mansonia* mosquito species, and the monthly peak of the human pest mangrove biting midge species *Culicoides ornatus.* The following report outlines the findings of the June 2004 adult biting insect trapping and field survey. Further biting insect trapping will be conducted in September 2004 to indicate peak season pest biting midge numbers, and in November 2004 to indicate peak season salt marsh mosquito numbers, with additional field surveys to locate further potential mosquito breeding sites.

A desktop assessment was made using aerial photography to indicate potential human pest biting midge breeding sites.

1.3 Acknowledgments

We wish to acknowledge the assistance of Kylie Harvey of EcOZ Environmental Services who provided background information and aerial photography of the Blacktip Project.

We wish to acknowledge Ceri Morgan from Woodside Energy Ltd for on-site field co-ordination with the NLC, and Des Stones from Woodside Energy Ltd who provided MEB with a satellite phone for safety purposes.

We wish to acknowledge Popeye Briston and other NLC staff for assistance in navigation to the various survey sites.

MEB officer Jane Carter identified the mosquitoes. MEB officers Jane Carter and Allan Warchot identified the biting midges.

Figures were prepared by Jane Carter. Tables by Jane Carter and Allan Warchot. Text by Allan Warchot and Peter Whelan.

2. Project Aims

2.1 Aims

The aims were to;

- Conduct adult biting insect trapping at locations around the development area to locate likely biting insect problem areas.
- Conduct field surveys to locate actual and potential mosquito breeding sites
- Identify potential biting insect issues in regard to the development of the onshore gas pipeline and onshore gas processing plant.
- Provide mitigation strategies to prevent the creation of new mosquito breeding sites during the construction of the gas pipeline and associated facilities.
- Provide mitigation strategies to reduce biting insect pest problems, and to prevent the introduction of exotic mosquito species and mosquito borne disease into the development area.
- Outline potential biting insect health risks and risk periods for the workforce.

2.2 Significance and scope of the project

An evaluation of the Blacktip Project development area for potential biting insect problems is required for the Draft EIS. It is also a requirement to consider the impact of the development on biting insect populations and outline management procedures to reduce the impact of these insects.

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991a). These pests can disrupt the work force by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being. Minor biting midge pest problems can also occur near freshwater lakes and streams.

Mosquitoes area a serious potential public health issue in the NT, both as pest insects and as vectors of a number of human diseases including the potentially fatal disease caused by Murray Valley encephalitis virus (MVEV), and a number of other diseases caused by Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV).

The onshore gas processing plant development boundary is located approximately 1km from the nearest shoreline, approximately 1.5km south of a tidal and paperbark swamp, and approximately 3km north of a tidal swamp (Figure 2). Preliminary observations of aerial photographs indicated these were potentially significant mosquito breeding sites likely to affect the onshore development. The main mosquito species considered likely to affect the onshore development was the salt marsh mosquito *Ochlerotatus vigilax*, and the common banded mosquito *Culex annulirostris.* Both of these species are vectors for RRV and BFV, with *Cx. annulirostris* also a vector for MVEV. The onshore development was also considered to be subject to biting midge pest problems arising from the mangrove areas associated with these tidal swamps, and from the three mangrove foreshore sites adjacent to the onshore pipeline crossing.

In order to gauge the mosquito problem likely to affect the onshore part of the Blacktip Project, mosquito trapping was proposed to be carried out during the early dry season, to give an indication of the presence and relative numbers of most *Culex, Coquillettidia* and *Anopheles* species. Trapping was

also proposed to occur from 10 days after the monthly high tide in November over two nights, to indicate peak numbers of the salt marsh mosquito *Oc. vigilax*.

Trapping for biting midges, and in particular the mangrove biting midge species *C. ornatus* was also planned to occur at the same time as for mosquito trapping, with additional trapping over three nights around the full moon in September to indicate peak numbers of *C. ornatus* likely to affect the onshore element of the Blacktip Project.

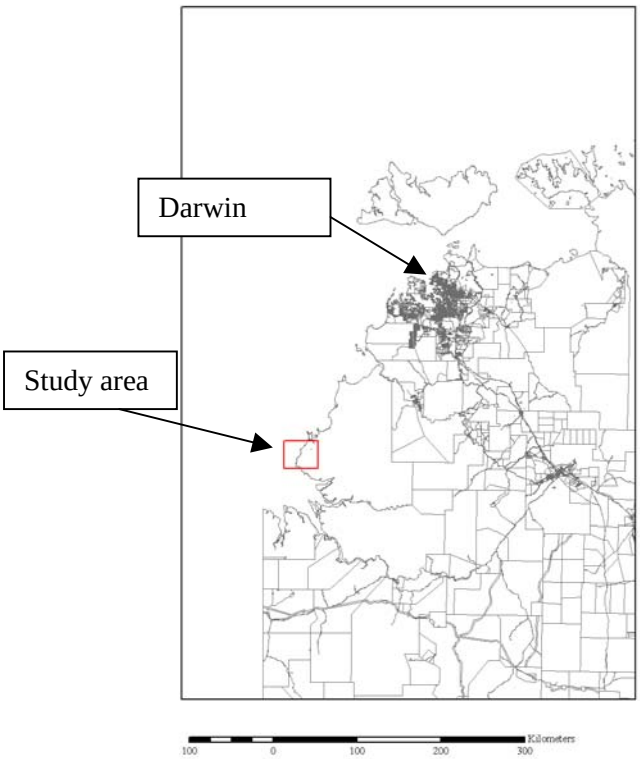
Seasonal trends of biting midges and mosquitoes were to be interpreted from relevant studies around Darwin. Potential biting midge breeding sites were to be assessed from aerial photographs using the biology of the biting midge, in particular *C. ornatus*. *Culex* and *Anopheles* species breeding sites were to be assessed in the early dry season when seasonal pools and swamps were present. Salt marsh mosquito breeding sites were to be assessed from inspections in June, September and November 2004, to locate upper tidal and dunal areas likely to hold tidal and rain water.

The following report highlights the findings of the June 2004 adult biting insect trapping and field surveys, with the associated discussion, conclusions and recommendations.

2.3 Study Site

The Blacktip Project area is near Port Keats on the western coast of the Northern Territory, with gas planned to be piped from the Joseph Bonaparte Gulf to an onshore gas processing plant approximately 8km west of the Port Keats community. The onshore gas facilities are located between two tidal swamps to the north and south, with a paperbark swamp associated with the tidal swamp to the north. The study area in regards to Darwin is outlined in Figure 1 below, with the study area alone further indicated in Figure 2.

Figure 1: Blacktip Project study area



3. Methods

3.1 Field inspection

3.1.1 Habitat inspection

Intensive field inspections of mosquito habitats were carried out during the early dry season on the 3rd of June, 2004. Evaluations of actual and potential mosquito breeding sites were made. Prospective habitats or habitats with water were inspected for the presence of mosquito larvae, aquatic predators, and vegetation. Potential mosquito breeding sites were sampled with a standard 270ml volume ladle dipper. Potential mosquito breeding sites were assessed for potential productivity based on topographical features, localised depressions, the presence of poorly draining areas, and vegetation patterns indicating location and extent of tidal influence or freshwater inundation.

No ground inspections were made for biting midge breeding sites. Assessments of potential *C. ornatus* biting midge breeding sites were made from aerial photographs using the known biology of *C. ornatus.*

Assessments of air photos were made to determine potential mosquito breeding and biting midge breeding sites before ground inspections.

3.1.2 Trap site selection

Assessments of air photos were made to locate likely areas to set adult biting insect monitoring traps. Actual adult biting insect trap sites were selected during initial field inspections on the morning of June 2nd 2004. Trap sites were selected based on proximity to potential breeding sites, to assess the productivity of these sites. This included setting traps near the tidal swamps to the north and south of the proposed development. Trap sites were also set near the onshore gas processing plant boundary, and where the gas pipeline crosses the shoreline, to gauge the biting insect problem likely to affect workers and the likely source of the biting insects.

All the trap sites were marked with flagging tape and referenced using a hand held Garmin GPS unit, to allow for the exact location of these sites during the initial and future trapping. The trap sites are indicated in Figures 2 & 3. Photos of the trap sites are in Appendix 1.

3.2 Survey dates and seasonal timing

Trapping for adult biting insects commenced mid afternoon on 2nd June, with traps collected the following mid-morning. This was designed to collect late afternoon, evening, night and early morning contributions to total midge and mosquito numbers. Trapping start dates and seasonal timing was;

- June 2, 2004 – Early dry season. Trapping one night before the full moon to monitor monthly highs in *C. ornatus* numbers, and post wet season presence and relative numbers of *Coquillettidia, Mansonia, Culex* and *Anopheles* species originating from nearby wetlands.

Further trapping and field surveys are proposed for;

- September 2004 – Late dry season. Trapping for three nights around the full moon to monitor peak season numbers of *C. ornatus.*

- November 2004 – Early Wet Season. Trapping for two nights starting 10 days after the monthly high tide to monitor peak season numbers of the salt marsh mosquito *Ochlerotatus vigilax.*

Habitat surveys were carried out on the 3rd of June 2004, to evaluate the presence of water and mosquito habitats resulting from the wet season, and the physical nature of the habitats. Surveys were

also conducted to locate potential salt marsh mosquito breeding habitats by locating potential or actual poorly draining areas within the upper tidal zone and coastal areas.

Further habitat surveys of upper tidal and coastal areas are to be conducted in September and November 2004.

3.3 Biting midge trapping

Trapping for the presence and relative abundance of biting midges was carried out overnight using carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consist of an insulated bucket, a suction fan powered by two 'D' cell batteries, a 'grain of wheat' light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height and baited with approximately 1kg of dry ice.

Biting midges were collected from the trapping on the night of June 2, 2004, and will be collected during three nights trapping in September 2004 and two nights trapping in November 2004. Traps in June 2004 were set between 1430 hours and 1600 hours, and collected the following morning between 0800 hours and 1030 hours.

Trap collections were killed by placing the catch containers in an esky with dry ice. The contents were carefully emptied into tissues, and the tissues gently folded and placed into sample containers. The sample containers with the catch contents were then returned to the esky with dry ice to preserve the catch. Trap collections were then transported back to the MEB laboratory in Darwin for processing.

At the MEB laboratory in Darwin, mosquitoes and biting midges were separated using a sieve. The midges were stored in 70% alcohol in individual tubes for each collection. For individual collections of 50 midges or less, all individual midges were identified. For midge collections above 50 individuals but below 1000 individuals, a sub-sample of 50 midges was identified, with the remaining bulk examined for any species not identified in the sub-sample. For collections over 1000 individuals, a sub sample of 50 individuals was identified, with a further sub-sample of 600 individuals scanned for any species not identified in the sub-sample of 50 individuals. Midges were identified with the aid of stereo microscopes using wing photos and taxonomic references (Dyce & Welling 1998, Wirth and Hubert 1989). Total numbers were estimated using a standard volume/number comparison method.

3.4 Biting midge population and seasonal trends

The species and relative numbers of human pest biting midges collected during the biting insect trapping for the Blacktip Project will be compared to the seasonal trend in pest *Culicoides* numbers collected during the Fairway Waters (Palmerston) study (Whelan et al 1998). Biting midge data from trapping in September 2004 will provide an overall picture on the maximum pest biting midge population likely to be experienced in the development area, and allow for comparisons with seasonal data collected for the Fairway Waters study to predict seasonal trends and populations likely to be present at the Blacktip Project development area.

The Fairway Waters study trapping was carried out on the night of the full moon for twelve continuous months, and hence is indicative of maximum seasonal numbers of the pest biting midges *C. ornatus. Culicoides ornatus* is the main biting midge species likely to affect the Blacktip Project development area. Seasonal trends in *C. ornatus* numbers in Fairway Waters should be similar to seasonal trends in *C. ornatus* numbers in the Blacktip Project area.

3.5 Mosquito trapping

Mosquitoes were sampled by the same traps used above for biting midge sampling. For mosquito collections under 300 individuals, all mosquitoes were individually identified. For mosquito collections over 300 individuals, a sub-sample of approximately 300 individuals was taken for

identification and weighed, with the remaining bulk sample also weighed. The bulk weight was divided by the sub-sample weight, to determine the multiplication factor for which the sub-sample was multiplied by to determine total numbers. All individuals in the sub-sample were identified, with the remaining bulk scanned for any species not detected in the sub-sample. Any additional species located in the bulk were entered into a database with the species from the sub-sample, but were excluded from multiplication.

3.6 Mosquito population and seasonal trends

An evaluation of the probable maximum numbers and relative numbers of all species of mosquitoes would require monthly trapping for a complete year, combined with trapping 10 days after a monthly high tide or significant rainfall in November or December. Monthly trapping for a complete year will not be conducted for the Blacktip Project.

Trapping in June 2004 for the Blacktip Project allowed for an indication of post wet season numbers of most *Culex, Anopheles, Coquillettidia* and *Mansonia* species. The unseasonal and above average rainfall in May has meant that mosquito numbers recorded in June are probably good indications of the likely magnitude of the relative numbers of the species. Trapping in November will allow for an indication of likely maximum numbers of the salt marsh mosquito.

The seasonal trend in mosquito populations likely to be encountered at the Blacktip Project development area can be interpreted from an evaluation of the weekly mosquito monitoring trapping at the Holmes Jungle trap site in Darwin. The Holmes Jungle trap site is located nearby to an extensive freshwater and brackish water reed swamp, similar in nature to the freshwater and brackish water reed swamp north of the Blacktip Project onshore gas processing facility. The reed swamp to the north of the Blacktip Project onshore gas processing facility is larger than the Holmes Jungle reed swamp, although there are semi-aquatic vegetation differences that indicate the peaks in mosquito numbers at the Blacktip Project area will occur a number of weeks sooner than at Holmes Jungle.

4. Results

4.1 Habitat survey

The Blacktip Project onshore gas facility is located approximately 1.5km south of a large seasonally inundated reed swamp subject to both tidal and freshwater flooding and a seasonally flooded paperbark swamp adjacent to the reed swamp (Swamp 1, Figure 5a). A small tidal creek is associated with Swamp 1. The facility is also located approximately 3km north of large tidal areas that includes a tidal creek, mudflat and salt-water grass areas (Swamp 2, Figure 5b). The gas pipeline crosses the shore between two large coastal vine thickets, and between three mangrove foreshore areas (Figures 5a & 5b).

The largest potential mosquito breeding site nearby to the development area is Swamp 1, with Swamp 2 also likely to contribute to mosquito populations at the Blacktip Project development area. Poorly draining interdune areas adjacent to the coastal vine thickets are also likely to contribute mosquito numbers at the development area.

Potential biting midge habitats assessed from air photos were present along three foreshore mangrove areas near the gas pipeline shore crossing (Figures 5a & 5b), and at the mangrove areas associated with Swamps 1& 2 (Figures 5a & 5b).

The results of the field surveys are presented in Table 3, with the results of the larval surveys and salinity samples of some sites shown. Photos of the larval habitats are presented in Appendix 2.

4.1.1 Field survey 2 and 3 June 2004

This initial field survey was carried out to locate trap sites and to identify major post wet season mosquito breeding areas. Surveys of potential late dry, and early to mid wet season mosquito breeding sites were also carried out. Trap location sites are shown in Figures 2 & 3, and photos of trap locations are shown in Appendix 2. Larval collection results and water sample results are shown in Table 3. Larval sample locations are shown in Figures 5a & 5b.

4.1.1.1 Swamp 1

Swamp 1 was a broad area (Approximately 5ha was surveyed or visually located) containing dense green *Eleocharis* reed areas, a large paperbark forest fringing the upper tidal area, large tidal mudflats, *Sporobolus virginicus* tidal grass areas, as well as small mangrove areas and large *Schoenoplectus* reed areas. The entire swamp was not surveyed. The area of swamp surveyed or visually located is highlighted in Figure 5a. Associated photos are provided in Appendix 2.

The swamp was extensively flooded during the time of the survey. The exact extent and vegetation make up of the swamp was not determined, due to access difficulties across the flooded swamp and time constraints. The exact extent and vegetation make up of the swamp will be determined in September 2004, when the swamp is dry and easily accessible. It can be assumed that the swamp drains towards the mangrove creek located north-west of the reed swamp areas.

Between the beachline and the swamp was a high sand dune (approximately 4m high in some sections). The tidal limit of the south-west end of the swamp consisted of dense emergent and lodged *Eleocharis* reeds adjacent to the sand dune, extending along the western side of a mudflat and grading into *Schoenoplectus* reed areas, and a large *Sporobolus* tide grass area (Approximately 5000m^2). The mudflat was approximately 5000m^2. To the east of the mudflat, *Sporobolus* and other tidal grass species bordered an open, green grassy paperbark area that was dry at the time of visit, and appears to be well drained. Standing *Schoenoplectus* reeds were noticed bordering all of the mangrove areas in the south-west end of the swamp. The *Schoenoplectus* and mangrove area downstream of the *Eleocharis* reeds and mudflat was approximately 3500m^2.

The south-east section of the swamp consisted of a very large area of dense lodged and emergent *Eleocharis* reeds (Approximately 23,000m^2), bordering a poorly draining densely vegetated paperbark swamp to the east. Further seaward, emergent *Schoenoplectus* reeds replaced the *Eleocharis* reeds. Dead paperbarks were noticed in the *Eleocharis* reed area bordering the paperbark swamp. Between the south-west and south-east end of the tidal swamp was a large *Schoenoplectus* reed and mangrove area (approximately 17,000m^2).

Ochlerotatus vigilax were found breeding in very high numbers at the south-west end of the swamp, which was partially flooded due to recent rainfall and high tides the night before the survey pushing floodwater into previously dry areas. Highest concentrations of larvae were associated with *Eleocharis*, *Sporobolus* and *Schoenoplectus* vegetation, with concentrations of up to 30 *Oc. vigilax* per ladle dip (2nd and 4th instars, pupae present) (Table 3). Lower concentrations of larvae were observed in the flooded, bare mudflat area. Positive areas for *Oc. vigilax* breeding in Swamp 1 were larval sites PKL 2 and PKL 4-7 (Figure 4a, Appendix 2).

Anopheles farauti s.l. larvae were found widespread in low concentrations (less than 1 larvae per ladle dip) in both *Eleocharis* and *Schoenoplectus* reed areas. *Anopheles farauti s.l.* were also found breeding in the paperbark swamp. Positive areas for *An. farauti s.l.* breeding were larval sites PKL 5 & 6 and PKL 8-9 (Figure 5, Table 3, Appendix 2).

Culex annulirostris larvae were found breeding in the *Eleocharis* reed area on the south-west side of the tidal reed swamp only (Larval site PKL 8, Figure 5, Appendix 2), in low concentrations of less than one larvae per ladle dip (Table 3).

4.1.1.2 Swamp 2

Only the northern end of this very large tidal and paperbark swamp area was surveyed, due to the distance of this swamp from the Blacktip Project development area. The larval collection locations are indicated in Figure 5.

The upper tidal limits of the northern end of the swamp consisted of a large, flat, dense grassy area. Small isolated depressions were located throughout this area, with *Ochlerotatus vigilax* found breeding in concentrations of 5 larvae per ladle dip in one area of 20m^2 (Larval site PKL 12, Table 3).

Further south of PKL 12, the upper tidal area becomes a narrow strip of grass between mangroves and a paperbark swamp. Small depressions in the tidal grass areas and an eroded flowline at the paperbark/grass margin revealed *Oc. vigilax* and *Verrallina funerea* breeding at 3.75 and 1.25 larvae per ladle dip respectively (PKL 11, Table 3, Appendix 2).

Further south of PKL 11 was a large mudflat bordering a tidal grass area (PKL 10). An extensive, shallow depression (Approx. 10,000m^2) was present in the upper tidal area of the mudflat, with *Oc. vigilax* larvae found at 0.83 larvae per ladle dip, and *An. farauti s.l.* larvae found at 0.17 larvae per ladle dip (Table 3). Only the western edge of the depression was surveyed.

4.1.1.3 Southern coastal vine thicket

Several interdune areas adjacent to the coastal vine thicket south of the onshore pipeline crossing were surveyed to locate potential salt marsh mosquito breeding sites. Survey sites are indicated as PKL 14 – PKL 17. The interdune area between PKL 14 and PKL 15 was not surveyed, this area will be surveyed in September 2004.

PKL 14 was a small localised low lying area in the sand dunes near the mangrove margin. The evidence of lush green vegetation indicates that rainwater pooling occurs in this site, with the area of flooding likely to be up to 80m^2. This depression is a likely salt marsh mosquito breeding site after the first flooding rainfall in the early to mid wet season.

PKL 15 was a large depression of approximately 500m^2, located behind the main beach sand dune and sparsely vegetated with paperbark trees. This site may be a minor *Anopheles* and *Culex* species breeding site after monsoonal rainfall.

PKL 16 consisted of several flowlines from the interdune area to the main beach dune. The invert of the main beach dune was higher than the invert of the flowlines, indicating rainwater pooling is likely to occur in the interdune areas behind the main beach dune after monsoonal rainfall. The edge of the vegetation line was characterised by Beach Hibiscus. Behind the Beach Hibiscus were several large flowlines in the interdune area. These poorly draining flowlines are likely to be large sources of *Oc. vigilax* after monsoonal rainfall.

PKL 17 also consisted of a flowline from the interdune area to the main beach dune. The invert of the main beach dune was higher that the invert of the flowline, indicating probable rainwater pooling in the flowline within the interdune area. This site is likely to be a large source of *Oc. vigilax* after monsoonal rainfall.

4.2 Biting midge trapping

The summary of the biting midge trapping from all nine adult trapping sites are shown in Table 1. Adult biting insect trap locations are shown in Figure 2 & 3.

4.2.1 Species present

A total of 3531 adult female biting midges were collected from the nine adult biting insect traps, representing at least 8 different species (Table 1).

The majority of biting midges collected were *Culicoides ornatus*, representing 87.4% of total biting midges trapped. The next most frequently recovered species were *C. austropalpalis* (3.6%), *C. immaculatus* (3.34%), *C.* undescribed sp. *No. 6* (2.1%), *C. bundyensis* (1.5%), *C. narrabeenensis* (0.4%), *C. papuensis* (0.31%) and *C. actoni* (0.06%) (Table 1).

Culicoides ornatus was the only major pest human biting midge species trapped. The highest individual collection of female *C. ornatus* was 2,530.

The biology and pest significance of selected *Culicoides* species are provided in Appendix 3.

4.2.2 Spatial abundance

The relative spatial abundance of all species collected from the nine adult biting insect traps is shown in Table 1. The spatial abundance of *C. ornatus* is also shown in Figure 3.

The highest spatial abundance of biting midges was at site 6, accounting for 74.79% of all biting midges collected. The site with the second highest spatial abundance was site 5, with 14.16% of all biting midges trapped.

Culicoides immaculatus was most abundant at site 6 (55), followed by site 4 (26), site 9 (20) and site 8 (15), with minimal to nil numbers at other trap sites.

Culicoides narrabeenensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides austropalpalis was most abundant at site 5 (100), followed by site 7 (19), with minimal to nil numbers at other trap sites.

Culicoides bundyensis was most abundant at site 2 (44), with minimal to nil numbers at other trap sites.

Culicoides undescribed sp. *No. 6* was most abundant as site 6 (55), with minimal to nil numbers at other trap sites.

Culicoides papuensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides actoni was only found in low numbers (2) at site 2.

For individual collections of *C. ornatus*, the highest numbers occurred at site 6 (2530), followed by site 5 (380), site 4 (68), site 2 (52), site 9 (34), site 7 (9), site 8 (8), site 3 (4) and site 1 (1) (Table 1, Figure 3).

4.2.3 Seasonal abundance

The seasonal abundance of the main human pest biting midge species *C. ornatus* is shown in Figure 7, which depicts the results of 12 months trapping on the night of full moon at Fairway Waters in Palmerston. Figure 7 indicates that the seasonal peak in *C. ornatus* numbers occurs during the mid to late dry season months of August, September and October, with low numbers in the wet season, with numbers starting to rise from the early dry season.

Biting midge trapping will be conducted at all nine Blacktip Project trap sites for three nights around the full moon in September 2004, to locate peak season *C. ornatus* numbers at the various locations around the Blacktip Project development site.

4.2.4 Biting midge breeding sites

An assessment of probable *C. ornatus* breeding sites was made from aerial photography and an assessment of the June 2004 trapping results. Probable *C. ornatus* breeding sites are pointed out in Figure 5a & 5b.

The largest *C. ornatus* breeding site appears to be the upper tidal mangrove creek areas associated with the distant Swamp 2 to the south of the Blacktip Project area. High pest numbers were trapped adjacent to Swamp 2. Closer to the Blacktip Project area, the small *Sonneratia* foreshores to the north and south of the onshore pipeline crossing appear to be a source of minor numbers of *C. ornatus*. Swamp 1 may be a small source of *C. ornatus.*

4.3 Mosquito trapping

4.3.1 Species present

There were a total of 6,429 female adult mosquitoes trapped from the nine adult biting insect traps, representing 19 species (Table 2).

Anopheles farauti s.l. was the most abundant species trapped, representing 33.92% of all mosquitoes trapped. The next most abundant species were *Culex annulirostris* (20.28%), *Coquillettiddia xanthogaster* (19.66%), *Culex sitiens* (9.52%), *Ochlerotatus vigilax* (5.15%) and *Culex vishnui* grp. (4.09%).

The highest number of females of various species from a single trap was *An. farauti s.l.* (1271), followed by *Cx. annulirostris* (604), *Cq. xanthogaster* (470), *Cx. sitiens* (326), *Cx. vishnui* grp. (167), *Oc. vigilax* (102) and *An. bancrofti* (96).

Culex vishnui grp. includes two undescribed species, *Cx. sp 32* of marks and *Cx. sp* near *vishnui.* Both species are very difficult to separate morphologically as adults, and are not regarded as human pest species.

Anopheles farauti s.l. is a species complex that includes the species *An. farauti* (brackish water breeder), *An. hinesorum* and *An. torresiensis* (freshwater breeders). These species are impossible to separate morphologically so are combined to form the *An. farauti s.l.* species complex. However, as the major mosquito breeding site Swamp 1 has extensive brackish water areas, the majority of *An. farauti s.l.* collected were likely to be *An. farauti*.

The biology and disease significance of the common mosquito species is described in Appendix 4.

4.3.2 Spatial abundance

The relative spatial abundance of all mosquito species collected from the nine adult biting insect traps is shown in Table 2. The spatial abundance of six selected important mosquito species is shown in Figure 2.

The highest number of mosquitoes were trapped at site 7, representing 30.32% of all mosquitoes trapped, followed by site 1 (24.48%), site 5 (10.61%), site 6 (8.45%), site 3 (8.37%), site 4 (6.07%), site 8 (5.91%), site 2 (3.39%) and site 9 (2.41%).

The highest total number of *An. farauti s.l.* was at site 7 (1271), followed by site 1 (364), site 8 (269), site 2 (121), and site 5 (120), with relatively few or none at the remaining trap sites.

The highest total number of *Cx. annulirostris* was at site 1 (604), followed by site 7 (226), site 6 (124), site 3 (122), site 5 (87) and site 8 (54), with relatively few others at the remaining trap sites.

The highest total number of *Cq. xanthogaster* was at site 1 (470), followed by site 3 (378), site 6 (141), site 7 (113) and site 4 (50), with relatively few others at the remaining trap sites.

The highest total number of *Cx. sitiens* was at site 5 (326), followed by site 4 (98), site 6 (77) and site 7 (71), with relatively few to nil at the remaining trap sites.

The highest total number of *Cx. vishnui* grp. was at site 4 (167), followed by site 5 (68), with relatively few to none at the remaining trap sites.

The highest total number of *An. bancrofti* was at site 1 (96), followed by site 7 (50), with relatively few to none at the remaining trap sites.

The highest total number of *Oc. vigilax* was at site 6 (102), followed by site 7 (100) and site 9 (38), with relatively few at the remaining trap sites.

4.3.3 Seasonal abundance

The seasonal abundance of mosquito species at the Blacktip Project area can be inferred from weekly mosquito monitoring from the Holmes Jungle weekly adult mosquito monitoring results (Figure 6). The Holmes Jungle trap site is situated near to an extensive tidal and rain inundated reed swamp that includes *Eleocharis* and *Schoenoplectus* reeds, making it similar in habitat to Swamp 1. Freshwater mosquito breeding at Swamp 1 is unlikely to extend into the dry season for as long as that encountered at Holmes Jungle, due to Holmes Jungle swamp being fed by dry season flows from a freshwater creekline, which prolongs flooding of the swamp and is indicated by *Typha sp.* at the start of the reed swamp. Swamp 1 does not have this feature. It is likely that high mosquito breeding in Swamp 1 will continue until late June only in wet years, with Swamp 1 expected to be significantly dry by early June in average rainfall years, and be significantly dry before the end of May in dry years.

Ochlerotatus vigilax numbers begin to rise at Holmes Jungle from around late September to a peak in November and December, with low numbers occurring in January. This species is virtually absent for the remaining months of the year, although in some years minor numbers can occur in May, June and July, when high tides push floodwaters into recently dried areas of the reed swamp, or

uncharacteristically late significant rainfall occurs. It should be noted that much higher numbers of *Oc. vigilax* would be sourced from the Holmes Jungle reed swamp if aerial control of *Oc. vigilax* larvae was not carried out by MEB, so the numbers depicted in Figure 6 is a much reduced indication of the true numbers that would normally arise from the swamp. Numbers of this species at Swamp 1 are likely to follow similar seasonal trends.

Culex annulirostris numbers generally show two peaks during the year at Holmes Jungle, with a mid wet season peak in January and February, and post wet season peak from April to August. The post wet season peak is generally the larger and more extended of the two peaks, due to more favourable dense reed habitat areas with restricted predator access during the post wet season months. Numbers are minor for the remaining months of the year. At Swamp 1, peak *Cx. annulirostris* abundance is likely to be similar to Holmes Jungle, except the post wet season peak is likely to be expected between April and June.

Anopheles farauti s.l. numbers at Holmes Jungle generally peak for a short period during the post wet season months of April to June, with numbers relatively low to absent for the remaining months of the year. Numbers of this species is likely to show a similar trend at Swamp 1.

Anopheles bancroftii numbers at Holmes Jungle generally peak in the post wet season months of April to August, with moderate numbers in the mid to late wet season months of January, February and March. This species is generally absent for the remaining months of the year. Numbers of this species at Swamp 1 are likely to follow this trend, except for post wet season breeding to finish by the end of June in average rainfall years.

Coquillettiddia xanthogaster numbers at Holmes Jungle peak in the post wet season months of May to August, with a minor peak in the mid wet season months of January and February. Numbers of this species are generally low or absent for the remaining months of the year. Numbers of this species at Swamp 1 are likely to follow this trend, except for post wet season breeding to finish by the end of June.

Another potential pest mosquito species is *Mansonia uniformis*, which was trapped in low numbers during the Blacktip Project trapping in June 2004. *Mansonia uniformis* numbers generally peak in the mid wet season months of January and February, with a minor peak in the post wet season months of May and June, and low to nil numbers for the remaining months of the year. It is possible that elevated numbers of this species will be present at Swamp 1 in January and February.

4.4 Location of various development elements

The development plans were evaluated as a desktop study. The impact of the development on existing biting insect populations and the capacity to create new breeding sites is discussed in Section 5 under the various headings of biting midges or mosquitoes. Suggested measures to reduce mosquito problems are dealt with separately in section 5.2.2.

The development plans available were preliminary. The various elements are presented below.

4.4.1 Shore crossing

The pipeline shore crossing will occur through a beach dunal area between two coastal vine thickets. There is a low lying woodland area behind the dune. The shore crossing is within flight range of various species of mosquitoes likely to originate from the southern coastal vine thicket to the south, and from Swamps 1 & 2. The beach dune is high in elevation and therefore appears well drained.

The shore crossing is close to foreshore *Sonneratia* mangrove areas, and is within flight distance of *C. ornatus* biting midges from Swamp 2.

4.4.2 Onshore Gas Processing Plant and Ancillary Facilities

The onshore gas processing plant and ancillary facilities is located within the flight range of various species of mosquitoes likely to originate from the southern coastal vine thicket to the west and south-west, and from Swamps 1 & 2. Swamp 1 will be by far the major source of mosquitoes for the onshore gas processing plant and ancillary facility areas.

The onshore gas processing plant and ancillary facilities is also located within the flight range of *C. ornatus* from the *Sonneratia* foreshores , and from Swamps 1& 2.

5.0 Discussion

5.1 Biting midges

5.1.1 Species present

Thirty-three (33) species of *Culicoides* have been recorded in the Darwin area (Whelan et al 1997). Eight (8) species of *Culicoides* were collected during the Blacktip Project trapping in June 2004. Of the 8 species trapped, *C. ornatus* is by far the major potential pest species, both in terms of numbers and because this species is considered the most significant pest human biting midge species in the Top End of the NT. The most important or common pest species in Darwin Harbour, their biology, and their season prevalence are summarised in Appendix 3.

More intensive trapping in the Blacktip Project area may reveal more species, although it is unlikely that any other *Culicoides* species trapped would be a major human pest species or be present in numbers high enough to cause a human pest problem.

Culicoides actoni were trapped in very low numbers at one site only. This species has been recorded biting humans (Wirth & Hubert 1989), although it is unlikely to be of any major pest significance. The larval habitat of this species is unknown (With & Hubert 1989).

Culicoides bundyensi and *C. austropalpalis* were trapped in minor numbers and are not regarded as human pest species.

Culicoides papuensis were trapped in very low numbers and breed in similar areas as *C. ornatus* (Shivas 1999). There appears to be no published records of this species biting humans in Australia, and Shivas (1999) also did not record this species biting human bait. It is therefore unlikely that this species is of human pest significance in Australia.

Culicoides narrabeenensis rarely bites people, so it is unlikely to be of any pest significance in the Blacktip Project area. This species breeds at the edge of freshwater.

Culicoides undescribed sp. *No. 6* were trapped in low numbers. This species rarely bites humans so are not considered to be of any human pest significance.

Culicoides immaculatus were trapped in minor numbers. This species can be confused with other *Culicoides* species, so those *C. immaculatus* found during the Blacktip Project trapping need their identity confirmed.

5.1.2 Probable breeding sites

Culicoides ornatus will be the most important pest biting midge species affecting the Blacktip Project area.

The actual breeding sites for *C. ornatus* have not been located in the areas surrounding the Blacktip Project. However the breeding sites can be inferred from investigations of breeding sites around Darwin Harbour (Shivas et al 1997, Shivas 1999). Probable breeding sites are pointed out in Figures 5a and 5b.

Investigations of breeding sites in Darwin Harbour have located the breeding sites of *C. ornatus* by adult emergence trapping (Shivas et. al. 1997, Shivas 1999). The midge breeds in the dry season in the mangrove mud in the creek banks of upper tidal tributaries between Mean Low Water Neap (MLWN) and Mean High Water Neap (MHWN). Larval sampling has revealed significant breeding at tidal

elevations of 4.7m ACD to 5.5m ACD at creekbank habitats in Darwin Harbour (Shivas 1999). The prime breeding sites are in a narrow zone in the upper section of narrow creek banks associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina*. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy (Shivas 1999, Whelan 2003). Breeding also occurs in a broad band centred around the edge of the vegetation line on the upper part of the creekbank i.e just above MHWN (Shivas 1999, Shivas 2001).

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* mangrove zone facing open water. These breeding sites are usually associated with mud substrates and not with sandy substrates. Narrow beach fringing mangrove areas are usually not appreciable sources of *C. ornatus*, particularly in areas with sandy substrates (Shivas 1999). Wet season emergence in foreshore breeding habitat shifts from the *Sonneratia* mangrove zone into the adjacent *Rhizophora* zone (Shivas & Whelan 2001).

During the wet season, emergence on the creek bank decreases to insignificant levels in direct response to rainfall (Shivas et. al. 1997). Significant emergence in the wet season shifts to the *Ceriops* transition zone at the back edge of the creek bank forest. This is just below MHWS (Mean High Water Spring or average high tide mark) or 6.9m ACD in Darwin Harbour. This is where the mixed *Ceriops* starts in a transition from the taller creek bank mangroves to the smaller mangroves in drier, less frequently flooded areas only reached by tides from 6.5 to 6.8m.

To eliminate most *C. ornatus* breeding sites it would be necessary to remove or permanently flood the neap tide habitats of upper tidal creek areas, the transitional *Ceriops* zone, and the *Sonneratia* foreshore and adjacent *Rhizophora* zone within 1.5km of the development area. This would be environmentally unacceptable.

The development will not reduce or significantly affect the major biting midge breeding sites that are currently causing the pest problem. Breeding sites for *C. ornatus* likely to affect the Blacktip Project include the *Sonneratia* foreshores adjacent to the gas pipeline shore crossing, the upper tidal creek mangrove areas to the south of the Blacktip Project site and the upper tidal creek mangrove area to the north of the Blacktip Project site. Preliminary trapping indicates the mangrove creek area to the south of the Blacktip Project site is by far the largest breeding site affecting the development area.

The breeding sites affecting the Blacktip Project are likely to pose only minor biting midge pest problems, due to the absence of nearby extensive areas of foreshore *Sonneratia* mangroves, and the distance of the Blacktip Project from extensive upper tidal creek (dendritic) mangrove areas.

5.1.3 Spatial abundance and dispersal

Collections of *C. ornatus* in Darwin Harbour have been greatest near extensive dendritic areas of mangroves and at the head of tidal creeks, with numbers highest within 1 – 1.5 km of these areas (Shivas & Whelan 2001). High numbers are usually present on the slope of escarpments facing extensive breeding areas. The highest numbers recorded for the Blacktip Project trapping in June 2004 were close to the mangroves at site 6 (Swamp 2), so it is likely that high numbers were also present in the hinterland area up to 1.5 km from the upper tidal creek mangrove areas near site 6.

The development area is at least 3km from the most productive nearby *C. ornatus* breeding site (Upper tidal creek mangrove areas associated with Swamp 2), although minor pest problems may be experienced in the development area, as *C. ornatus* are capable of dispersing in low numbers for at least 3.5km (Shivas & Whelan 2001).

5.1.4 Seasonal fluctuations

Culicoides ornatus numbers reach a yearly peak in the months of August to November (Mid to late dry season) around the time of the full moon, with a smaller peak around the time of the new moon (Figure 8). Numbers are markedly reduced during the wet season months. Numbers begin to rise from the early dry season months of May or June to the August to November peak (Figure 8).

Sampling in June 2004 at the study site revealed *C. ornatus* numbers as they were beginning to rise from the wet season lows. Further sampling in September 2004 around the time of the full moon should reveal peak season maximum numbers likely to affect the Blacktip Project. The seasonal maximum numbers can vary between the months of August to November (Figure 8), although trapping in September will indicate *C. ornatus* populations during the peak season, and likely maximum numbers. At Fairway Waters, peak season numbers in late August were approximately 10 times greater than numbers in June. It is likely that trapping in September 2004 in the study area will reveal a similar trend in seasonal variations of *C. ornatus.*

5.1.5 Limitations

Ideally to fully gauge the *C. ornatus* population affecting the Blacktip Project, sampling would need to be carried out over three nights around the full moon for every month of the year, to cater for the expected maximum peak dispersal. This species has a range of breeding sites, which exhibit different breeding and dispersal characteristics over a three-day period (Shivas 1997, Shivas 1999).

Traps set one day before the full moon in June 2004 were likely to sample peak numbers from creekbank habitats, but were likely to miss peak numbers from the *Sonneratia* foreshore site, due to maximum dispersal from these sites occurring up to four days before peak dispersal from creekbank habitats (Shivas 1999, Shivas & Whelan 2001). There would have been a delay in maximum numbers at the development site compared to maximum numbers at the mangrove site, due to the distance of the development site from the mangrove breeding sites. Traps set near the development area may have missed maximum monthly numbers for June, due to *C. ornatus* possibly not reaching the development area in peak numbers by the night of trapping.

Traps set over a three night period around the full moon in September 2004 will sample peak season numbers, but may not sample peak season maximum numbers, which can occur around the full moon during any of the months of August to November.

5.1.6 Pest problems and public health

Minor biting midge pest problems in the Blacktip Project development area from *C. ornatus* may occur in the August to November period, particularly for three or four days around full moon nights. A minor pest problem may also occur around new moon nights in this period, but will be lower than for full moon nights. There are unlikely to be significant pest problems for the remaining months of the year.

The number of bites by *Culicoides* that will constitute a pest problem will largely depend on the individual being bitten. It has been suggested that over 60 bites per hour for most experienced biting midge workers are unacceptable (Whelan et. al. 1997a). For people unaccustomed to biting midge bites, one to five bites per hour may be unbearable.

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide trap and the number of bites that can be expected at the peak biting period (Whelan et. al. 1997a). The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO_2 trap over one night at the same position (Whelan et. al. 1997a). For example if there were 400 *C. ornatus* in a CO_2 trap this would equate to 100 bites per hour.

The trapping results indicate that the number of *C. ornatus* in a trap equating to 60 bites per hour (240 *C. ornatus* per trap night) was only exceeded at sites 5 & 6, which were located at least 3km from the Blacktip Project area. Numbers trapped within the vicinity of the Blacktip Project area did not exceed pest numbers, although the low numbers trapped may still cause a minor nuisance to some people. Extended trapping in September 2004 is likely to reveal higher numbers of *C. ornatus,* and give a better indication of abundance in the development area.

An expected minor pest problem will affect construction workers and outdoor workers in the Blacktip Project development area. It is not expected that outdoor activities will be significantly affected by *C. ornatus* pest problems, with particular problems primarily posed to personnel who are particularly sensitive to insect bites.. Peak biting times for this species are in the hours either side of sunset and sunrise. It should be noted however that construction workers within 1.5km of Swamp 2, or at or near Port Keats, will be exposed to much higher levels of biting midges.

Culicoides ornatus bites can be a significant pest problem and can cause associated health problems. The bites are painful and large numbers of bites can cause a generalized reaction in non-immune people. Many people, particularly newly arrived or newly exposed people, suffer from bite reactions that can lead to intense itching, scratching, skin lesions, secondary infection and scarring.

Of other *Culicoides* species collected, *C. immaculatus* bite people readily but are usually found only near their breeding sites at rock-sand or sandy beaches. This species may cause a minor nuisance problem for construction workers at the onshore pipeline crossing site only.

5.1.7 Measures to reduce biting midge pest problems

5.1.7.1 Alteration or removal of breeding habitat

The development is not likely to impact on any of the major pest biting midge breeding sites, because the development will mostly be constructed above the tide margin and not within any mangrove zone where most problem midges breed.

5.1.7.2 Biting midge buffer zones

A biting midge buffer zone can be defined as an area of separation between the biting midge breeding or harbouring areas and the development. An effective buffer width should be a minimum of 1.5km (Liehne 1985, Shivas & Whelan 2001). The onshore gas processing plant and ancillary facilities are approximately 3km from the nearest extensive *C. ornatus* breeding sites (Swamp 2), ensuring an effective buffer distance.

If there are biting midge pest problems for at least some people in the development area, additional measures can be taken to reduce biting midge numbers. The use of UV or white lights in non personnel areas can act as a diversion for biting midges, although the use of lights alone is not likely to provide a useful or effective buffer (Shivas & Whelan 2001).

5.1.7.3 Biting midge larval control by insecticides

The prime breeding habitat of *C. ornatus* are upper tidal creek habitats and at the seaward fringe of extensive mangrove areas, and will generally be at the margin and under a canopy of mangrove vegetation. Insecticide treatment of biting midge larvae in these habitats is unproven, highly impractical and likely to be environmentally unacceptable.

5.1.7.4 Biting midge adult control

'Fogging' or the application of aerosols against adult biting midges can offer some scope for the reduction of biting midge populations. Aerosol application for adult biting midge control poses serious practical problems to achieve an effective measure of control. These include timing of control, the

necessary environmental and weather conditions, access requirements, the non-specificity of most adulticides, and the failure of aerosols to penetrate thick vegetation.

It is unlikely that pest biting midges will reach populations sufficient to warrant adult fogging operations in the Blacktip Project area.

However if there is a need to reduce any pest problems, a new residual insecticide product aimed at adult biting midge and mosquito barrier control (Bistar 80SC, active ingredient 0.1% bifenthrin) has been proven very successful in reducing adult biting midges around residences for up to six weeks in Hervey Bay QLD (Standfast et al 2003, Appendix 7). It is likely to reduce adult biting midge numbers in prepared or landscaped areas and if required, could be used as part of a strategy for biting midge protection. It is recommended that specific landscaping (the use of dense shrub type vegetation) and/or shade cloth fencing be erected around personnel areas to enable enhanced protection by any bifenthrin applications.

5.1.7.5 Personal protection and avoidance

There may be periods when biting midge populations reach levels that warrant personal protection strategies. It is possible that minor pest numbers of *C. ornatus* will affect at least some people in the Blacktip Project area for three or four days around the full and new moon in the months of August to November, with greatest problems occurring around the time of the full moon. Biting midge pest problems are unlikely to occur in the Blacktip Project area at other times of the year. The main pest period will be the hour either side of sunset and sunrise (Whelan & Hayes 1993, Whelan et al 1994).

There are a number of avoidance and personal self-protection measures that can be taken to reduce biting midge pest problems. These include the use of diversionary lights between sources and morning or evening use areas, fine insect screens, light proof curtains, avoidance of areas of pest biting midge activity, avoidance of problem areas or exposure at times of peak biting activity, and personal protective clothing and personal repellents at times or locations of exposure to biting midges (Appendix 5 and 6). If bifenthrin barrier treatments are to be used as mentioned in Section 5.1.7.4 above, then the personnel areas to be protected will need to be specifically landscaped.

Normal insect screening will not be adequate to stop *C. ornatus* entering buildings. However, normal screening, including outwardly opening insect screen doors will stop a considerable portion of *Culicoides* from entering personnel areas and can be made much more effective by applying a residual insecticide such as bifenthrin on the screening. There are finer insect screens that can prevent biting insect entry, and if these are acceptable, should be used. The use of light proof curtains at doors and windows, and avoiding incandescent or white fluorescent lights directly outside doors or windows can reduce the numbers of midges attracted to these entry sites.

5.2 Mosquitoes

5.2.1 Species present

Over 100 mosquito species have been recorded in the Northern Territory. Nineteen (19) species were recorded from the June 2004 sampling for the Blacktip Project. The most significant species in terms of abundance was *Anopheles farauti s.l.* The most significant species in terms of disease potential was *Culex annulirostris.* Due to the presence of a nearby extensive coastal reed swamp (Swamp 1), it is predicted that the salt marsh mosquito *Oc. vigilax* will be the most important mosquito species in terms of posing a pest problem.

5.2.2 Mosquito breeding sites

Larval surveys conducted during the June 2004 survey revealed mosquito breeding sites that will cause pest and potential disease problems for the Blacktip Project development site. The mosquito breeding sites are shown in Figure 7. Each of these sites are dealt with separately below.

5.2.2.1 Swamp 1

This site was an extensive reed swamp and paperbark swamp (approximately 5ha was surveyed or visually inspected), with associated mudflats and tidal grass areas. The reed swamp was subject to both tidal and freshwater influence, while the paperbark swamp was subject to freshwater influence. The extent of each mosquito breeding habitat surveyed is roughly delineated in Figure 4a. The full extent of the swamp will be determined in September 2004, when the swamp is dry and easily accessible.

The reed swamp has probably occurred as a result of a barrier between the swamp and the invert of the small tidal creek downstream of the reed swamp, creating an extensive poorly draining area. Much of the swamp was not surveyed. Investigations will be carried out in September when the swamp is dry and easily accessible to determine the exact constitution of the swamp.

The reed swamp was a major source of *Anopheles farauti s.l., Culex annulirostris,* and *Ochlerotatus vigilax* larvae during the post wet season. *Coquillettidia xanthogaster* larvae were not located, as the larvae of this species attach themselves to submerged aquatic vegetation, making sampling with standard ladles and buckets very difficult. Numbers of most *Culex, Anopheles* and *Coquillettidia* species reach a peak in the post wet season months in reed swamp habitats, due to the presence of dense reed growth and isolated heavily vegetated areas creating ideal habitats with restricted predator access. Most larvae found in the June 2004 survey were located amongst dense vegetation. The location of large numbers of *Oc. vigilax* larvae was a direct result of unseasonally high dry season rainfall in the four or five days prior to the survey, resulting in the re-flooding of previously dry areas of the swamp. Monthly high tides the night before the survey also pushed floodwater into previously dry areas, possibly resulting in further hatches of *Oc. vigilax* larvae.

During the late dry season and early wet season, the reed swamp and associated mudflats, and the tidal creek downstream of the reed swamp are likely to be sources of extreme numbers of the salt marsh mosquito *Oc. vigilax.* Extensive areas of the swamp are likely to be dry by the time of the late dry season, providing vast breeding areas for the salt marsh mosquito, which lays its eggs on damp or drying mud or near plant stems. Eggs hatch after inundation from tidal or rainwater. Peak populations would occur in November and December, and possible early January.

During the early to mid wet season when the swamp becomes permanently flooded, the reed swamp will cease to be a source of *Oc. vigilax* and become a source of pest numbers of *Cx. annulirostris, An. bancrofti,* and possibly *Ma. uniformis.* Numbers would be relatively low during the wet season when the reed swamp becomes colonised with aquatic predators of mosquito larvae, but would rise after the wet season when the drying swamp and lodged reeds creates areas with restricted predator access.

5.2.2.2 Swamp 2

The northern section of this swamp consisted of extensive tidal grass and tidal mudflat areas bordering a narrow paperbark swamp, and freshwater creekline to the south. Only the northern section of the swamp was surveyed, due to the distance of the remaining areas of the swamp from the Blacktip Project site being outside the major pest dispersal range for most pest mosquito species (Appendix 4).

The extensive tidal grass areas surveyed contained many shallow poorly draining areas, with a few areas spot surveyed revealing salt marsh mosquito breeding. The large mudflat to the south was also a salt marsh mosquito breeding site. During the late dry and early wet season, it is likely that this swamp will contribute to pest numbers of the salt marsh mosquito to the Blacktip Project development area.

The remaining areas of the swamp (to the south of the freshwater creekline) not surveyed may contain large salt marsh mosquito breeding sites that could contribute to pest numbers at the Blacktip Project area during the late dry season and early wet season.

The paperbark swamp was relatively narrow and appeared to be relatively well drained. *Culex, Anopheles* and *Coquillettidia* numbers were lower at the adult trap sites set near this swamp, and at the trap site near the southern boundary of the onshore gas processing plant, compared to the traps set at Swamp 1 and at the northern boundary of the onshore gas processing plant. This indicates that the swamp is a relatively small source for wet season and post wet season mosquito breeding species.

The upper reaches of the tidally influenced creeks associated with this large swamp may also be salt marsh mosquito breeding sites in the late dry season, contributing to pest numbers at the Blacktip Project site.

5.2.2.3 Southern coastal vine thicket

The coastal vine thicket was situated behind a coastal dune just south of the pipeline shore crossing, hence was dry at the time of visit in June 2004. Small areas of the interdune area adjacent to the coastal vine thicket were surveyed, with several potentially large salt marsh mosquito breeding sites located. Further more extensive surveys of the interdune area adjacent to the southern coastal vine thicket will be conducted in September 2004.

Pest salt marsh mosquito problems are likely to arise from the interdune areas after monsoonal rainfall in late December, January and February. Minor numbers of *Anopheles* and *Culex* species may arise from the interdune areas during January and February.

5.2.2.4 Northern coastal vine thicket

The interdune area associated with smaller coastal vine thicket slightly north of the pipeline shore crossing was not surveyed. It will be surveyed in September 2004 to locate potential mosquito breeding sites. It is possible that pest numbers of the salt marsh mosquito may breed in any poorly draining areas that may be present in the coastal vine thicket.

5.2.3 Spatial abundance and dispersal

The current survey indicated that most post wet season mosquitoes likely to affect the development area were originating from Swamp 1. The mosquitoes were dispersing in appreciable numbers to at least the northern boundary of the onshore gas processing plant site. There was a large reduction in *An. farauti s.l.* numbers at the northern boundary of the onshore gas processing site compared to the swamp, although numbers were still high. *Culex annulirostris* and *Cq. xanthogaster* numbers were higher at the northern boundary of the gas processing site compared to the swamp, indicating active dispersal into the nearby woodland areas. Numbers of *Anopheles* and *Culex* species, as well as *Cq. xanthogaster* and potentially *Ma. uniformis* are likely to be higher at the northern section of the onshore gas processing plant site compared to the southern section. Swamp 2 is not expected to be a significant source of mosquitoes in the post wet season.

Both swamp trap sites recorded similar low numbers of the salt marsh mosquito *Oc. vigilax*. These were low season numbers only, with numbers in the late dry season and early wet season likely to be high at both sites, with numbers at Swamp 1 expected to be extreme. This species will be breeding in peak pest numbers after monthly high tides or rainfall in the late dry and early wet season months of October, November, December and early January. This species has a very active dispersal characteristic and will fly at least 3.5km in pest numbers from significant breeding sites. Both of these swamps will contribute significant pest numbers of *Oc. vigilax* to the development site, Swamp 1 being the major source, with numbers likely to be high throughout the development area. Pest numbers of *Oc. vigilax* are likely to arise from at least Swamp 1 in the early dry season, after high tides or un-seasonal rainfall.

Mid wet season *Oc. vigilax* breeding in the interdune areas adjacent to the coastal vine thickets in January and/or February, in particular the southern coastal vine thicket, is likely to cause pest problems for the Blacktip Project, although minor compared to the expected pest problem from

Swamp 1 & 2. *Anopheles* and *Culex* species breeding in the coastal vine thickets may cause minor pest problems at the shore crossing, and minor nuisance problems only along the western half of the onshore gas processing plant.

5.2.4 Seasonal fluctuations

After assessing results from the Holmes Jungle reed swamp habitat, it can be assumed that most *Anopheles, Culex* and *Coquillettidia* species affecting the Blacktip Project site would reach peak numbers in the post wet season months of April, May and June. *Culex annulirostris* are also likely to have a mid wet season minor peak in January and February. *Anopheles bancroftii* may have a mid to late wet season minor peak in February and March. Large or extended wet season rainfall may see numbers of these species continue until the end of June, while a small wet season may see numbers continue into early June, until the major breeding sites affecting the Blacktip Project site (Swamp 1) dries up to a significant extent.

5.2.5 Pest problems and public health

There are likely to be severe pest problems of *Oc. vigilax* present at the Blacktip Project development area for up to 10 days in the late dry season and early wet season months of October to January. The June 2004 survey results also indicates that pest problems of this mosquito species can occur in the early dry season, dependant on environmental conditions such as unseasonal rainfall or high tides. When present at peak numbers in November and December, pest problems at Swamp 1 are likely to be extreme, with severe pest problems likely for the Blacktip Project development area. High risk periods for Ross River virus (RRV) and Barmah Forest virus (BFV) disease transmission will occur from *Oc. vigilax* when numbers are high in the months of November to January. Macropod (wallaby) hosts for these viruses are present in the general area, increasing the risk of RRV and BFV transmission in the development area.

Anopheles farauti s.l. numbers will be very high in May and June within 500m of Swamp 1, with high numbers up to 1.5km from Swamp 1 (which includes the northern section of the onshore gas processing plant). Moderate to high numbers may also be present in March and April. This species is the most important potential malaria vector, but risk of transmission is dependent on other factors such as the presence of imported cases with infective stages in the blood and degree of exposure during after sundown peak biting periods. All potential workers should be screened for symptoms of malaria before entering the Blacktip Project site.

If potential cases of malaria are present in the Blacktip Project site, the affected person should be kept indoors at night to prevent the potential infection of local *An. farauti s.l.* mosquitoes, until the person has sought medical advice and is cleared or appropriately treated for malaria. If actual cases of malaria are present in the development area and are assessed as risk cases, traps would need to be set to assess the numbers of adult *An. farauti s.l.* If there is a risk of local transmission, fogging will need to be conducted at the nearest breeding ground or harbouring area to the development, which will be Swamp 1, and along at least the northern boundary of the onshore gas processing plant. The success of this fogging in reducing the numbers of *Anopheles* and associated risk will be entirely dependent on wind direction and access, hence unfavourable environmental conditions may not allow adequate risk reduction. This emphasises the need for appropriate screening of workers, and the rapid detection of cases and application of appropriate treatment and precautionary measures, rather than relying on an insecticide solution.

Culex annulirostris were recorded in moderate pest numbers at the northern boundary of the onshore gas processing plant, although due to the size of the *Eleocharis* reed areas in Swamp 1, high to severe pest numbers are expected. Pest numbers of this species can be expected in the early to mid wet season months of January and February, when Swamp 1 is first flooded after heavy rainfall. High to severe pest problems are expected for extended periods during the post wet season months of April, May and June. This species is a vector of RRV and BFV, and will pose a risk of these viruses to workers in the

development area from December to March. *Culex annulirostris* is also a vector of Murray Valley encephalitis virus (MVEV), with the presence of the freshwater reed swamp (Swamp 1) and associated water bird hosts for the virus increasing the risk of MVEV transmission in the development area. The main risk period for MVEV transmission in the development area will be from January to June.

Anopheles bancroftii numbers were low at the time of trapping in June 2004. Due to the presence of an extensive *Eleocharis* reed area, as well as a large paperbark swamp at Swamp 1, it is expected that pest numbers of this species will be present at Swamp 1 in the post wet season months of April and May, with reduced numbers in June, and disperse in pest numbers to the development site. The low numbers collected in June 2004 seems abnormal for this type of habitat. This species is a potential malaria vector, but is not likely to pose an appreciable risk for malaria transmission unless it is present in very high numbers. This species is likely to cause pest problems only.

Coquillettidia xanthogaster will reach moderate to high pest numbers in the vicinity of Swamp 1 and at the Blacktip Project development site in the months of April, May and June. This species is of little consequence as a disease vector, hence is considered a pest problem only.

Mansonia uniformis were collected in very low numbers. Highest numbers have been recorded in the mid wet season months of January and February at Holmes Jungle, so it is possible that pest numbers of this species may be present in the vicinity of Swamp 1, however this species disperses less than other mosquito species and may not dipserse in appreciable pest numbers to the development site. This species is of little consequence as a disease vector, hence is considered a pest problem only.

5.3 Potential mosquito borne diseases

5.3.1 Arboviruses

The most important potential endemic mosquito borne diseases in this area are those caused by Murray Valley encephalitis virus (MVEV), Ross River virus (RRV) and Barmah Forest virus (BFV) (Mackenzie et al 1994; Russell 1995, Whelan et al 1992). As there is no vaccine against these diseases, the best method of prevention is self-protection from mosquito bites (Appendix 5).

The greatest period of risk for Murray Valley encephalitis virus disease at the Blacktip Project development site is when *Culex annulirostris* numbers are elevated in the mid wet season to early dry season months of January to June. *Culex annulirostris* is also a vector of RRV and BFV, with the greatest risk period of RRV and BFV transmission from this species also being in the January to March period.

Ochlerotatus vigilax is a vector of RRV and BFV. The vector status of this species is enhanced due to its persistent and day biting habits. High to severe numbers of this species will occur in the Blacktip Project area in the months of September to early January, with low to moderate pest numbers likely in late January and February. The greatest risk period of RRV and BFV transmission from this species will be from October to January.

The dengue mosquito species *Aedes aegypti* and *Aedes albopictus* were not trapped, and are not likely to be present in the Blacktip Project area. *Aedes aegypti* is currently endemic to North Queensland, and a population has recently been detected in Tennant Creek. *Aedes albopictus* is not present in Australia. These two mosquito species breed in artificial receptacles, with *Ae. aegypti* usually only found in association with human residences (Lee et al 1987). There is a risk of importation of these species into Port Keats and the Blacktip Project area from artificial receptacles sourced from vessels from overseas and Queensland. Road transport from Queensland and Tennant Creek may also introduce *Ae. aegypti* into the Port Keats and Blacktip Project area. Any cargo from overseas, and from Queensland and Tennant Creek should be inspected and treated if necessary, as per DHCS

guidelines (Whelan 1988, Appendix 8) to prevent the introduction of exotic mosquito species into the area.

5.3.2 Malaria

Malaria is no longer present in the Northern Territory, but there is always a risk of re-introduction, if a proportion of the workforce is mobile and sourced from countries where malaria is present. Cases of imported malaria may not be rapidly detected in isolated areas with reduced medical services and may subsequently infect the local species of *Anopheles* mosquitoes.

The primary potential vector species for malaria in Australia is generally considered to be *Anopheles farauti s.l.* because of its known association with the disease in Papua New Guinea, and because it was shown to be a vector in an epidemic in Cairns in 1942 (Russel 1987). It is the principal potential vector in the Top End of the NT (Whelan 1981). However, Russel (1987) showed that *An. annulipes* in south-east Australia was relatively long lived and therefore *An. annulipes* in the NT must also be considered a probable potential vector of malaria. *Anopheles annulipes* was the probable vector of malaria epidemics on some areas of the NT prior to 1962. *Anopheles hilli, An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose a significant risk as it is not as long lived as the other species (Russel 1987).

If more than 10 individuals of *An. farauti s.l.* or one of the other species bite a malarious person (with the sexual forms of the parasite in their blood) there is a good chance that at least one will survive the minimum of 10 days necessary before it is capable of transmitting malaria to another person. Malaria transmission is more likely to occur if relatively high numbers of female *An. farauti s.l.* have bitten the malarious person.

If malaria cases occur in the Blacktip Project area, the individual should be kept indoors at night away from mosquito bites until a risk assessment is made by MEB. It is important for the individual to receive appropriate treatment to eliminate the parasite in their blood, before the patient is exposed to mosquitoes. Patients should avoid spending evenings and nights close to Swamp 1, which includes the northern section of the onshore gas processing plant. Any accommodation and personnel facilities should be sited in the southern section of the onshore gas processing plant.

Any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria. Only patients exposed after sundown would be at risk of spreading malaria, as *Anopheles* species bite only after dusk. Suspected malaria patients should be advised to seek medical advice.

In the present development, *An. annulipes* and *An. amictus* are not likely to be present in relatively high numbers. *Anopheles hilli* (brackish to saltwater breeder) may be present in moderate to high pest numbers in the post wet season months of April, May and June. Numbers of *An. bancroftii* may be present in moderate to high pest numbers in the period of April to June.

Anopheles farauti s.l. were recorded at very high levels in June. High to very high numbers of *An. farauti s.l.* will be present in the months of April, May and June. Numbers of *An. farauti s.l.* are not likely to be significant after June. There is a very high risk of local malaria transmission in the months of April to June if a malaria patient is present in the development area and within 2km of Swamp 1. The greatest risk area will be those areas within 1km of Swamp 1, with significant risks for the northern section of the onshore gas processing plant.

The finding of very high numbers of *An farauti s.l.* near the Blacktip Project area has considerable implications on what can be defined as high risk areas for malaria transmission in the Northern Territory. The Blacktip Project trapping results indicate potentially significant malaria risk areas exist along coastal and sub-coastal areas on the western edge of the NT as far west as the Port Keats vicinity. Limited trapping in late May at Treachery Bay in 1882 (Whelan 1982), located on the coast

approximately 25km south of the Blacktip Project area failed to reveal any *An. farauti s.l.* adults, and *An. farauti s.l.* is generally absent from Western Australia. This indicates that the Port Keats and the Blacktip Project vicinity is perhaps near the western limit of the *An. farauti s.l.* and the potential malaria high risk zone in the Northern Territory. The numbers trapped at Swamp 1 are comparable to *An. farauti s.l.* numbers around brackish swamps near Darwin, indicating that a very high risk for malaria transmission exists for the Blacktip Project development and surrounding areas near Swamp 1, comparable to some of the higher risk localities in the rest of the NT.

5.4 Evaluation of development plans and suggested mosquito control measures

5.4.1 General considerations

5.4.1.1 Internal drainage

The development will require internal drainage capacity. Any retention of water and particularly the colonization of reeds and grasses in temporary of perennial flooded drains or depressions could lead to new additional mosquito breeding sites. This internal system should be free draining, with erosion prevention structures wherever necessary, particularly at discharge points. Water discharged from drains should not be allowed to pool in nearby depressions or poorly draining areas.

Open unlined stormwater drains containing organically polluted water will breed mosquitoes. If there are dry season low flows in these drain from leaking ponds or other wastewater, the drains will become significant mosquito breeding sites. Problem drains will be characterised by extensive grass growth and stagnant pools with greed filamentous algae. Any drain with dry season low flow that develops these characteristics will need to be formalised with impervious linings and low flow facilities. Water should not be allowed to pool at the drain end point.

5.4.1.2 Containment bunding

It is likely that fuel and condensate storage tanks will require containment bunding. There is a potential for containment bunding to collect rain water and breed mosquitoes. All containment bunding should have drainage facilities so that they can be completely drained on a weekly basis during the wet season. Bunded areas should be formalised to prevent vegetation growth and mosquito breeding.

5.4.1.3 Water storage features

Any water storage pond has a great capacity to become a new mosquito breeding sites. The capacity of the water storage pond or dam to breed mosquitoes will depend on salinity, vegetation growth, the presence of fish, and the rate of draw down of water. A stable freshwater pond level will encourage *Eleocharis* and *Typha* reed growth around the margins and promote mosquito breeding. Brackish water storage will enable *Shoenoplectus* reeds to establish around the margins. All water storage ponds should be at least 1.8m deep with steep sloping sides.

Any pond should be maintained to ensure native fish are present and can be maintained permanently in the feature. The floor of the ponds should slope slightly towards the water entry point, to form a sink area when water levels are low, to minimise the formation of isolated pools when water is drawn down to low levels. If there is high dry season leakage from a freshwater pond, an appreciable permanent freshwater habitat will develop downstream that could become a large source of mosquitoes. Dry season leakage from water storage ponds should be prevented. Any wet season overflow from water storage ponds should be formalised and discharge to a well drained area, where the water does not end up pooling and causing mosquito breeding. Regular maintenance would be required to ensure any water storage pond is free of vegetation.

Any rainwater tanks and septic tanks should be completely sealed to prevent mosquito breeding. Any sewage treatment ponds should have concrete edges and effluent discharge should be sprinkler dispersed or discharge to the sea, with discharge to the sea the preferred option in regards to preventing mosquito breeding. Any sewage treatment facility requires approval by the NT Department of Health and Community Services.

5.4.1.4 Borrow pits or depressions

Borrow pits can be large sources of *Cx. annulirostris* and *Anopheles* species. Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent the creation of new surface water features.

5.4.1.5 Artificial receptacles

Any artificial receptacles that can hold rainwater should be stored under cover, holed or disposed of such that they can not be filled with water. Receptacles such as old tyres, drums, and disused machinery can be breeding sites for exotic mosquito species such as *Ae. aegypti* and *Ae. albopictus,* which can transmit dengue fever, as well as the endemic pest species *Oc. notoscriptus.* Failure to have sanitation measures for receptacles will increase the potential for new pest mosquito problems, and increase the risk of importation and establishment of exotic dengue mosquito species.

Any machinery and other equipment supplies from North Queensland, Tennant Creek or overseas can introduce exotic mosquito species into the development area. Appropriate inspection and sanitation procedures are required to ensure that any machinery and other equipment capable of holding water do not introduce exotic mosquitoes into the development area or Port Keats. This will include searching for the presence of water and mosquito larvae, and emptying and treating any water holding, or potential water holding receptacles with a chlorine solution or a residual insecticide to kill any mosquito larvae or eggs that may be present (Appendix 8).

5.4.2 Development elements

5.4.2.1 Onshore gas pipeline

The laying of the gas pipeline has the potential to create new mosquito breeding sites. From the onshore beach crossing to the onshore gas processing plant, the construction of the pipeline must not lead to the impoundment of water. The pipeline should be buried and soil re-compacted to match the existing ground surface level. Any discrepancy in the finished level of the buried pipeline may lead to either the upstream impoundment of water if the finished level is higher than the natural surface level, or lead to pooling on top of the buried pipeline if the finished level is below natural surface level. Care must be taken to ensure the remaining spoil from the digging of the pipeline trench is stored in a manner to prevent the impoundment of water. Any disturbance to the ground caused by machinery should be rectified as soon as possible.

5.4.2.2 Onshore gas processing plant

Stormwater drainage should be constructed as mentioned in Section 5.4.1.1. Stormwater drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this already productive mosquito breeding site. Water from bunded areas, bunded drains and washdown areas should not be allowed to pool for more than five days. This may require water to be directed from the bunded areas and drains and washdown area to the processed water treatment plant on a weekly basis during the wet season, and whenever necessary to prevent mosquito breeding during the dry season. Bunded areas, bunded drains and wahsdown areas should be formalised to prevent vegetation growth and mosquito breeding.

Settling ponds should be constructed as mentioned in Section 5.4.1.3.

5.4.2.3 Access roads

Culverts should be fitted to access roads where necessary to prevent the upstream ponding of water for periods that will enable mosquito breeding.

5.4.3 Major mosquito breeding site control

5.4.3.1 Swamp 1

General comments

Generally a swamp of this size and potential as a mosquito breeding site close to residential areas would warrant either an engineering solution or periodic insecticide control to reduce mosquito numbers.

An engineering solution to reduce mosquito breeding would require several large drainage systems through the lowest areas of the various reed habitats, mudflats, as well as the paperbark swamp, to drain water to the tidal creek and into the sea. A central channel would need to be excavated in the upper reaches of the tidal creek to help the free flow of water into the regularly flushed tidal area of the creek. Yearly maintenance would be required to maintain the effectiveness of the drains. Even with a drainage system, insecticide control would still be required, but on a smaller scale than if there was no drainage construction. In light of the time limited construction period, and the small continuing operational staff, this engineering solution is not an appropriate control measure.

Control of mosquito breeding in the swamp by an aerial application of the biological larvicide *Bacillus thuringiensis* var. *israelensis* (B.t.i.) would be required within two to three days after significant rainfall or monthly high tides in September to January to temporarily (B.t.i. would only be effective for 1-2 days after being applied) control *Oc. vigilax* breeding. Alternatively methoprene 30 day residual pellets can be applied prior to tidal or rain flooding to provide longer lasting control of mosquito larvae, with pellets lasting for 30 days under water inundation before reapplication is required. The advantage for methoprene pellets is that they can be applied when breeding sites are dry, and hence timing of application is not as critical as with B.t.i. applications. It is likely that two or three methoprene 30 day residual pellet treatments will last the peak *Oc. vigilax* season months of October, November, December and early January. Methoprene 30 day residual pellets would need to be initially applied before the monthly high tide in October.

Further aerial insecticide control would be required in the post wet season months of April to June to control *Culex, Anopheles* and *Coquillettidia* breeding. Methoprene 30 day residual pellets can be applied at the start of April and reapplied every 30 days until the swamp sufficiently dries, which could be late May or late June, depending on the size of the wet season. The swamp is very large and can only be controlled successfully through the aerial application of a mosquito larvicide. Due to Swamp 1 being a large and productive mosquito breeding site, mosquito control is recommended for at least the construction phase, to minimise the risk of the transmission of potentially debilitating mosquito borne diseases when the workforce is large and more exposed.

Specific comments

Due to the distance of the swamp from the Blacktip Project site, and the limited operational staff required to run the onshore gas processing plant, it would be inappropriate to require the proponent to carry out expensive engineering solutions. There would also be issues with environmental issues and cultural sensitivity at Swamp 1.

It is however recommended that mosquito breeding at Swamp 1 be controlled during the construction phase to protect the public health of the larger workforce. Swamp 1 is very large and not all potential breeding areas have been delineated. All potential breeding areas in this swamp will be delineated in September 2004 and details provided to the proponent. Due to the size of the swamp insecticide

control would be expensive, and the proponent may only wish to carry out limited control. If limited control is to be conducted, the *Eleocharis* and *Shoenoplectus* reed areas of Swamp 1 are the areas of the swamp that should be targeted.

A simple and cheaper way to help reduce mosquito breeding in this swamp in the late dry and early to mid wet season would be to conduct annual burning of the reed swamp. This will remove dead reeds and would result in less prolific *Oc. vigilax* breeding. It may also reduce mid wet season numbers of *Culex* and *Anopheles* species, due to the absence of dead reeds providing high organic content in the water, allowing ease of predator access to mosquito larvae when the swamp is flooded, and enabling disruptive wave action to prevent larval development. Annual burning of the swamp however will not prevent all mosquito pest problems from this and other sources.

5.4.3.2 Swamp 2

General comments
The mosquito breeding areas can be treated with methoprene 30 day residual pellets. Aerial application of insecticides will significantly reduce the time involved in controlling mosquitoes at Swamp 2.

The best measure to reduce *Oc. vigilax* breeding at Swamp 2 would be to locate depressions in the upper tidal area after it has been burnt, and judiciously treat the depressions with methoprene 30 day residual pellets. Methoprene 30 day residual pellets should also be used to treat the large shallow depression in the mudflat. Methoprene 30 day residual pellets would need to be applied before the monthly high tide in late dry season month of October, with a further treatment required after the pellets have been inundated with water for 30 days or more. It is likely that two or three treatments will be sufficient to last the peak *Oc. vigilax* season of October, November, December and early January.

Specific comments
Due to the considerable distance of this tidal area from the Blacktip Project development area, it is not necessary to consider an engineering solution for mosquito breeding. However it is recommended that limited mosquito control or management be conducted in this area. The mosquito breeding potential of this tidal area is considerably smaller than Swamp 1, as there are no reed areas or extensive poorly draining areas. Most mosquito breeding likely to occur in shallow depressions in the grassy upper tidal area, and in the large depression in the mudflat.

Annual burning of the upper tidal grass areas is likely to result in less prolific *Oc. vigilax* breeding, and is recommended. Mosquito control does not appear to be warranted, due to the distance of this site from the development area and lower productivity of this area compared to Swamp 1.

5.4.3.3 Southern coastal vine thicket

General comments
Rectification of the poorly draining interdune areas adjacent to the Coastal Vine Thicket can be achieved by grading the flowlines from the interdune areas through the main beach dune, to allow water to drain from the poorly draining interdune areas. This will however allow tide entry into the interdune areas, resulting in the potential die back of vegetation. This engineering solution does not appear to be environmentally acceptable.

Alternatively aerial application of methoprene 30 day residual pellets before the start of monsoon rainfall could provide seasonal control of *Oc. vigilax* in the Coastal Vine Thicket. Further investigations of the interdune area adjacent to the southern Coastal Vine Thicket are required to locate all potential areas of flooding. *Ochlerotatus vigilax* breeding in the forest is likely to be a once or twice off event every year, so only one application of methoprene 30 day residual pellets per annum would be required.

Specific comments
The Coastal Vine Thickets and adjacent interdune areas have not been fully surveyed for potential mosquito breeding sites. Further surveys will be conducted in September 2004. Even if the breeding areas are delineated on ground, location of the breeding sites through the forest canopy may be difficult therefore it appears not to be suitable to require the proponent to conduct aerial control operations in the interdunal areas. Significant breeding will only occur in January or February, therefore avoidance of this area in January and February would be the most practical solution to reducing mosquito problems.

5.5 Personal protection measures

Personal protection measures will be required to reduce the mosquito pest problem. The major pest mosquito problem will be from *Oc. vigilax* during the late dry season and early wet season, as this species will bite during the day and will reach potentially severe numbers. Pest problems will also be encountered from other mosquito species during the mid wet season and post wet season, although the pest problems from other species will be mainly encountered after sundown.

All workers should be notified of the potential pest and disease problem associated with mosquitoes, and be made aware of periods of expected high numbers. All prospective workers should be provided with personal protection guidelines, which are provided in Appendix 5.

There may be periods or areas where workers notice pest mosquito problems. Workers should be advised to report any mosquito problems to the Environmental Officer, so that the Environmental Officer can provide warnings to other workers (such as in-coming workers) who are unaware of the mosquito problem or problem areas.

During the construction phase the Environmental Officer for the Blacktip Project should issue warnings to the workforce when mosquito numbers are expected to be high. Warnings will be required for the post wet season months of April to June, when mosquito numbers are expected to be continually high. Pest problems are likely to be high and continual in the mid wet season months of January and February, with minor to low pest problems in March. Pest mosquito problems in these months will occur mainly after sundown. The Blacktip Project Environmental Officer should advise workers of these problem periods and the need to avoid being exposed after sundown and the need for personal protection measures.

The greatest pest mosquito problems will occur approximately 9 days after the monthly high tide or flooding rainfall in the months of September to January. This problem will arise from the salt marsh mosquito, with very high pest problems likely to occur for at least 10 days in these months. The salt marsh mosquito bites readily during the daytime, therefore is likely to impact on the workforce and lead to complaints. The Blacktip Project Environmental Officer should advise workers of the potential day and night biting mosquito problem during these months and the need for personal protection or avoidance. Workers should be advised that large mosquito breeding sources exist at Swamps 1 & 2, and the interdune areas associated with the southern Coastal Vine Thicket.

5.6 Mosquito control

During the construction phase, temporary wet season mosquito breeding sites may be created in the Blacktip Project area and considerable breeding will occur in Swamps 1 & 2 and the interdune depressions adjacent to the southern coastal vine thicket. Very high numbers of the salt marsh mosquito may disrupt the workforce from the months of September to January, with most pest problems arising from Swamp 1.

Mosquito larval control should be conducted by the proponent and under the duties of the Blacktip Project Environmental Officer to control salt marsh mosquitoes during the construction phase, as this

mosquito species bites during the daytime and would therefore be harder to avoid. Aerial salt marsh mosquito control should be conducted in Swamp 1, with at least the highly productive reed areas controlled with methoprene 30 day pellets in the months of October to January. The MEB will delineate the reed areas of the swamp in September 2004 and provide the details to the proponent. Aerial larval control could then be carried out in the reed areas by the proponent before the monthly high tide in October, and after every 30 days of pellet inundation with water until the end of January.

Mosquito larval control does not appear to be warranted for the upper tidal areas of Swamp 2 and the interdunal areas associated with the southern Coastal Vine Thicket. Swamp 2 is located at least 3km away from the development area, and does not contain extensive mosquito breeding sites as Swamp 1 does. Pest numbers of the salt marsh mosquito will disperse to the development area from Swamp 2, but will only be a minor source compared to Swamp 1. Salt marsh mosquito breeding in the interdunal areas will only occur as a once or twice off event in January and/or February. Construction activities near the Coastal Vine Thickets should therefore be limited or avoided in January or February to avoid mosquito problems from the interdune areas.

Mosquito larval control of Swamp 1 does not appear to be warranted during the late wet season and post wet season months of April to June. Problem mosquito species in these months generally only bite after sundown, hence mosquito problems in these months can be avoided by preventing being exposed after sundown.

Adult mosquito control measures may be required in the development area if mosquito numbers reach extreme levels, or if there is a case of mosquito borne disease and subsequent entomological investigations indicate a further disease transmission risk. However adult mosquito control is inefficient because of the dependence on wind and the provision of satisfactory access to ensure the adequate dispersal of the insecticide. Adult mosquito control by ground operations would only be successful in the mosquitoes were breeding or harbouring in accessible areas relatively close to where they were causing the problem.

The use of bifenthrin barrier control for adult mosquito pest reduction has proven successful in Hervey Bay QLD (Standfast et. al. 2003), but this product has not been successfully trialled under local conditions. It will however provide adult mosquito control to some extent, and will be suitable to use in the development area in conjunction with appropriate landscaping in a similar methodology as recommended for biting midges (see Section 5.1.7.6.).

5.7 Mosquito monitoring and reporting

The Blacktip Project Environmental Officer should check Swamps 1 & 2 in late June or July during the construction phase to see if the swamps are dry enough to burn. If the swamps are dry enough to burn, then burning of the reed and grass areas of the swamps should be arranged and approved by the appropriate people from the Northern Land Council.

During the construction phase the Blacktip Project Environmental Officer should conduct initial inspections of incoming artificial receptacles such as machinery, used tyres or other receptacles capable of holding small amounts of water from overseas, North Queensland or Tennant Creek for mosquito breeding. Mosquito larvae should be sampled using a ladle or pipette, whichever is most suitable. Any mosquito breeding or likely water holding receptacles should be treated as per DHCS guidelines. Monthly periodic inspections of artificial receptacles should be also conducted to locate mosquito breeding, with appropriate treatment taken as necessary. A final inspection of artificial receptacles should be conducted upon the completion of the construction phase. Any mosquito larvae should be kept in a sample container with 70% alcohol and sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.

Monthly inspections of the development area should be conducted by the Blacktip Project Environmental Officer in the wet season of the construction phase to locate any new mosquito breeding sites created by machinery disturbance. The processed water settling ponds and any bunded area or drain should be also checked monthly for mosquito breeding during the construction phase. Mosquito larval sampling can be conducted using a standard ladle painted white, to allow for the easier location of larvae in the ladle. Mosquito larval samples should be sent to the MEB laboratory in Darwin for analysis, with MEB to provide advice and control recommendations.

After construction of the Blacktip Project is finished, the MEB should be engaged to conduct a post construction inspection of the development area, to locate any potential or actual mosquito breeding sites created by the development. Appropriate mitigation measures would be provided for any actual or potential mosquito problem created by the development.

5.8 Limitations

The Blacktip Project trapping in June 2004 provided only very limited information on mosquitoes and biting midges in the Blacktip Project area vicinity. Trapping for mosquito species diversity and abundance at any new development should ideally be carried out for at least 12 months on a monthly basis. Trapping in November and December approximately 10 – 12 days after the monthly high tide or significant rainfall would provide an indication of peak numbers of *Oc. vigilax*. Trapping on a monthly basis will provide a better indication of the relative abundance of most other species.

The entire mosquito breeding potential of Swamp 1 was not determined, due to access difficulties and time constraints. Only a small section of the southern end of the swamp was surveyed, and it is likely that more extensive mosquito breeding sites exist in the northern area of the swamp that will contribute to greater pest numbers of mosquitoes.

Only the northern tidal area of the Yelcher Beach tidal area was surveyed. It is possible extensive mosquito breeding sites exist further south and may contribute some mosquito numbers to the development site.

6. Conclusions

The major findings from the June 2004 survey and assessment were:

6.1 Biting midges

a) Species

- *Culicoides ornatus* was the principal species of biting midge collected, representing 87.4% of all biting midges recovered

b) Source

- The largest biting midge breeding sites likely to affect the Blacktip Project area are the upper tidal creek mangrove areas associated with Swamp 2, which is located approximately 3km south-west of the onshore gas processing plant. Minor breeding sites may be the *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing. Minor breeding sites may also be located in the small mangrove tidal creek area associated with Swamp 1, approximately 2km north of the onshore gas processing plant.

c) Pest problem

- *Culicoides ornatus* will be the principal biting midge pest species in the Blacktip Project development area.

- *Culicoides ornatus* may cause minor pest problems in the Blacktip Project development area in the months of August to November. It is unlikely that pest numbers of this species will affect the development area during other periods of the year.

- Highest numbers will be present in those areas of the development nearest to Swamp 2.

- Pest problems, when they occur, will be greatest for three or four days around the full moon and new moon periods in the months of August to November, with numbers being greater during full moon periods. Pest problems are likely to be greatest one hour either side of sunset, and one hour either side of sunrise.

- Adult biting midge trapping in September 2004 around the time of the full moon will be conducted to indicate actual peak season numbers of *C. ornatus* affecting the Blacktip Project area.

d) Mitigation measures

- The development will not reduce or affect the *C. ornatus* breeding sites likely to affect the Blacktip Project area.

- High use personnel areas such as accommodation, mess and recreation areas should be screened and landscaped to allow effective insecticide barrier control of midges. Yellow or red lights should be used in outdoor personnel areas, as well a light proof curtains for personnel buildings, to prevent attracting biting midges.

- The use of white or UV lights in non-personnel areas can be used to divert biting midges away from personnel areas.

- It is unlikely that *C. ornatus* will reach numbers sufficient to warrant fogging with insecticides in the development area, due to the considerable buffer distance of the development area from Swamp 2.

- The elimination of biting midge breeding sites is not feasible. It would require the filling of a considerable portion of the upper tidal creek mangrove areas in Swamp 1 and 2, and the filling of the entire *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing.

- The workforce and visitors should be notified of a potential minor biting midge pest problem in the months of August to November, and they need to take appropriate personal protection precautions.

- The NT Government will not be responsible for any biting midge monitoring or control operations at the development site and within the vicinity of the development.

6.2 Mosquitoes

a) Species

- The species occurring in highest numbers during June 2004 were, in decreasing order of prevalence, *An. farauti s.l.* (the Australian malaria mosquito), *Cx. annulirostris* (the common banded mosquito), *Cq. xanthogaster* (the golden mosquito), *Cx. sitiens* (the salt water *Culex* mosquito) and *Oc. vigilax* (the salt marsh mosquito).

- *Anopheles farauti s.l., Cx. annulirostris* and *Oc. vigilax* will be the most important mosquito species affecting the Blacktip Project development area.

b) Source

- By far the major source of mosquitoes to the Blacktip Project area will be Swamp 1, a tidal and rainwater influenced swamp located approximately 1.5km north of the onshore gas processing plant. This swamp will be a breeding ground for extreme numbers of *Oc. vigilax*, very high numbers of *An. farauti s.l.* and high to very high numbers of *Cx. annulirostris.* This swamp will also be a breeding ground for non-disease transmitting pest mosquito species such as *Cq. xanthogaster, An. bancroftii* and *Ma. uniformis.*

- Swamp 2, a tidal and rainwater influenced swamp located approximately 3km south-west of the onshore gas processing plant, will also provide pest numbers of *Oc. vigilax* to the development sites. The interdunal areas adjacent to the coastal vine thicket to the south (referred to as 'Southern Coastal Vine Thicket') of the onshore gas pipeline crossing is also a likely significant *Oc. vigilax* breeding site.

c) Pest and potential disease problem

- *Ochlerotatus vigilax* will pose the greatest pest problem. Severe pest problems may occur for up to 10 days per month from September to January inclusive. Low to moderate pest problems may occur in February. Pest numbers will appear from 9 days after significant rainfall or monthly high tides in the months of September to February.

- *Ochlerotatus vigilax* will pose a high risk for Ross River Virus (RRV) and Barmah Forest Virus (BFV) transmission in the October to January period.

- *Culex annulirostris* were trapped in moderate pest numbers. A moderate pest problem from this species is likely to occur in the mid to late wet season months of January, February and March, with high to very high pest problems in the post wet season months of April, May and June. This species will pose a high risk for RRV and BFV transmission in January to March and a high risk for MVEV transmission from January to June.

- *Anopheles farauti s.l.* will pose a very high risk of local malaria transmission at the Blacktip Project development site, should a person with the infective stages of malaria be present in the

development area from April to June. High risk areas are located near Swamp 1 and the northern section of the onshore gas processing plant.

- Other mosquito species including *Cq. xanthogater* and *An. bancroftii* will cause pest problems only, mainly in the post wet season months of April, May and June.

d) Mitigation measures

- Advice should be given to all employees and visitors by the Blacktip Project Environmental Officer on the need for periodic personal protection measures against mosquitoes at the Blacktip Project area, to reduce pest problems and reduce exposure to mosquito borne diseases. Potential problem areas and problem periods should be pointed out to workers.

- Any mosquito complaint should be forwarded to the Blacktip Project Environmental Officer, who can then take remedial action by advising appropriate personal protection and advising other workers or visitors of problem periods or areas during the construction phase.

- Possible malaria cases should be reported as soon as possible to a doctor and health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes. This is to prevent the infection of local populations of *Anopheles* mosquitoes and subsequent local transmission. Employees recently arrived or returning from overseas should receive malaria awareness material.

- During the construction phase, any vessels and cargo capable of holding small amounts of water, such as machinery, used tyres etc from overseas or North Queensland should be inspected as per DHCS guidelines (Appendix 8) by the Blacktip Project Environmental Officer. This is to prevent the introduction of exotic dengue transmitting mosquitoes (*Ae. aegypti* and *Ae. albopictus*). Any road transport and cargo from North Queensland and Tennant Creek should also be inspected by the Blacktip Project Environmental Officer as per DHCS guidelines (Appendix 8), to prevent the introduction of *Ae. aegypti*. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.

- Artificial receptacles such as tyres, drums etc should be disposed of by landfill, holed or stored away from rainfall. If this is not possible, ongoing sanitation measures such as treatment with a chlorine solution or residual insecticide would be required to prevent mosquito breeding. Monthly inspections of artificial receptacles holding rainwater by the Blacktip Project Environmental Officer for mosquito breeding should be conducted during the construction phase, and a final inspection should be conducted upon the completion of construction, with appropriate treatment applied when necessary. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised by MEB.

- Swamps 1 & 2 should be burned annually as soon as possible after the swamps dry out each wet season. Burning reduces shelter for mosquito larvae, which allows predator access to larvae. The Blacktip Project Environmental officer should conduct inspections in late June or July to observe if the swamps are dry enough to burn.

- A mosquito larval control program for Swamp 1 should be established and conducted by the proponents and under the duties of the Blacktip Project Environmental Officer, to detect and control salt marsh mosquitoes during the construction phase. Helicopter larval control should be carried out at least in the productive reed areas of the swamp. The MEB will delineate the potentially most productive salt marsh mosquito breeding areas in September 2004 and provide this information to the proponents. The larvicide of choice would be a methoprene 30 day residual pellet formulation. The residual pellets should be applied at Swamp 1 before the October monthly high tide, and reapplied after every 30 days of water inundation in the breeding site until the end

of January. The Medical Entomology Branch should be consulted on any mosquito larval survey and control program.

- Stormwater drains throughout the development should have erosion control structures where appropriate. Drains with the likelihood of dry season low flows should be formalised with impervious linings and low flow facilities. All drains would need to be maintained annually to remove excess silt and vegetation. Drains should discharge to a suitable end point where water can not pool in downstream areas and cause mosquito breeding. Drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this swamp. Drains should be monitored monthly for mosquito breeding during the construction phase by the Blacktip Project Environmental Officer, with samples sent to the MEB laboratory in Darwin for analysis and advice on rectification measures.

- The processed water settling ponds should be deep and constructed with steep sides (1:2, 1:3 or 1:4 slope) to discourage marginal vegetation growth. A slightly sloping floor should be constructed so that during low water periods all of the water is contained in one area. Provisions should be allowed to ensure overflow water does not pool in any downstream areas, which could exacerbate mosquito breeding. The processed water ponds should be checked monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis and control recommendations.

- The bunded drains, washdown area, condensate and fuel bunded areas, as well as any other bunded area should contain provisions that ensures that water does not pool for more than five days in these structures, to prevent mosquito breeding. It may be necessary to drain these areas into the processed water settling ponds on a weekly basis in the wet season, and whenever necessary to prevent mosquito breeding in the dry season. These areas should be formalised to prevent the establishment of vegetation and consequent mosquito breeding. These areas should be monitored monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis advice.

- Construction activities should be monitored by the Blacktip Project Environmental Officer, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites. This would include monthly inspections for mosquito breeding during the wet season, with samples sent to the MEB laboratory in Darwin for analysis and advice.

- Sewage treatment facilities should dispose of effluent through sprinkler irrigation to designated areas or dispose of effluent to regularly flushed tidal areas. Disposal to regularly flushed tidal areas is the preferred option in regard to preventing mosquito breeding.

- Any high use personnel area for the onshore gas processing plant should be sited on the southern section of the onshore gas processing plant, as far away from Swamp 1 as possible. This is to create a greater buffer distance between personnel areas and the extensive mosquito breeding sources of Swamp 1.

- White or UV lights should be sited away from personnel areas, to divert mosquitoes to some extent away from personnel areas. Outdoor personnel areas should be fitted with yellow or red lights, and have light proof curtains fitted to prevent inside lights from attracting mosquitoes.

- The barrier spray bifenthrin should be utilised around personnel areas, to control adult mosquito numbers. The benefits of this product will be enhanced by planting shrub type vegetation or constructing a fence with dark shade matting around personnel areas, which can then be treated with the product. The shrub type vegetation or dark fencing will be attractive resting places for

mosquitoes (as well as biting midges), and they will receive a dose of the chemical when they rest on the treated surface. Bifenthrin can also be sprayed on insect screens and any other likely mosquito resting place.

- The laying of the underground pipeline must not result in the impediment of the natural flow of surface water. The finished surface must be level with the surrounding land. Any upstream embankment of water could lead to the creation of mosquito breeding sites. Any leftover spoil should not result in the embankment of water.

- Soil erosion, silt deposition and pooling of rain in excavations will need to be prevented to reduce the potential to create new mosquito breeding sites. Any disturbance caused by machinery should be rectified as soon as possible.

- Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent new surface water features.

- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

7.0 Recommendations

The major recommendations arising from the findings of the study are:

7.1 Biting midges

- The use of bifenthrin barrier treatments around personnel areas should be implemented to reduce adult biting midge numbers that could affect the workforce.

- The workforce and visitors should be notified of a potential minor biting midge pest problem in the development area in the months of August to November.

7.2 Mosquitoes

- There will be a requirement for periodic personal protection against mosquitoes at the Blacktip Project area to reduce pest problems and exposure to mosquito borne disease.

- Possible malaria cases should be reported as soon as possible to health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes.

- High use personnel areas should be sites as far away as possible from Swamp 1.

- Any vessels and cargo such as machinery or other receptacles capable of holding small amounts of water from overseas or Queensland, and road transport cargo from Queensland or Tennant Creek should be inspected as per DHCS guidelines to prevent the introduction of the dengue mosquito.

- Mosquito larval control with methoprene 30 day residual pellets is recommended for Swamp 1, to control salt marsh mosquitoes. This is recommended for the construction phase.

- Swamps 1 & 2 should be burned annually during the construction phase when the swamps dry after the wet season.

- Stormwater drains should be constructed in a manner that does not lead to the creation of new mosquito breeding sites.

- The processed water settling ponds should be constructed in a manner that does not lead to the creation of mosquito breeding sites. Hardy native fish species should be stocked in the settling ponds.

- Bunded areas should be managed to prevent mosquito breeding.

- Artificial receptacles should be managed to prevent mosquito breeding.

- Sewage treatment facilities should dispose of effluent through sprinkler irrigation or disposal to a regularly flushed tidal area. Disposal to a regularly flushed tidal area is the preferred option.

- Bifenthrin barrier treatment should be used around high use personnel areas, to reduce adult mosquito populations in these areas.

- The laying of the underground pipeline must not result in the ponding of water or impediment of the natural flow of surface water.

- Construction activities should be monitored, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites.

- The construction of borrow pits must not lead to the creation of mosquito breeding sites, and should be avoided within 1.5km of personnel areas and 1.5km of Port Keats residential areas.

- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

8.0 References

Cilek, J. E., Kline, D. L., and Hallmon, C. F., (2003), 'Evaluation of a novel removal trap system to reduce biting midge (Diptera: Ceratopogonidae) populations in Florida backyards', *Journal of Vector Ecology* 28 (1): 23-30.

Debenham, M. L., (1983), 'Australasian species of the blood feeding Forcipomyia subgenera Lasiohelea Dacnoforcipomyia (Diptera:Ceratopogonidae)', *Australian Journal of Zoology Supplementary Series* 95, pp. 1 - 66.

Department of Health & Community Services and Darwin City Council, Task Force Review (1989), *Mosquito control measures in Darwin*, DH&CS Darwin, NT.

Dyce, A., & Wellings, G. (1998), '*Culicoides of Australasia* (Morphology-Taxonomy-Systematics-Biogeography & Techniques). A Manual in four parts I-IV.' National Arbovirus Monitoring Program, Gosford *Culicoides* Workshop 27-29 October 1998.

Kelton, W. & Masters, A. (1984), '*Aedes aegypti* and vector survey Wadeye – January 1984'. Medical Entomology Branch, Northern Territory Department of Health.

Lee, D. J. (1944), 'An Atlas of the Mosquito Larvae of the Australasian Region. Tribes-Megarhinini and Culicini.' Department of Zoology, University of Sydney.

Lee, D. J. & Woodhill, A. R. (1944), 'The Anopheline Mosquitoes of the Australasian Region.' Publications of the University of Sydney, Department of Zoology. Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1982), 'The Culicidae of the Australasian Region Vol. 2', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1984), 'The Culicidae of the Australasian Region Vol. 3', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1987), 'The Culicidae of the Australasian Region Vol. 4', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Debenham, M. L., Griffiths, M., Marks, E. N. Bryan, J. H., & Russell, R. C., (1989), 'The Culicidae of the Australasian Region Vol. 7', University of Queensland and University of Sydney in collaboration with Commonwealth Department of Community Services and Health, Monograph Series, Entomology Monograph No. 2.

Liehne, P. F. in consultation with Medical Entomology Branch (1985), 'Mosquito and Biting Midge Investigations, Palmerston 1982-85', Palmerston Development Authority.

Merianos, A., Farland, A. M., Patel, M., Currie, B., Whelan, P. I., Dentith, H. & Smith, D. (1992), 'A concurrent outbreak of Barmah Forest and Ross River virus disease in Nhulunbuy, Northern Territory', *Comm Dis Intel*, vol. 16, no. 6, pp. 110-111.

Rohe, D. L. & Fall, R. R. (1979), 'A miniature battery powered CO_2 baited light trap for mosquito borne encephalitis virus surveillance', *Bull Soc Vector Research*, 4, pp. 24-27.

Russell, R. C., (1986), 'Dispersal of the arbovirus vector *Culex annulirostris* Skuse (Diptera:Culicidae) in the Murray Valley of Australia', *Gen Appl Ent*, 18.

Russell, R. C., (1987), 'Seasonal abundance, longevity and population age composition of potential malaria vectors in northern and southern Australia.' Aust. J. Zool.35:289-306.

Shivas, M., Whelan, P. I., & Webb, C. (1997), 'The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera:Ceratopogonidae) in mangroves near Darwin, NT, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 275-279.

Shivas, M. (1999), 'The larval biology of *Culicoides ornatus* Taylor in mangroves near Darwin, NT.' PHD. Faculty of Science, Northern Territory University Darwin.

Shivas, M. (2001), 'Hervey Bay Biting Midge Review 2001. Previous studies and research priorities.' Prepared for the Hervey Bay City Council, QLD.

Shivas, M., and Whelan, P. I. (2001), 'Biting midge research project' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.

Standfast, H., Fanning, I., Maloney, L., Purdie, D., and Brown, M. (2003), 'Field evaluation of Bistar 80 S.C. as an effective insecticide harbourage treatment for biting midges and mosquitoes infesting peri-domestic situations in an urban environment'. *Bulletin MCAA* vol. 15; 2, pp 19-33.

Tai, K. S., Whelan, P. I., Patel, M. S. & Currie, B. (1993), 'An outbreak of epidemic polyarthritis (Ross River virus disease) in the Northern Territory during the 1990-1991 wet season. *Medical Journal of Australia*, vol. 158, pp. 522-525.

Whelan, P.I. (1983), 'Vector Mosquito and Quarantine Survey North Coast of the Northern Territory 3-9 August 1983'. Medical Entomology Branch, Northern Territory Department of Health.

Whelan, P. I. (1988), 'Common mosquitoes in the NT', NT Department of Health & Community Services.

Whelan, P. I. (1994), 'Construction practice near tidal areas in the NT', *Bulletin of the Mosquito Control Association of Australia*, Vol. 6, No. 1, pp. 18-39.

Whelan, P. I. (1991a), 'Biting midge investigations near Darwin and their implications for urban planning', in *Proc. Nat. Conf. on Biting Midges*, Surfers Paradise, Qld, 8-9 Feb, 1990, pp. 39-50.

Whelan, P. I. (1991b), 'Murrumujuk, Gunn Point Peninsula area, biting insect investigation', Department of Health & Community Services.

Whelan, P. I. (1992), ''Murrumujuk, Gunn Point Peninsula area, biting insect investigation (Extracts)', *Bulletin of the Mosquito Control Association of Australia*, Vol. 4, No.1, pp 21-26.

Whelan, P.I. (1998), 'Exotic Mosquitoes Arriving on Seagoing Vessels. Recommended Inspection and Eradication Procedures', *Bulletin of the Mosquito Control Association of Australia*, Vol. 10, (2), pp. 14-22, July 1988.

Whelan, P. I. (2003), 'Biting midges or "sand flies" in the Northern Territory.' *Northern Territory Disease Control Bulletin* Vol. 10, No.3, pp. 1-9, September 2003.

Whelan, P. I., Booth, D. and Kelton, W. (1988), 'Biting insect investigations and comment on the proposed Newtown (Weddell) Development, Darwin, NT', Dept. of Health & Community Services.

Whelan, P.I., & Hayes, G.A., (1993), 'Biting insect investigations Darwin South, Stage I' (Study undertaken on behalf of the Dept of Lands, Housing and Local Government), NT Dept of Health & Community Services.

Whelan, P. I., Merianos, A., Patel, M., Tai, K. S. & Currie, B. (1993), 'The epidemiology of arbovirus infection in the Northern Territory 1980-92', *Arbovirus Research in Australia*, vol. 6, *Proc. of the 6th Arbovirus Conference, 1993*.

Whelan, P. I. & Weir, R. P. (1993), 'The isolation of alpha and flavi viruses from mosquitoes in the Northern Territory 1982-1992', *Arbovirus Research in Australia*, vol. 6, *Proceedings of the 6th Arbovirus Conference, 1992*.

Whelan, P. I., Montgomery, B.L., Hayes, G.A., Nowland, R.A. & Love, B.L. (1994), 'Biting insect investigations Darwin South Stage II. Twelve month baseline study of species, abundance and distribution of biting insects in the Darwin South area', Medical Entomology Branch report.

Whelan, P. I., Hayes, G., Montgomery, B. L. (1997a), 'Biting midge surveillance in Darwin Harbour, *Culicoides ornatus* (Diptera:Ceratopogonidae) abundance and dispersal', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 326-336.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V. (1997b), 'Ross River virus transmission in Darwin, Northern Territory, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 337-345.

Whelan P. I., Montgomery B.L., Hayes G.A., Nowland R.A. Love B.L & Carter J.M. (1997c) 'Biting insects of medical importance at Wickham Point, Darwin Harbour, February 1997', Medical Entomology Branch report.

Whelan, P.I., Love, B., Montgomery, B., Nowland, R., Carter, J., Hayes, G., (1998), 'Durack (Fairway Waters) Development and Biting Insects May 1996 - April 1997.' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.

Whelan, P. I., Hayes, G., Carter, J., Brogan, B., & Warchot, A. (2001), 'Biting insect survey and assessment Glyde Point October to June 2000-2001.' Study undertaken for Woodside Energy. Territory Health Services.

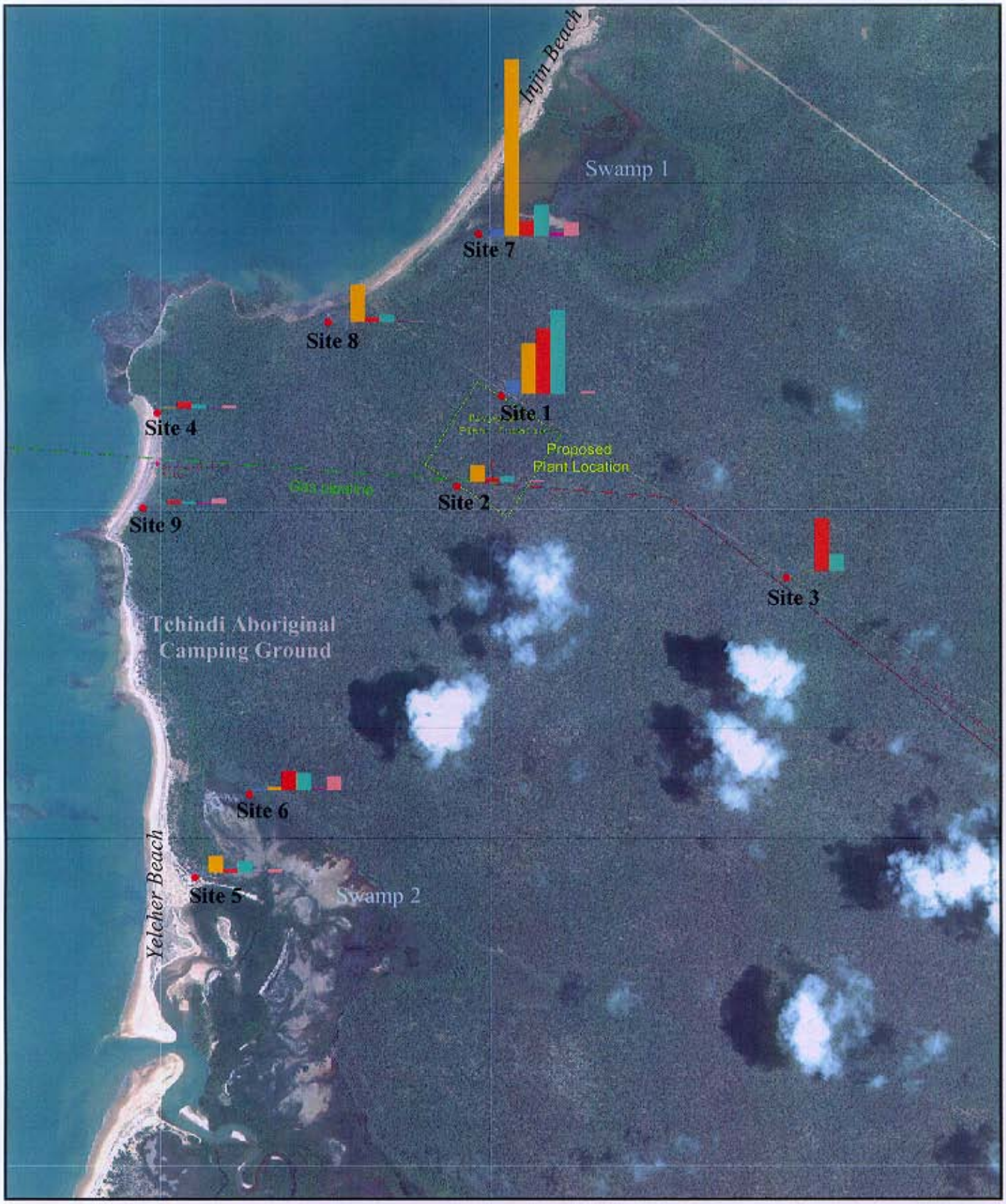
Whelan, P.I., & Warchot, A. (2003), 'Biting midge investigation Archer Sporting Complex, Palmerston August 2003.' Study undertaken for Palmerston City Council, Department of Health and Community Services.

Wightman, G.M. (1989), 'Mangroves of the Northern Territory', *Northern Territory Botanical Bulletin No. 7* (Conservation Commission, Palmerston, NT, now Parks & Wildlife Commission of the NT).

Wirth, W., & Hubert, A. (1989), '*Culicoides* of South East Asia.' The American Entomological Institute, Florida U.S.A.

Figures

Figure 2: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Spatial abundance of selected mosquito species collected in CO2 baited EVS traps



Legend

640 bar length represents 640 adult mosquitoes

- *An. bancroftii*
- *An. farauti s.l*
- *Cq. xanthogaster*
- *Cx. annulirostris*
- *Ma. uniformis*
- *Oc. vigilax*
- CO2 EVS trap site

0 500 1,000 1,500 Metres

Figure 3: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Spatial abundance of Culicoides ornatus collected in CO2 baited EVS traps



Legend

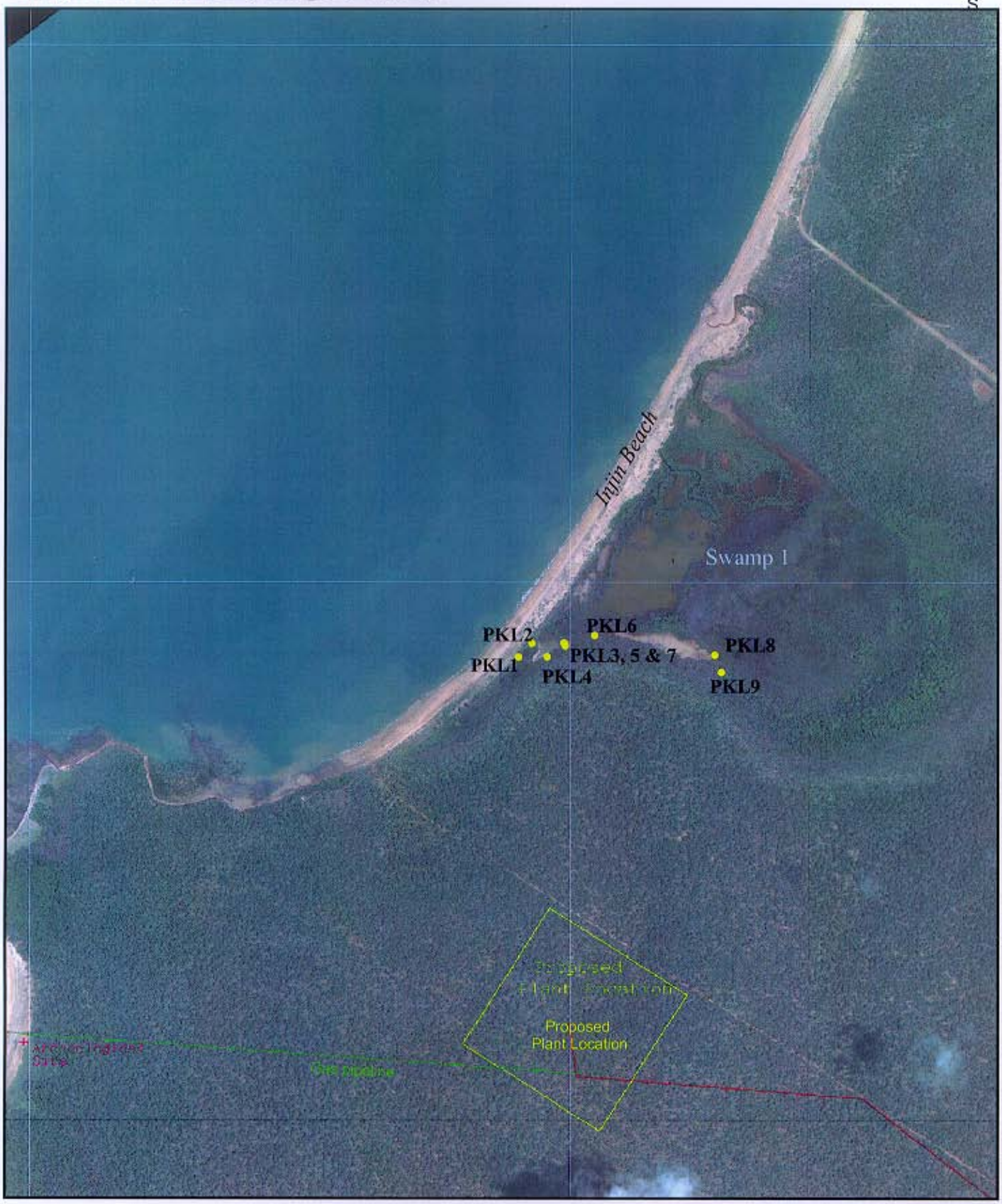
1300

This bar length represents 1,300 C. ornatus adults

C. ornatus

CO2 EVS trap site

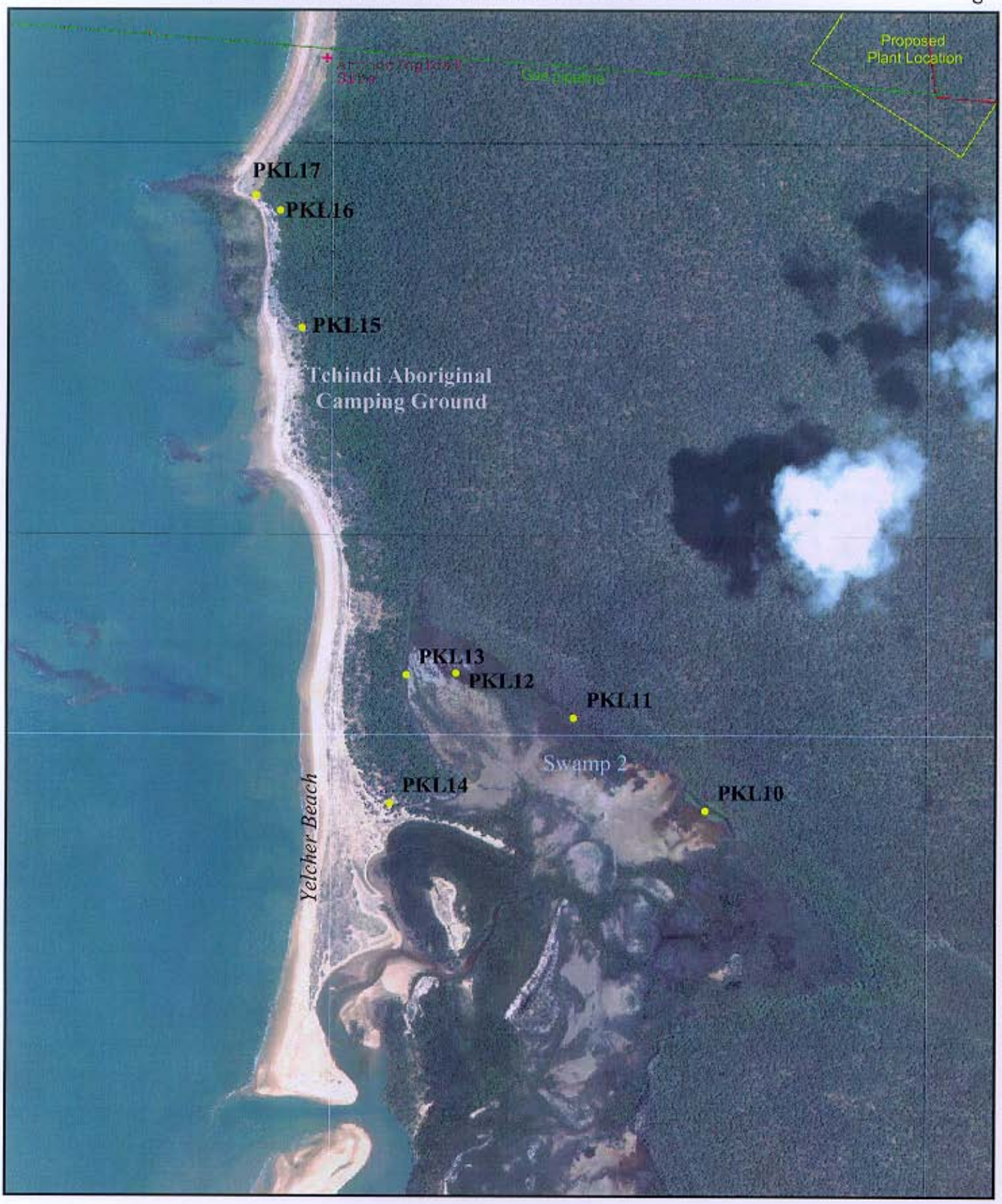
Figure 4a: Blacktip Project Biting Insect Survey, 3 June 2004
Mosquito larval sampling locations, Swamp 1



Legend

Mosquito larval sampling locations

Figure 4b: Blacktip Project Biting Insect Survey, 3 June 2004
Mosquito larval sampling locations, Swamp 2 and southern coastal vine thicket



Legend

Mosquito larval sampling locations

0 500 1,000 1,500 Metres

Figure 5a: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Actual and potential mosquito breeding sites, potential C. ornatus breeding sites, Swamp 1

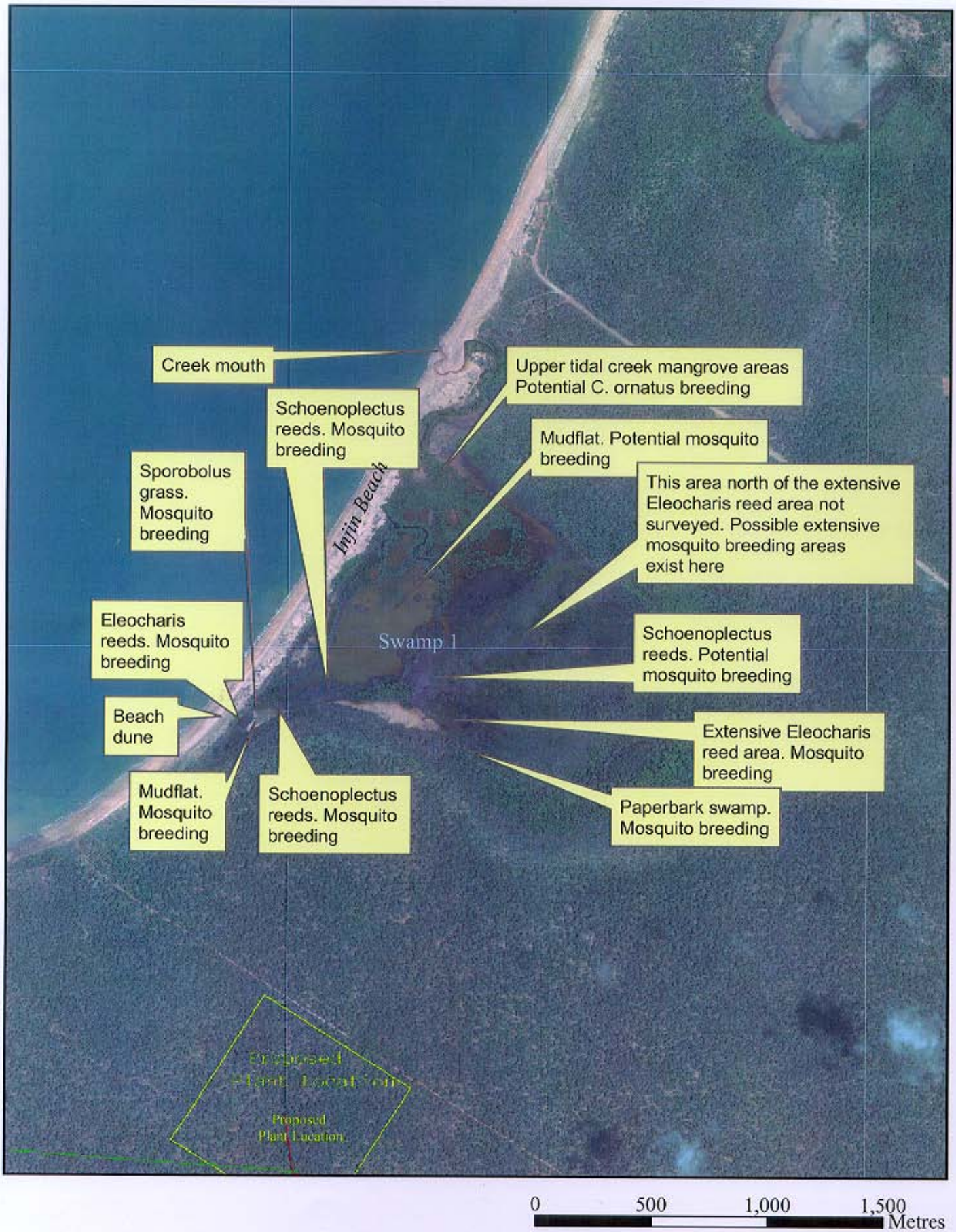


Figure 5b: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Actual and potential mosquito breeding sites, potential C. ornatus breeding sites. Swamp 2 and coastal vine thicket areas

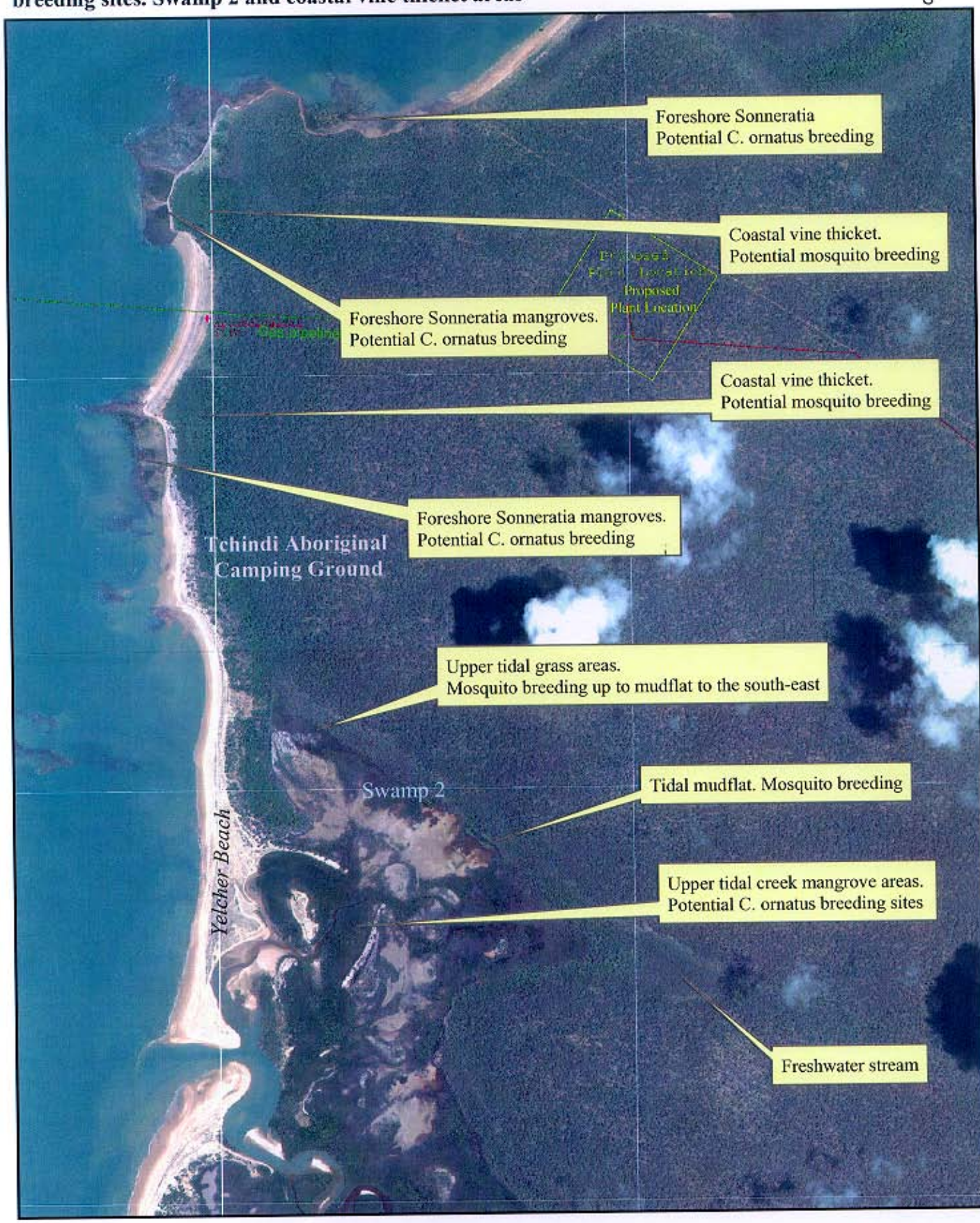


Figure 6 - Darwin weekly mosquito monitoring program - CO2 traps

HOLMES JUNGLE - 1996/02

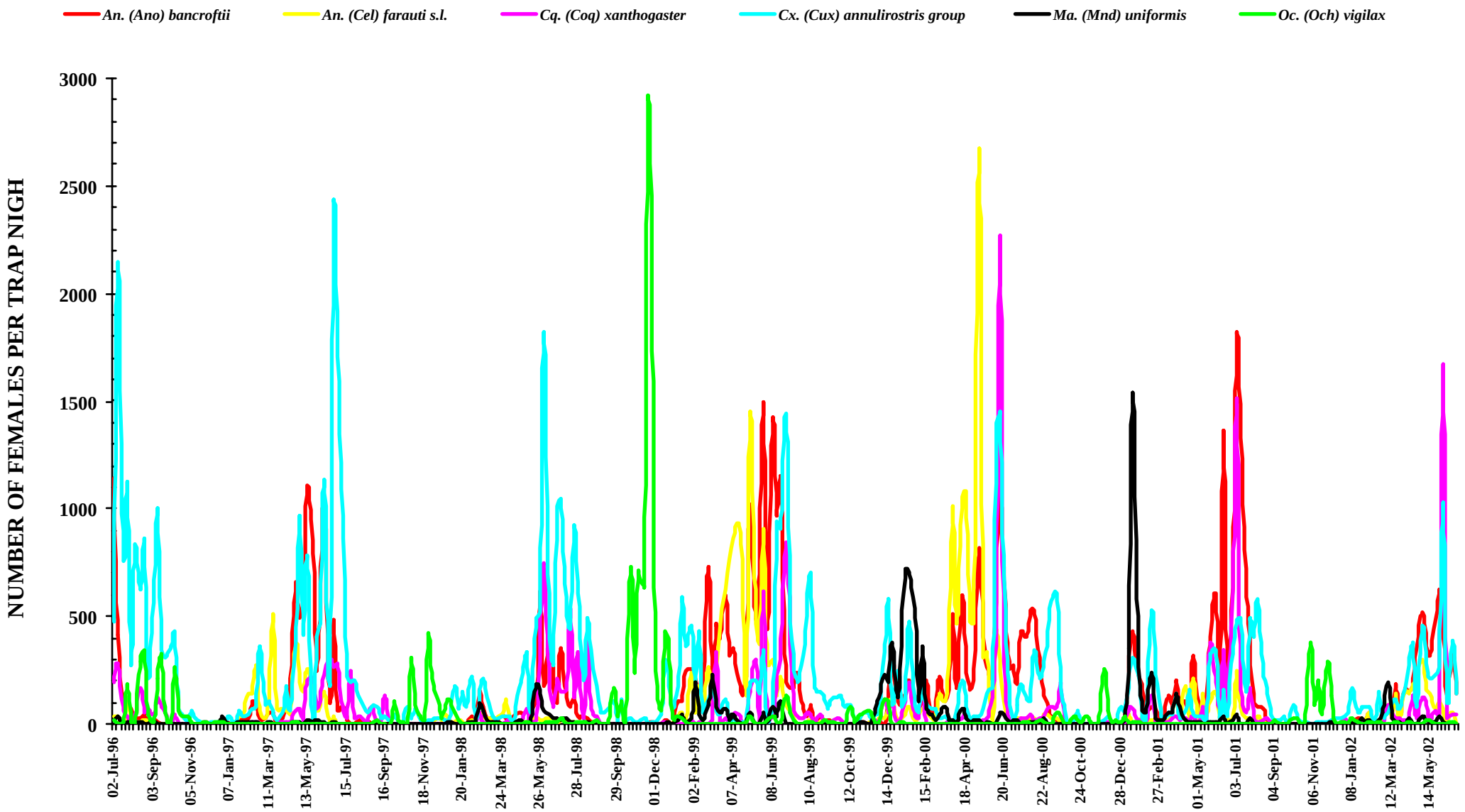
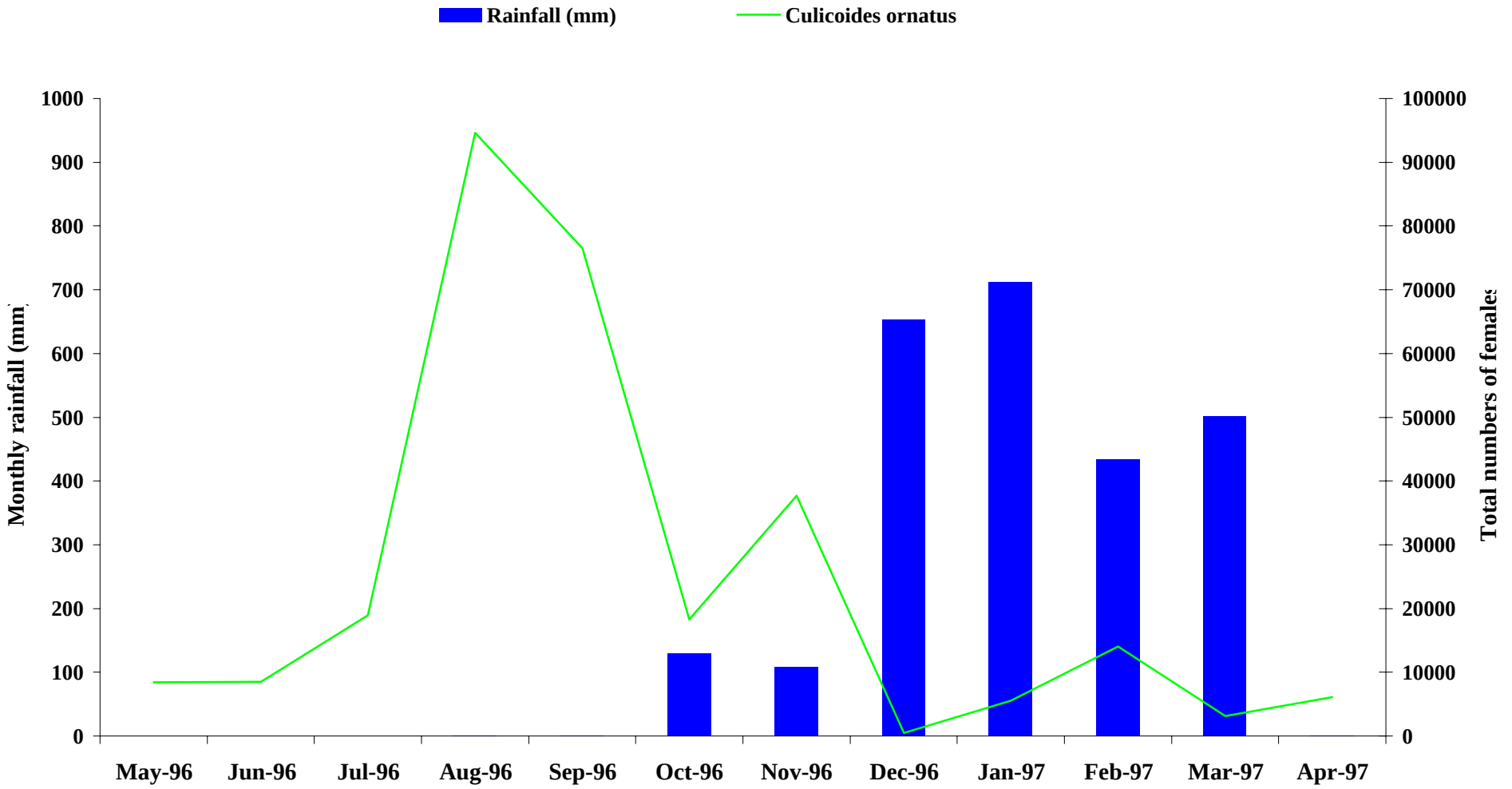


Figure 7 - Biting midge investigations "Fairway Waters" Palmerston May 1996 to April 1997
Seasonal trend of *C. ornatus* collected from all sites on all monthly trap nights,
and total monthly rainfall.



Tables

Table 1: BlacktipProject. Total number of female biting midges collected in CO2 baited EVS traps set on the afternoon of June 2, 2004 (one night before full moon). Refer to Figure 2 for trap locations

	Biting midge species										
Trap location	*C. (Ava) actoni*	*C. (Orn grp) ornatus*	*C. (Orn grp) papuensis*	*C. (Orn grp) undescribed sp No 6*	*C. (Vic grp) bundyensis*	*C. (Wil grp) austropalpalis*	*C. (Wil grp) narrabeenensis*	*C. (Wir) immaculatus*	*Culicoides unidentifiable*	**TOTAL**	**% OF TOTAL**
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	0	1	0	0	0	0	0	0	7	8	0.23
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	2	52	0	0	44	0	0	2	0	100	2.83
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	0	4	0	0	5	8	1	0	25	43	1.22
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	68	0	6	0	0	0	26	0	100	2.83
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping Ground	0	380	10	0	0	100	10	0	0	500	14.16
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	0	2530	1	55	0	0	0	55	0	2641	74.79
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	0	9	0	12	4	19	3	0	0	47	1.33
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	0	8	0	0	0	0	0	15	0	23	0.65
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	0	34	0	1	0	0	0	20	14	69	1.95
TOTAL	2	3086	11	74	53	127	14	118	46	3531	100
% OF TOTAL	0.06	87.40	0.31	2.10	1.50	3.60	0.40	3.34	1.30	100	

Table 2: BlacktipProject. Total number of female mosquitoes collected in CO2 baited EVS traps set on the afternoon of June 2, 2004 (one night before the full moon). Refer to Figure 2 for trap locations

	Mosquito species																				
Trap location	*An. (Ano) bancroftii*	*An. (Ano) powelli*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*Cq. (Coq) xanthogaster*	*Cx. (Cui) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) palpalis*	*Cx. (Cux) sitiens*	*Cx. (Cux) squamosus*	*Cx. (Cux) Vishnui group*	*Cx. (Lop) species 167*	*Ho. ( ) species 157*	*Ma. (Mnd) uniformis*	*Oc. (Cha) elchoensis*	*Oc. (Fin) notoscriptus*	*Oc. (Och) vigilax*	*Ur. (Ura) lateralis*	*Ve. (Ver) funerea*	**TOTAL**	**% OF TOTAL**
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	96	0	364	10	470	0	604	0	0	0	0	0	10	0	1	0	19	0	0	1574	24.48
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	4	1	121	0	27	0	40	9	1	0	0	0	0	0	2	0	13	0	0	218	3.39
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	7	0	4	2	378	4	122	11	0	0	4	4	0	0	0	0	2	0	0	538	8.37
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	0	7	1	50	7	30	2	98	0	167	0	0	5	0	0	23	0	0	390	6.07
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping	7	0	120	0	26	14	87	0	326	0	68	2	0	2	0	2	26	0	2	682	10.61
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	15	0	25	33	141	12	124	0	77	0	0	0	2	10	0	0	102	2	0	543	8.45
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	50	0	1271	13	113	38	226	0	71	0	13	0	17	29	0	0	100	4	4	1949	30.32
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	7	0	269	1	34	0	54	0	0	0	1	0	1	5	0	0	8	0	0	380	5.91
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	2	0	0	0	25	10	17	0	39	2	10	3	0	9	0	0	38	0	0	155	2.41
TOTAL	188	1	2181	60	1264	85	1304	22	612	2	263	9	30	60	3	2	331	6	6	6429	100
% OF TOTAL	2.92	0.02	33.92	0.93	19.66	1.32	20.28	0.34	9.52	0.03	4.09	0.14	0.47	0.93	0.05	0.03	5.15	0.09	0.09	100	

Table 3: Larval mosquito survey results. BlacktipProject Biting Insect Study June 2004. (Refer to Figure 4a & 4b for site locations)

Site number	Date	Site description	Water presence	Specific conductivity us/cm	Species	Comments
PKL1	03-Jun-04	Injin beach tidal/freshwater swamp. Grassy area near *Eleocharis* reeds, south-west edge of swamp, west of mudflat (Swamp 1)	Pooling	n/c	*Ve. funerea* 1 x 4th instar (5/dip)	Water pooling in grassy area near E*leocharis* reeds. Recent rainfall, previous evening high tide added to flooding. Area flooded approximately 40m^2.
PKL2	03-Jun-04	Injin beach tidal/freshwater swamp. *Eleocharis* reed and *Sporobolus* grass area south-west edge of swamp, west of mudflat and south of mangroves (Swamp 1)	Flooded	n/c	*Oc. vigilax* 29 x 4th instar (22/dip) *Cx. sitiens* 4 x 2nd, 1 x 3rd, 4 x 4th instar (7/dip) *Culicine* pupae x 2 (1/dip)	Extent of flooding approximately 5000m^2. Breeding widespread throughout entire flooded area. Recent rainfall, previous evening high tide added to flooding
PKL3	03-Jun-04	Injin beach tidal/freshwater swamp. *Shoenoplectus*/ mangrove interface (Swamp 1)	Flooded	n/c	*Cx. sitiens* 1 x 2nd, 1 x pupae (5/dip)	Extent of flooding approximately 3500m^2. Breeding widespread throughout entire flooded area
PKL4	03-Jun-04	Injin beach tidal/freshwater swamp. Tidal mudflat, south-east end of swamp (Swamp 1)	Flooded	n/c	*Oc. vigilax* 4 x 4th, 1 x 3rd instar (1.7/dip) *Cx. sitiens* 1 x 4th instar (0.3/dip)	Larvae found amongst grassy edge, although were widespread throughout the mudflat. Area of water approximately 5000m^2.
PKL5	03-Jun-04	Injin beach tidal/freshwater swamp. *Shoenoplectus*/ mangrove interface, SE edge of reed area (Swamp 1)	Flooded	13,500	*An. farauti* 11 x 4th, 4 x 3rd instars (0.5/dip) *An. hilli* 2 x 4th instar (0.07/dip) *Cx. sitiens* 3 x 4th, 1 x 2nd instar (0.14/dip) *Oc. vigilax* 95 x 4th, 23 x 3rd, 2 x 2nd instars (4.2/dip) *Anopheline pupae* x 2 (0.07/dip)	Area flooded approximately 3500m^2. Larvae widespread
PKL6	03-Jun-04	Injin beach tidal/freshwater swamp. *Shoenoplectus* reed area between two mangrove areas, south margin of swamp (Swamp 1)	Flooded	18,900	*Cx. sitiens* 5 x 4th, 3 x 3rd, 1 x 2nd, 2 x 1st instars (0.85/dip) *Oc. vigilax* 1 x 4th instar (0.077/dip) *An. farauti* 1 x 3rd instar (0.077/dip)	Area flooded approximately 17000 m^2. Larvae widespread

PKL7	03-Jun-04	Injin beach tidal/freshwater swamp. *Schoenoplectus* reed area, south-west margin of swamp (Swamp 1).	Flooded	n/c	*Oc. vigilax* 2 x 4th instars (0.9/dip) *Cx. sitiens* 1 x 4th, 6 x 3rd, 2 x 2nd instars (4.1/dip)	Area flooded approximately 3500m^2. Larvae widespread
PKL8	03-Jun-04	Injin beach tidal/freshwater swamp. Extensive *Eleocharis* reed area, south edge of swamp (Swamp 1)	Flooded	800	*An. bancroftii* 8 x 4th, 7 x 3rd instars (1.34/dip) *An. farauti* 2 x 3rd, 1 x 2nd instars (0.27/dip) *An. sp.* 3 x 2nd instars (0.27/dip) *Cx. annulirostris* 8 x 4th, 10 x 3rd, 4 x 2nd instars (2/dip) *Cx. sp. 32* 1 x 4th, 2 x 2nd instars (0.27/dip) *Mi. metallica* 1 x 3rd, 2 x 2nd instars (0.27/dip) *Mi. elegans* 1 x 3rd instar (0.09/dip) *Ur. nivipes* 1 x 4th instar (0.09/dip) *Cx. bitaeniorhynchus* 2 x 4th instar (0.18/dip) *Cx. (Lop) sp 155* 2 x 4th, 1 x 3rd instars (0.27/dip)	Area flooded approximately 23,000m^2. Larvae widespread
PKL9	03-Jun-04	Injin beach paperbark swamp. Pigrooted area south of *Eleocharis* reed area (Swamp 1).	Pooling	n/c	*Cx. halifaxii* 1 x 2nd instar (0.07/dip) *Cx. pullus* 5 x 4th, 7 x 3rd instars (0.83/dip) *Ve. funerea* 5 x 4th, 1 x 3rd, 2 x 2nd instars (0.48/dip) *Cx. (Lop) sp 155* 2 x 4th, 2 x 2nd instars (0.28/dip) *Culicine pupae* x 1 (0.07/dip) *Ur. tibialis* 1 x 2nd instar (0.07/dip) *An. farauti* 2 x 3rd instar, 1 x 2nd instar (0.21/dip)	Area pooling approximately 50m^2. Extensive flooding also noticed in the paperbark swamp to the east of this location.

PKL10	03-Jun-04	Large tidal mudflat north of freshwater creekline (Swamp 2)	Flooded	n/c	*Oc. vigilax* 4 x 4th, 1 x 2nd instar (0.83/dip) *An. farauti* 1 x 2nd instar (0.17/dip)	Area of flooding approximately 10,000m^2. Only eastern edge checked for mosquito breeding, larvae found along edge.
PKL11	03-Jun-04	Narrow tidal grass area between mangroves and paperbark fringe, including flowline from paperbarks to tidal area (Swamp 2)	Pooling	n/c	*Oc. vigilax* 4 x 4th, 2 x 3rd instars (3.75/dip) *Ve. funerea* 2 x 4th instar (1.12/dip)	Animal disturbed areas in paperbark forest and tidal grass area. Breeding found in tidal grass and paperbark fringe flowline. Area of water checked for breeding was approximately 40m^2, with the area breeding approximately 10m^2.
PKL12	03-Jun-04	Large tidal grass plain (Swamp 2)	Pooling	n/c	*Oc. vigilax* 6 x 3rd, 1 x 2nd instars (5/dip)	Area of water approximately 50m^2. Larvae found in 20m^2 area of water. Considerable areas of this tidal grass area may pool water in the late dry and early wet season.
PKL13	03-Jun-04	Depressions in vehicle track along upper tidal margin of tidal grass swamp, and depressions in mudflat (Swamp 2)	Pooling	n/c	Nil mosquitoes	
PKL14	03-Jun-04	Depression in sand dune	Dry	n/a	Nil mosquitoes	Evidence of green grass indicates wet season pooling. Depression approximately 80m^2.
PKL15	03-Jun-04	Paperbark swamp behind beach dune, in-between coastal vine thicket	Dry	n/a	Nil mosquitoes	Water may pool for up to 500m^2 during wet season
PKL 16	03-Jun-04	Coastal vine thicket. Restricted flowlines in vine forest	Dry	n/a	Nil mosquitoes	Could be large salt marsh mosquito breeding site
PKL17	03-Jun-04	Coastal vine thicket. Restricted flowlines in vine forest	Dry	n/a	Nil mosquitoes	Could be large salt marsh mosquito breeding site

Appendix 1



Trap site 1: Near centre of northern boundary of onshore gas processing plant, approximately 15 in from access road. People pictured are NLC helpers and Jane Carter of MEB.



Trap site 2: Centre of southern boundary of onshore gas processing plant site. Jane Carter in foreground, NLC workers in background.



Trap site 3: Approximately 2km south-east of onshore gas processing plant north-east boundary, 15m in from access track.



Trap site 4: South-west edge of northern coastal vine thicket. Approximately 5m in from beach dune



Trap site 5: In dunal area near mangroves of Swamp 1, south of southern coastal vine thicket and Tchindi Aboriginal Camping Ground



Trap site 6: Swamp 2. Paperbark/tidal grass fringe. Popeye Briston on right of picture with other NLC workers. Jane Carter holding trap.



Trap site 7: Swamp 1, south-west edge. Trap set in paperbark margin in centre of picture



Trap site 8: Approximately 50m east from shoreline cliff face, north-west of onshore gas processing plant site



Trap site 9: North-west edge of southern coastal vine thicket.

Appendix 2



Photo 1. Swamp 1, looking east from PKL1. *Sporobolus sp.* tidal grass area, corner of mudflat middle left hand side of picture.



Photo 2: Swamp 1. Looking NE from PKL1. Brown areas are *Eleocharis* reeds. Flooded mudflat located behind *Eleocharis* reeds.



Photo 3: Swamp 1. Dense flooded *Eleocharis* reed area just south of PKL2 Green area north of *Eleocharis* reeds,west of mudflat consists of *Sporobolus sp.* grass.



Photo 4: Swamp 1. Larval site PKL6, looking north. *Shoenoplectus* reeds associated with mangroves in centre of picture. Further extensive mudflat and *Shoenoplectus* area located behind this mangrove/*Shoenoplectus* area.



Photo 5: Swamp 1. Larval site PKL9. Pig rooted paperbark swamp, looking east. Similar areas like this extend for a considerable distance



Photo 6: Swamp 1, larval site PKL8. Extensive *Eleocharis* reed area, pig rooted area bottom right hand corner of picture. Photo taken looking east.



Photo 7: Swamp 1. Larval site PKL8. *Eleocharis* reed area looking north. *Shoenoplectus* reeds seen as dark brown band at northern limit of *Eleocharis* reeds.



Photo 8: Swamp 1. Larval site PKL8. Paperbark/*Eleocharis* fringe, looking east. Extensive feral pig damage.



Photo 9: Southern Coastal vine thicket interdune area. Larval site PKL17. Flowline from dune vegetation to frontal beach dune.



Photo 10: Southern Coastal vine thicket interdune area. Larval site PKL17. Flowline from forest to frontal beach dune.



Photo 11: Southern Coastal vine thicket interdune area. Larval site PKL16. Beach Hibiscus at entrance to flowlines in forest



Photo 12: Interdune flowline adjacent to Southern Coastal vine thicket. Larval site PKL 16. Inside forest from Photo 11.



Photo 13: Interdune flowline adjacent to Southern Coastal vine thicket. Larval site PKL16. Inside forest from Photo 11.



Photo 14: Interdune depression and flowline adjacent to Southern Coastal vine thicket. Larval site PKL 15. Low lying area looking north, frontal beach dune to the left of photo.



Photo 15: Interdune depression and flowline adjacent to Southern Coastal vine thicket. Larval site PKL15, Photo taken looking south



Photo 16: Interdune depression adjacent toSouthern coastal vine thicket. Larval site PKL14. Low lying area, mangrove margin to the right, vine thicket to the left.



Photo 17: Swamp 2. Larval site PKL 13. Upper tidal limit, looking south-east.



Photo 18: Swamp 2. Larval site PKL13, upper tidal limit looking south..



Photo 19: Swamp 2. Large upper tidal grassy area slightly east of Larval site PKL13, looking south-east. Paperbark margin in background.



Photo 20: Swamp 2. Larval site PKL12. Upper tidal grassy area, looking south into mangrove margin



Photo 21: Swamp 2. Larval site PKL 11. Paperbark/upper tidal grass margin, looking east.



Photo 22: Swamp 2. Larval site PKL 10. Poorly draining mudflat area in upper high tide zone, bordering tidal grass area. Photo looking west.

Appendix 3

TABLE 1

SUMMARY OF THE BIOLOGY OF SELECTED *CULICOIDES* SPECIES IN THE TOP END OF THE NORTHERN TERRITORY

Peter Whelan, Medical Entomology Branch, Territory Health Services

Species	Larval Ecology	Adult Ecology
C. ornatus	Dry season – breeds between Mean Low Water Neap (MLWN) and MHWN tide mark in creekbanks of small tidal creeks. Breeds in highest numbers at creekbank habitats around Mean High Water Neap (MHWN) in association with *Avicennia* pneumatophores. Breeds in *Sonneratia* foreshore habitats associated with mud substrates. Wet season – transitional *Ceriops* zone just below Mean High Water Spring (MHWS) at back edge of creekbank forest. *Rhizophora* transitional zone adjacent to *Sonneratia* foreshore habitats.	Bites people readily and a serious human pest. Bites other mammals; crepuscular; disperses in pest numbers to 2 km and up to 4 km. Emergence around neap tide time with peak dispersal over 3 days around full moon. Disperses readily to higher ground up to 1.5 km from mangroves.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)	Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.	Crepuscular. Rarely bites people.
C. marksi	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
C. narrabeenensis	Breeds at edge of fresh water.	Rarely bites people.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	Upper estuary.	Occasionally bites people.
C. pallidothorax	Breeds near fresh water.	NT species, rarely bites people.
C. flumineus	Similar to *C. ornatus* but at a lower level on creekbanks of small upper tidal tributaries. Also breed in crab burrows on creekbank.	Readily bites people but rarely encountered out of mangroves.
C. immaculatus?	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species	Relatively common in lower reaches of mangrove creeks and bites viciously.
C. immaculatus	Sandy wave washed beach sand often with rocks, near neap high tide level. Neap tide species	A relatively rare to minor pest . Found near breeding sites only.

C. ?subimmaculatus (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.

Adapted from information by Allan Dyce and pers com Martin Shivas 1998. Minor revision January 2004.

TABLE 2

SEASONAL PREVALENCE OF SELECTED *CULICOIDES* SPECIES IN THE TOP END OF THE NT

Peter Whelan
Medical Entomology Branch, Territory Health Services

Species	Seasonal Prevalence
C. ornatus	The major human pest species within 2km of mangroves at coast. High localised populations all year round, with maximum numbers occurring in September to October and minimum in the wet season.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)	A major species near extensive areas of mangroves at coast. High numbers in the late dry season and early wet season, and has low populations in the post wet season.
C. marksi	A major species in sub-coastal and inland areas, with only low populations at coast. Low populations in the late dry season and moderate populations in the early wet and post wet to mid dry seasons.
C. narrabeenensis	A minor species with peak numbers in the early to mid dry season.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	A minor species. Peak numbers in mid wet season.
C. pallidothorax	A minor species. Peak populations during the early to mid wet season.
C. flumineus	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
C. ? immaculatus	A serious pest in lower reaches of mangrove creeks
C. immaculatus	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
C. ?subimmaculatus (northern form)	An important pest species. Moderate numbers near favoured wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

Adapted from information by Allan Dyce and pers. comm. Martin Shivas 1998. Minor revision January 2004.

Appendix 4

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT
OF HEALTH
AND COMMUNITY
SERVICES

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT PEST AND VECTOR STATUS HABITATS AND BREEDING SITES

P.I. Whelan
Medical Entomology Branch
Department of Health and Community Services
1997

Updated January 2004

For more information contact:
Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: (08) 8922 8333
Fax: (08) 8922 8820
E-mail: peter.whelan@nt.gov.au

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND VECTOR STATUS HABITATS
AND BREEDING SITES

Peter Whelan
Senior Medical Entomologist
NT Department of Health and Community Services
1997

These summary tables are intended as a guide and for assistance to environmental health officers and other public health officers involved in mosquito awareness, surveillance and control programs. They are of a general nature only. They are based on selected literature and my 25 years of field experience as an entomologist in the NT.

Flight range
Adult mosquitoes generally disperse in reasonable numbers, at least 1.6 km from their breeding site. However, some fly much longer distances in search of blood meals (eg. *Oc. vigilax, Oc. normanensis* and *Cq. xanthogaster*) and some generally do not fly far at all (eg. *Ve. funerea, Oc. kochi, Oc. tremulus, Cx. quinquefasciatus* and *Ma. uniformis)*

Species identities
Where there are species complexes which are difficult or impossible to separate morphologically, there is no data regarding the vector capacity of the individual members of the complex. For example, *An. farauti* (formerly *An. farauti* No. 1) is a probable vector of malaria in New Guinea and was probably responsible for the Cairns epidemic in 1942. However, there is no indication of the vector performance of *An.hinesorum* (formerly *An. farauti* No. 2) or *An. torresiensis* (formerly *An. farauti* No. 3) in Australia.

Pest levels
Pest level is very subjective and depends on the population of people subjected to attack and their habits/clothing/location at sunset in an overall setting of size and productivity of nearest breeding sites. CO2 trap levels below the threshold may still be a localised nuisance but are not regarded as at a significant pest level. CO2 trap threshholds generally hold for the Top End of the NT but may vary under different local conditions such as, proximity to breeding site and productivity of breeding site, the topography and vegetation between breeding sites and residential areas, and location and exact position of mosquito traps.

Total of all species present at a given location gives an indication of the total pest level. For protected people, (people inside screened houses at night after sundown) there is no real pest problem even at very high levels. Before sundown the pests in residential areas are primarily *Ochlerotatus vigilax* and *Ochlerotatus notoscriptus* within flight range of breeding sites and on a seasonal basis. Other species can be pests in shaded/heavily vegetated areas at times during the day but generally have peak biting levels in the first two hours after sundown.

MAJOR PEST AND VECTOR MOSQUITO SPECIES

IN THE TOP END OF THE NT*

Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997

SPECIES	PEST STATUS [1]	VECTOR STATUS
An. annulipes s.l. [2]	Widespread pest, bites at night and will enter houses.	Potential malaria vector.
An. bancroftii	Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.	Potential malaria vector.
An. farauti s.l. [2]	Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.	Major potential vector of malaria.
An. hilli	Coastal pest, bites at night, enters houses. Common near brackish water swamps.	Potential malaria vector.
An. meraukensis	Local pest, bites after dark. Very common near extensive freshwater swamp.	Not potential malaria vector.
Cx. annulirostris	Major pest, very common and widespread in both urban an rural areas. Bites mainly in evening and at night.	Major arbovirus vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV) and Barmah Forest virus (BFV) and dog heart worm. Vector of numerous other arboviruses.
Cx. quinquefasciatus	Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.	Potential arbovirus vector (MVEV). Vector of heartworm of dogs.
Cx. sitiens	Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.	Probably no diseases. Possible RRV disease.
Cq. xanthogaster	Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.	No diseases. Filariasis in frill neck lizard
Ma. uniformis	Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.	No diseases.
Oc. kochi	Local pest at breeding site, does not disperse. Restricted to *Pandanus* thickets.	No diseases.
Oc. normanensis	Major pest, bites in evening and night within 3 km of breeding sites. Plagues in inland areas a week after widespread flooding rains in wet season.	Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.
Oc. notoscriptus	Local urban pest, container or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.	Potential Ross River virus vector. Major vector of heartworm of dogs.
Oc. tremulus	Local urban pest, container or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.	No diseases.
Oc. vigilax	Major pest, bites day or night within 5 km of breeding sites. Plagues associated with high tides in late dry season, early wet season. Fly up to 60 km in pest numbers.	Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.
Ve. funerea	Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forrest near tidal brackish swamps & Creeks.	Potential RRV and BFV arbovirus vector.

*** Adapted and revised from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982 -85".**

BIOLOGICAL ATTRIBUTES OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END^ OF THE NT*

Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997

SPECIES	IMMATURE STAGES	ADULT STAGES
An. annulipes s.l.	Eggs laid singly on water surface; any freshwater body but numerous near *Eleocharis* reed swamps; temporary or permanent; some containers; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.
An. bancroftii	Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or *Eleocharis* reed swamps.	Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.
***An. farauti s.l.* (Includes *An. farauti, An. hinesorum* and *An. torresiensis*)**	Eggs laid singly on surface; larvae feed on water surface. *An. farauti* breeds in brackish water; *An. hinesorum* and *An. torresiensis* breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
An. hilli	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in *Schoenoplectus* reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
An. meraukensis	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater *Eleocharis* reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
Cx. annulirostris	Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic containers and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.	Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.
Cx. quinquefasciatus	Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.	Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.
Cx. sitiens	Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
Cq. xanthogaster	Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with *Eleocharis* and *Typha* reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers and will disperse widely up to 3 - 5 km. Readily feed on birds and mammals including humans; rest in cool vegetation and bite mainly at dusk, also shade during day. Strongly attracted to light and easily disturbed.
Ma. uniformis	Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to *Cq. xanthogaster*.	Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.

SPECIES	IMMATURE STAGES	ADULT STAGES
Oc. vigilax	Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with *Schoenoplectus littoralis* or landward ill draining mangrove areas; larvae browse on substrate.	Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km; shelter in thick vegetation.
Oc. kochi	Eggs laid singly on the axils of *Pandanus* leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
Oc. normanensis	Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.	Major pest species. Extreme numbers after flooding rains for 1- 2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3 - 5 km in pest numbers.
Oc. notoscriptus	Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic container habitats.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
Ve. funerea	Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.	Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.

*** Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85".**

^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.

SEASONAL PREVALENCE OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT*

Peter Whelan Medical Entomology Branch, Department of Health and Community Services 1997

SPECIES	SUMMARY OF BIOLOGY & SEASONAL PREVALENCE
An. annulipes s.l.	Freshwater streams and vegetated swamps. Low to moderate numbers in the wet season, the persistence of populations after the wet season dependent on surface water.
An. bancroftii	Freshwater, paperbark and *Eleocharis* reed swamps and creeks. High to very high numbers at post wet and early dry season, when emergent vegetation at peak and standing water starting to recede.
An. farauti s.l.	Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.
An. hilli	Brackish/saltwater breeder, often associated with *Schoenoplectus* reed swamps or creeks or remnant pools in landward mangroves. Low numbers except near extensive brackish water swamps in late wet and early dry season.
An. meraukensis	Open shallow freshwater *Eleocharis* reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season,
Ma. uniformis	Same as *Cq. xanthogaster* but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.
Cx. annulirostris	Breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways Exploits temporary vegetated ground pools in wet season. High numbers in polluted or wastewater with vegetation in dry season. High to very high numbers in the early to mid dry season.
Cx. quinquefasciatus	Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.
Cx. sitiens	Breeds in salt to brackish coastal pools or swamps. Low numbers except locally in tidal pools in upper tide zone in late dry, early wet season, and late wet season.
Cq. xanthogaster	Breeds in freshwater *Eleocharis* reed swamps and creeks. Very high numbers in mid to late dry season when maximum plant growth present in permanent and semi permanent swamps and creeks.
Oc. kochi	Breeds in *Pandanus* axils. Moderate numbers in wet season in *Pandanus* thickets.
Oc. normanensis	Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.
Oc. notoscriptus	Tree hole or artificial container breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.
Oc. tremulus	Tree hole or container breeder. Low numbers in wet season and early dry season.
Oc. vigilax	Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.
Ve. funerea	Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.

*** Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85".**

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND DISEASE VECTOR STATUS
Peter Whelan 1997
Medical Entomology Branch, Department of Health and Community Services

Species/	**Nuisance status**	**Disease Vector Status**		**Potential vectors in the NT**	**Peak Abundance**
(Common Name)		**Current**	**Potential**		
Ochlerotatus vigilax (Salt marsh mosquito)	+++++	+++	++++	RRV BFV	September - January
Ochlerotatus normanensis (Floodwater mosquito)	+++++	+++	++++	RRV BFV	January - April
Culex annulirostris (Common banded mosquito)	+++++	+++++	+++++	MVEV, KUN RRV, BFV, JEV, others	January - August
Culex gelidus (The frosty mosquito)	+	+	+++	MVEV, KUNV, RRV BFV, JEV, others	January-April
Culex palpalis (Freshwater banded mosquito)	+++	++	+++	MVEV, KUNV RRV, BFV, JEV, others	January-August
Anopheles bancroftii (Black malaria mosquito)	+++	Nil	+	Malaria (possible)	February - July
Coquillettidia xanthogaster (The golden mosquito)	+++	Nil	Nil	None known	March - August
Mansonia uniformis (Waterlily mosquito)	+++	Nil	Nil	None known	March - June
Anopheles farauti s.l. (Australian malaria mosquito)	+	Nil	+++++	Malaria (probable)	March - June
Culex quinquefasciatus (Brown house mosquito)	+++	+	+	MVEV (possible)	January - Jun
Ochlerotatus notoscriptus (Container mosquito)	+	+	++	RRV (probable)	Jan - June
Verallina funerea (Brackish water moquito)	+++	+	++	RRV, BFV (probable)	Oct - Jan

LEGEND

RRV - Ross River virus BFV - Barmah Forest virus	MVEV - Murray Valley encephalitis virus JEV - Japanese encephalitis virus KUNV - Kunjin virus	+ Minor pest on Disease Potential	+++++ Major pest on Disease Potential

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
INDICATIVE PEST LEVELS
Peter Whelan 2002
Medical Entomology Branch, Department of Health and Community Services

Species	Main distribution	Peak Period	CO_2 Trap at Residence *	CO_2 Trap at Monitoring Site #
Ochlerotatus vigilax	Top End, north of Wave Hill, Larrimah and Borroloola	September - January	20	50
Ochlerotatus normanensis	Subcoastal Top End south to Ti Tree	January - April	30	50
Culex annulirostris	NT wide	January to August	50	100
Anopheles bancroftii	Top End north of Victoria and Roper River, south to Larrimah	February - July	30	60
Coquillettidia xanthogaster	Top End north of Victoria and Roper River, south to Larrimah	March - August	30	60
Mansonia uniformis	Top End south to Larrimah	March - June	30	60
Anopheles farauti s.l.	Top End north of Port Keats, Pine Creek, and Numbulwar	March - June	30	50
Culex quinquefasciatus	NT wide, primarily near residential areas	January - June	20	30
Ochlerotatus notoscriptus	NT wide, generally near residential areas	January - June	30	30
Verrallina funerea	Top End primarily coastal and sub-coastal but occasionally south to Larrimah	Nov - March	20	100

Pest Levels

* Indicative significant pest threshold levels (mosquitoes per CO_2 trap per night) at residence for relatively unprotected people at peak biting times.

Indicative significant pest threshold levels (mosquitoes per CO2 trap per night) in residential areas from monitoring sites close to but outside of residential areas, and for monitoring sites between the residential areas and major mosquito breeding areas that are within 2km of residential areas.

Problem Mosquito Species In The Top End Of The NT Habitat and Flight Range Peter Whelan 1997 Medical Entomology Branch, Department of Health and Community Services			
Species/Common name	**Habitat Description**	**Habitat Indicators**	**Flight Range & Pest Solutions**
Ochlerotatus vigilax (Salt marsh mosquito)	Brackish reed swamps Upper mangrove margin and tidal creek extremities	Extensive mangrove areas with freshwater creek entry. Tidally or sea spray affected rock pools, depressions in coastal sand dunes and vegetated areas above tidal limit. Disturbed upper tidal areas. Tidal brackish swamps with *Schoenoplectus* reeds.	0 - 5 km major pest 5 - 50 km pest numbers 50 - over 200 km dispersal
Ochlerotatus normanensis (Floodwater mosquito)	Flooded freshwater sub-coastal or inland floodways and creeks	Broad, flat sub-coastal and inland drainage floors of minor and major creeks.	0 - 2 km major pest 2 - 5 km pest numbers
Culex annulirostris (Common banded mosquito)	Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents	Extensive reed swamps with *Eleocharis* or *Typha* reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, *Lemna* (Duckweed), *Azolla* (water fern).	0 - 3 km major pest 2 - 10 km pest numbers 10 - 15 km dispersal
Verrallina funerea *(brackish mosquito)*	Upper reaches of mangroves with fresh water inflow. Rain filled coastal swamps	Brackish mangroves & mangrove fern. Schoenoplectus reed swamps. Shaded rainfilled coastal depressions & creeklines. Under beach hibiscus & Casuarina trees	0-500m minor pest Day pest in closed forrest near breeding sites.
Anopheles bancroftii (Black malaria mosquito)	Freshwater and coastal reed swamps. Shaded streams and swamps	Extensive seasonally inundated *Melaleuca* paperbark swamps. *Eleocharis* and *Typha* reed swamps.	0 - 3 km major pest 3 - 5 km pest numbers
Coquillettidia xanthogaster (The golden mosquito)	Freshwater swamps with reeds Vegetated streams	Extensive *Eleocharis* and *Typha* reed swamps. Paperbark creek lines.	0 - 3 km major pest 3 - 5 km pest numbers
Mansonia uniformis (Waterlily mosquito)	Extensive freshwater reed swamp	Extensive *Eleocharis* and *Typha* reed swamps with water lilies.	0 - 2 km major pest 2 - 3 km dispersal
Anopheles farauti s.l. (Australian malaria mosquito)	Coastal and brackish reed swamps Freshwater swamps and vegetated streams	Brackish *Schoenoplectus* and *Eleocharis* reed swamps. Upper reaches of mangrove creeks with freshwater influence.	0 - 1.5 km minor pest 1.5 - 3 km dispersal
Culex quinquefasciatus (Brown house mosquito)	Storm drains, artificial containers Septic tanks Waste water ponds	Polluted ground or artificial containers. Filamentous green algae, *Lemna* (Duckweed), Azolla (water fern), or high organic water. Tyres, drums and other containers	0 - 500 m major pest 500 m - 1 km pest numbers
Ochlerotatus notoscriptus (Container mosquito)	Tree holes or artificial containers	Trees with natural collections of water including *Eucalyptus*, *Ficus*, *Poinciana* and *Adansonia*. Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks.	0 - 500 m minor pest 500 m - 1 km dispersal

Appendix 5

Northern Territory Government
Department of Health and Community Services

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES IN THE NT

PETER WHELAN
SENIOR MEDICAL ENTOMOLOGIST
DARWIN
NORTHERN TERRITORY
AUSTRALIA

April 2004*

Published in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

* Minor revisions 2004

For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGES

P. I. Whelan,
Department of Health and Community Services
April 2004

Adapted from paper by P. Whelan in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

1.0 MOSQUITO & BITING MIDGE BITES

Mosquitoes and biting midges (genus Culicoides and sometimes erroneously called sand flies) can reach sufficient numbers in various localities to be considered serious pests. The bites themselves can be painful and extremely annoying, and people suffer varying degrees of reaction to bites (Lee 1975). However the possibility of the spread of various diseases by their blood sucking habits to either humans or animals is a more serious outcome. Mosquitoes can carry viruses such as Murray Valley encephalitis, Kunjin, Ross River, and Barmah Forest virus, which cause human disease (Russell 1995). Biting midges do not carry any pathogens in Australia that cause human disease.

Female mosquitoes or biting midges bite to take blood from their hosts, which is necessary for the development of eggs.

Mosquitoes and biting midges show considerable variation in their preference for hosts. Some species feed selectively on cattle, horses, marsupials, amphibians, birds or humans, while other species are relatively indiscriminate feeders.

The time of feeding varies for different species. Many mosquitoes feed just after sunset while others are more active at other times including late in the night, in the late afternoon, or in the early morning. Biting midges are most active in the evening and early morning.

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily entering houses to feed on people, while others will only bite people outdoors.

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains substances that the human body recognises as foreign and often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

Some people can become very sensitive after being bitten and suffer a general reaction from further bites. The bites may itch for days, producing restlessness, loss of sleep and nervous irritation. Scratched bites can lead to secondary infections and result in ugly scars. On the other hand, some people become tolerant to particular species and suffer little after-effects from repeated bites.

Biting insects create problems in the enjoyment of outdoor activities, causing a reluctance to enter certain areas after sundown or forcing people to be confined to insect-proof areas at certain times of the year. Personal protection and avoidance measures can offer considerable protection from bites, as well as offering protection against mosquito-borne disease.

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

A sensible precaution to prevent biting insect attack is to avoid areas that are known to have high biting insect activity.

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of salt marsh mosquitoes (particularly *Aedes vigilax* and various other pest mosquitoes (Russell 1995). The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or significant rain. Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan, Merianos et al., 1997).

Other areas of high mosquito activity are the large seasonally flooded areas associated with rivers or drainage lines, flooded coastal swamps, extensive reed swamps and lagoons, ill defined or poorly draining creeks, extensive irrigation areas, and wastewater disposal facilities. Densely shaded areas near these habitats should be avoided during the day, and accommodation areas should be at least 3 km from extensive areas of these habitats.

Extensive areas of mangroves or estuarine areas with sandy beaches are potential sources of biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al., 1997).

If camping or selecting house sites near creeks, rivers or lagoons, choose localities of the water body which have steep margins or little marginal emergent vegetation, have swiftly running water with little marginal pooling or vegetation, or do not arise from or empty into a nearby swamp area. Exposed beaches or cliffs away from mangrove or estuary areas are preferred sites to avoid both mosquitoes and biting midges. In more inland areas, locations on hills or rises at least 3 km from ill defined drainage lines, poorly flowing creeks and seasonally flooded areas should avoid the worst mosquito problems.

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres and drums, blocked roof gutters, old fishponds, or localised ponding of drains. Sites with mosquitoes breeding can be rectified by physically removing the source or through the use of insecticides.

3.0 SCREENING

The best method of avoiding attack at night is to stay inside insect-screened houses. Screens can be made of galvanised iron, copper, bronze, aluminium or plastic. Near the coast, iron or copper screens are not recommended because of the corrosive action of salt sprays. Homes near biting midge breeding sites require either fine mesh screens or lightproof curtains.

Screens should be of the correct mesh, fit tightly and be in good repair. Biting insects frequently follow people into buildings and for this reason, screen doors should open outward and have automatic closing devices. Insecticides such as permethrin or deltamethrin sprayed on or around screens may give added protection against mosquitoes or biting midges, but care is needed as some insecticides affect screens.

It is advisable to use an insect proof tent when camping near potential biting insect areas. Coastal areas subject to attack by biting midges require tents to be fitted with a finer mesh screening.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. Generally standard mosquito nets are not sufficient to prevent biting midge attack. White netting is best as mosquitoes accidentally admitted into the net are easily seen and killed. The net is suspended over the bed and tucked under the mattress. An aerosol pyrethrin spray can be used to kill mosquitoes that enter the net. Care is needed not to leave exposed parts of the body in contact with the net, as mosquitoes will bite through the net. Nets can be made more effective by impregnation with permethrin (Lines et al. 1985).

5.0 INSECT PROOF CLOTHING

Head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. Head nets with 1-1.5 meshes to the centimetre are recommended for good visibility and comfort, and additional treatment of the net with a repellent will discourage insect attack. Thick clothing or tightly woven material offers protection against bites. Light coloured, long sleeved shirts and full-length trousers are recommended. For particular risk areas or occupations, protective clothing can be impregnated with permethrin or other synthetic pyrethroid insecticides such as bifenthrin to give added protection (Burgess et al. 1988). Sleeves and collars should be kept buttoned and trousers tucked in socks during biting insect risk periods. Protection is very necessary near areas of salt marsh, mangroves, or large fresh water swamps where the various species of mosquitoes may be very abundant during the day in shaded situations, as well as at night.

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.

Repellents with the chemical diethyl toluamide (DEET) or picaridin give the best protection. Some specific repellent products, such as Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands such as Rid, Tropical Strength Aerogard, Bushman's, Muskol, or Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient.

Application of repellents over large areas of the body or on extensive areas of children is not recommended particularly those repellents with high concentrations of DEET. Protection from mosquito penetration through open weave clothes can be obtained by applying a light application of aerosol repellent to the exterior of clothing. Repellents should be supplementary to protective clothing and should not be regarded as substitutes.

Personal repellents are available as sprays, creams or gels. The creams or gels usually last longer than the aerosol formulations. Repellents can prevent bites from 2 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer.

Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

Plants with reported insecticidal properties such as neem trees and the citrosa plant have not been shown to act as mosquito repellents just by growing in the vicinity of people (Mitchell 1992, Matsuda et al. 1996). Growing or positioning these plants near evening activity areas will not prevent mosquito attack. However some plants have some repellency effects as smoke or liniments (see section 12, emergency biting insect protection)

7.0 ANIMAL DIVERSION

Camping upwind near congregations of stock or domestic animals will serve to divert mosquitoes or biting midges to alternative hosts. Similar considerations can be made when planning residential sites and animal holding areas in a rural situation. Dogs of darker colour tend to attract some species of mosquitoes more than lighter colours and can divert some pest problems from people in close vicinity in outdoor situations in the evening.

8.0 LIGHTING DIVERSION

Many mosquito and biting midge species are attracted to light. This can cause pest problems in unscreened houses or when camping. The use of yellow or red incandescent bulbs or fluorescent tubes rather than white light will reduce the attractiveness of lights to insects. An incandescent or ultra violet light placed at a distance from a house or camp can serve to attract insects to an alternative area. This is more effective if the light is close to the breeding site, or between the breeding site and the accommodation area. The attractive lights should not be close to accommodation or directly down wind of accommodation areas. Light proof

curtains or similar screening can be very effective in reducing the attraction of biting insects to areas that are illuminated at night.

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area they can be knocked down with pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric insecticide pads. These devices are only effective in relatively closed areas such as inside buildings or where there are only slight breezes. They should be backed up with other measures such as suitable protective clothing or repellents

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are Maldison or Bioresmethrin. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control will only be temporary (hours) and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

Application of residual insecticides such as maldison, permethrin or other synthetic pyrethroids sprayed as a mist spray to point of run off on building surfaces or nearby vegetation can sometimes give short term (a few days) relief. This method is useful as a barrier protection when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985). There are some longer term residual synthetic pyrethroids such as bifenthrin that can be used as barrier sprays and provide a number of weeks protection (Standfast et al 2003). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer. Care must be taken with all synthetic pyrethroids around fishponds, fish tanks and other nearby fish habitats to avoid spray drift or run off, as these insecticides are efficient fish poisons.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the

vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers lotion, Dermocaine and Paraderm creme, and non-proprietary products such as tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions.

Other products for internal application for more general symptoms include antihistamine products such as Phenergan, Telfast and Vallergan. Check with your doctor or pharmacist for any products for the latest product and safety information.

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as Hyptis (horehound), Vitex (black plum), Calytrix (Turkey bush), Melaleuca species (Paper bark) and Eucalyptus species (gum trees) can make the smoke more effective. A small native plant Pterocaulon serrulatum (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Climbing relatively high trees or choosing locations exposed to the wind can also offer protection from some species.

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulpa, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing deet or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection, and the most comfortable, require an awareness of the potential problems and adequate preparation.

REFERENCES

Aborigines of the Northern Territory of Australia (1988) Traditional Bush Medicines, An Aboriginal Pharmacopoeia, Greenhouse Publications pp 184-185.

Burgess, N., Carter, S., Dodd, G., & Shirley, C. (1988), 'Permethrin fabric treatment for the protection of personnel from biting insect and other arthropod attack', *International Pest Control*, vol. 30, no. 6.

Charlwood, J. D., & Jolley, D., (1984), 'The coil works (against mosquitoes in Papua New Guinea), *Trans Roy Soc Trop Med Hyg*, vol. 78.

Curtis, C. F. (1986), 'Fact and fiction in mosquito attraction and repulsion', *Parasitology Today*, vol. 2, no. 11.

Helson, B. & Surgeoner, G. (1983), 'Permethrin as a residual lawn spray for adult mosquito control', *Mosquito News*, vol. 43, no. 2.

Lee, D. J. (1975), 'Arthropod bites and stings and other injurious effects', *School of Public Health & Tropical Medicine, University of Sydney*.

Lines, J. D., Curtis, C. F., Myamba, J., Njau, R. (1985), 'Tests of repellent or insecticide impregnated curtains, bednets and anklets against malaria vectors in Tanzania', *WHO* VBC/85.920.

Matsuda, B. M., Surgeoner, G. A., Heal, J. D., Tucker, A. O., Maciarello, M. J. (1996), 'Essential oil analysis and field evaluation of the citrosa plant *Pelargonium citrosum* as a repellent against populations of *Aedes* mosquitoes', *Journal of the American Mosquito Control Association*, vol. 12, no. 1, pp. 69-74.

Mitchell, L. (1992), 'Mythical mosquito control', *Wing Beats*, vol. 3, no. 2, Florida Mosquito Control Association.

Russell, R. C. (1995), 'Arboviruses and their vectors in Australia: an update on the ecology and epidemiology of mosquito borne viruses', *Review of Medical Veterinary Entomology*, vol. 83, no. 4.

Schreck, C. E., Haile, D. G., Kline, D. L. (1984), 'The effectiveness of permethrin and deet alone or in combination for protection against *Aedes taeniorhynchus* ', *Am J Trop Med Hyg*, vol. 33, no. 4.

Standfast H., Fanning I. Maloney L., Purdie D. and Brown M. "Field evaluation of Bistar 80SC as an effective insecticide treatment for biting midges (Culicoides) and mosquitoes infesting peri-domestic situations in an urban environment" Bulletin Mos Cont Assoc Aust Vol 15 ;2 2003.

Whelan, P. I. (1990), 'Biting midge investigations near Darwin and their implications for urban planning', *Proceedings of the National Conference on Biting Midge, Surfers Paradise*, February 1990.

Whelan, P. I., Hayes, G., Montgomery, B. L.(1997), 'Biting midge surveillance in Darwin harbour, *Culicoides ornatus* (Diptera: Ceratopogonidae) abundance and dispersal', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia, Second" Conference Mosquito Control Association of Australia*, Surfers Paradise.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V.(1997) , 'Ross River virus transmission in Darwin, Northern Territory, Australia', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia", Second Conference Mosquito Control Association of Australia*, Surfers Paradise.

Appendix 6

Northern Territory Government
Department of Health and Community Services

BITING MIDGES OR "SANDFLIES" IN THE NT

PETER WHELAN
SENIOR MEDICAL ENTOMOLOGIST
DARWIN
NORTHERN TERRITORY
AUSTRALIA
July 2003

The Northern Territory Disease Control Bulletin Vol 10, No. 3, September 2003

For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

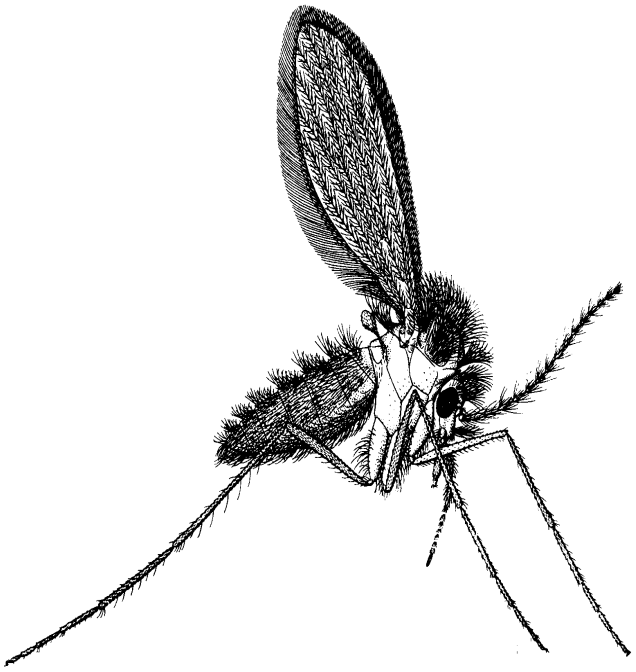
Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

Biting Midges or 'Sandflies' in the Northern Territory

Peter Whelan, Senior Medical Entomologist,
DHCS
Darwin NT

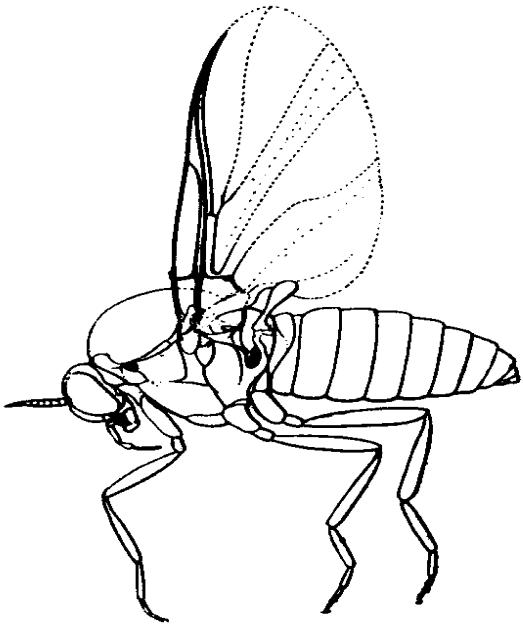
1.0 Introduction

Biting midges are small blood sucking flies in the family *Ceratopogonidae*. They are commonly referred to as "sandflies" in northern Australia. The term "sand fly" is a misused term for a number of families of small biting flies. This includes the true sandflies (Family *Psychodidae*) which are not pests of humans in Australia, as well as black flies (Family *Simulidae*) which are serious pests in the inland areas of Qld and NSW following flooding, and the biting midges (Family *Ceratopogonidae*).[1]



Phlebotomus – a female "Sand Fly"

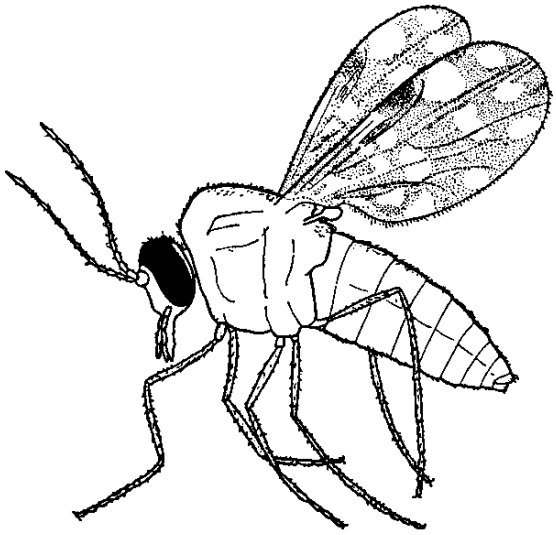
Insects of Medical Importance
British Museum 1956



Simulium – a female "Black Fly"

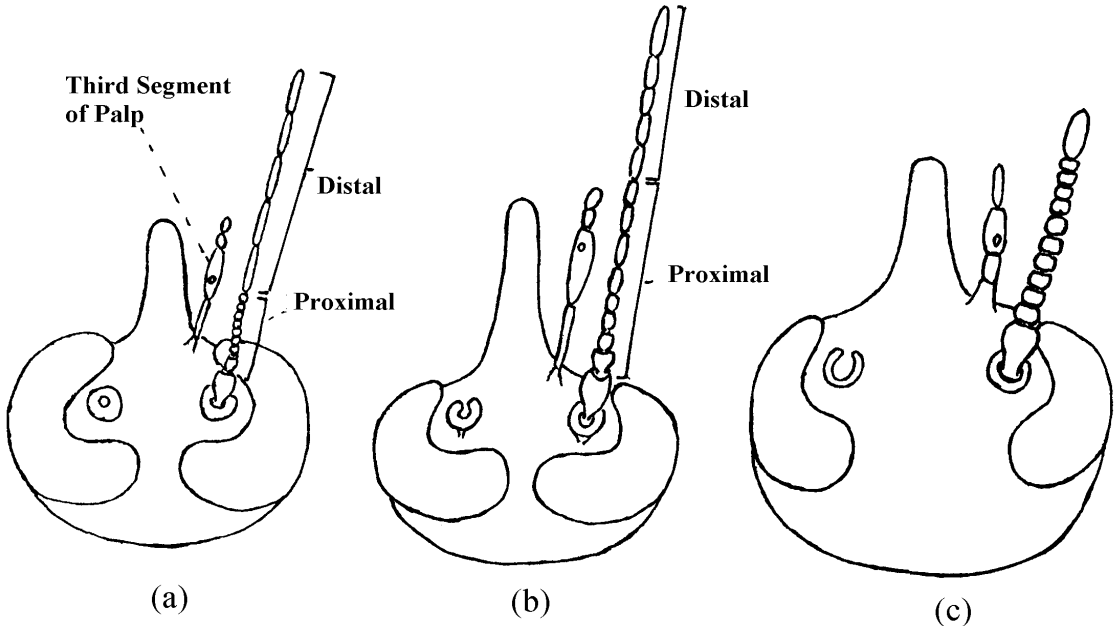
Insects of Medical Importance.
British Museum 1956

Biting midges are the major midge pest problem in Northern Australia.[2] A number of members of this family bite people in the Northern Territory. They include two species in the genus *Lasiohelea*, which are found biting in small numbers in shaded areas in or near dense forests during the day. A species of *Styloconops* is found in small numbers biting and swarming around the head on open sandy beaches during the day. The members of the *Culicoides* genus are more common, with many species and a wide range of breeding sites and biting habits.



Culicoides – a female "Biting Midge"

Entomology for Students of Medicine. Blackwell Scientific Ltd. 1962



Heads of *Ceratopogonidae* (Biting Midges) (a) *Lasiohelea* (b) *Culicoides* (c) *Styloconops*

Atlas of Common Queensland Mosquitoes. Queensland Institute of Medical Research, 1982

Thirty-three species of *Culicoides* have been recorded from the Darwin area.[3] The *Culicoides* species include some species that don't bite vertebrates, some which preferentially bite cattle and other domestic animals, and the few species that are serious pests of people. The breeding sites include fresh water margins and cattle dung. Most of the serious human pest species breed in tidal and estuarine sites.

Culicoides midges are small, robust flies, approximately 1 mm in length with two wings usually showing a pattern of clear patches on a grey background. They have a short, forward directing proboscis or mouthparts for piercing skin and sucking blood.

Two species, *Culicoides flumineus* and *Culicoides* species near *subimmaculatus* can be severe human pests in mangrove areas across the Top End of the NT, but are rarely found outside mangrove forests.[4]

One species, *Culicoides ornatus,* sometimes referred to as the "mangrove midge", is found in association with mangroves across northern Australia, and is usually responsible for severe biting midge pest problems near the coast. This species is a major pest because it occurs in very high numbers and has a habit of invading nearby residential or recreational areas.

Culicoides ornatus is becoming an increasing problem across northern Australia due to urban development encroaching nearer to their major breeding places.[5,6,7] They can impose serious restrictions on outdoor activities within flight range of their mangrove breeding sites due to the extremely annoying and painful bites, and to the discomforting after effects of the bites.

2.0 Bites of Biting Midges

It is only the female midges that bite. Biting midges do not transmit disease to humans in Australia. Their main human medical importance is as a biting pest.

Midges must take a blood meal for their eggs to mature. They do not, as is sometimes believed, urinate on people to cause discomfort. In the process of biting and sucking blood, they inject a salivary secretion that produces a skin reaction of varying intensity, depending on an individual's reaction. Bites usually produce a classic allergic response, with the first bite producing no noticeable effect, and the subsequent bites producing the reactions. If the exposure to midges is reasonably continuous, a process of desensitization may follow. People continuously exposed are usually tolerant to the bites, and generally have no reaction or show a mild reaction with a small red spot.[8]

The average reaction for newly exposed people is a red spot that develops a small dome shaped blister with a hole at the top. In people who are more sensitive to bites, the reaction may result in a red swelling over an area of a few centimetres. The bite area can be extremely itchy, and scratching is very difficult to avoid. Reactions may last 3 - 4 days with slowly decreasing irritation. Sometimes scratching breaks the skin and allows secondary bacterial infections that lead to unsightly sores and residual scarring.

3.0 Treatment of Bites

Mild reactions from bites require little treatment other than the application of soothing lotions. Proprietary products such as Eurax, Stingose, Medicreme, Katers Lotion, Democaine and Paraderm crème can give relief from bites or prevent secondary infection. Useful non-proprietary products include tea tree oil, eucalyptus oil, aloe vera gel, or methylated spirits. Painful reactions to bites can be appreciably reduced by the intermittent application of ice packs to the bite site.

More severe reactions may need medical advice and systemic treatment using antihistamine products such as Phenergan, Telfast or Vallergan. Check with your doctor or pharmacist for available products and safety information.

4.0 Breeding Sites of *Culicoides ornatus*

Culicoides ornatus is by far the most common biting midge pest around the coast of the Northern Territory.[3]

This midge breeds in the highest numbers in the dry season in the mangrove mud in the creek banks of upper tidal tributaries around the mean high water neap tide mark. This corresponds to an area reached by tides from 4.8 to 6.0 m in Darwin Harbor.[4,9] The prime breeding sites are in a narrow zone in the upper section of the creek bank associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina* on narrow creek banks. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy.[4] Broad mangrove areas with many tidal tributaries will have a considerable area of breeding sites.

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* or woodland mangrove zone facing open water. These breeding sites are usually associated with mud substrates and not with sandy substrates. Narrow beach fringing mangrove areas are usually not appreciable sources of *Culicoides ornatus,* particularly in areas with sandy substrates.[4]

Another site exploited only in the wet season is in the *Ceriops* transition zone at the back of the creek bank forest. This is just below MHWS (Mean High Water Spring or average high tide mark) or 6.6m ACD (Admiralty Chart Datum) in Darwin harbor. This is where the mixed *Ceriops* starts in a transition from the taller creek bank mangroves to the smaller mangroves in drier, less frequently flooded areas only reached by tides from 6.5 to 6.8m.

The larvae are small active worm-like creatures that are confined to the surface mud. The larvae take in excess of 6 weeks to mature, when they change into a relatively inactive, air-breathing pupa. The pupa stage lasts only two to three days and the adults emerge around the time of neap tides.[9]

5.0 The Flight Activity of *Culicoides ornatus*

The numbers of adults emerging from pupa cases is related to the lunar cycle, with sudden rises in numbers inside their mangrove breeding sites of the order of 16 times the number occurring on the previous day. The peak in emergence occurs in the two days around the neap tide, although emergence of adults can continue for up to 4 days after the neap tide.[4]

The adults mate soon after emergence. The males are short lived while the females stay in the mangroves to develop and lay their first batch of eggs. The females then start to disperse from the mangroves in an active flight inland in search of blood meals. The dispersal starts about 2 days before the spring tide, and reaches a peak around the day of the spring tide. They show a marked abundance around spring tides with full moons, but are also numerous around spring tides of the new moon.[3]

The adults seek shelter in winds above 8 km/hour, so that there is little tendency for them to be borne long distances by strong winds. Light breezes from their breeding areas will however aid their dispersal flight. They are active fliers and despite their small size, are relatively hardy insects.

Mass movements of adults can occur to 0.5 to 1.5 km from the mangrove margin of their major breeding sites, although they will move greater distances up creeks and rivers with dense tree cover which form avenues of humidity for dispersal. The dispersal is a purposeful one, with the midges actively flying away from the mangroves. Often higher numbers can be found up to 1.0 km from the mangroves compared to numbers in the mangroves or at the mangrove margin. Elevated hills or escarpments within 1.5 km of prolific biting midge breeding sites often exhibit higher biting midge numbers compared with lower adjacent areas. Minor pest numbers can be detected up to 3 km from the nearest mangrove margin.

Most *C. ornatus* bite in the morning and evening. There is a peak in biting activity in the one hour either side of sunset, with a smaller peak in the one-hour after sunrise of about half the sunset peak. However there is a low level of activity throughout the night.

6.0 Seasonal Abundance of *Culicoides ornatus*

The annual peak of *Culicoides ornatus* adults in the NT is in the August to October period in the late dry season, with lowest numbers in January and February during the wet season. Populations start to build up from the end of the wet season to the late dry season with a slight decrease in the coldest months of June and July. Populations start to decline rapidly after the first heavy rains occur. However pest numbers can still be present during the seasonal lows in the mid dry season and the mid wet season.

There are three different breeding sites in the mangroves, with varying seasonal productivity from the different breeding sites. Mangroves with small tidal tributaries that contain the prime creek bank breeding sites are dry season breeding sites. The greatest productivity from these creeks occurs in the August to October period. They are not significant sources of midges in the wet season.[4] The back of small mangrove creeks in the *Ceriops* transition zones has moderate productivity in the wet season.[4,9] Areas with extensive *Sonneratia* zones will have moderate productivity at least in the dry season[4] and probably all year around.

Highest numbers of *Culicoides ornatus* occur for the four days around the full moon, with high numbers to a lesser extent, four days around the new moon.

7.0 Protection from Bites of *Culicoides ornatus*

7.1 *Avoidance*

Culicoides ornatus bite primarily in the early morning or evening around sunrise and sunset. Attacks can occur in the daytime in shaded areas adjacent to the mangroves near major mangrove breeding areas or in dense creek vegetation that is continuous with the mangrove breeding places. They will continue to bite throughout a still, humid day and warm humid night, particularly in sheltered areas outside the mangroves but close to their breeding areas. Often there is only a little biting activity in the mangroves during the day during and just after the spring tide, as all midges have usually dispersed landward.

Landward areas that are close to and within one kilometre of broad areas of mangroves with many tidal creek tributaries, especially near densely vegetated creeks that run into the mangroves, should be avoided. This particularly applies to the two days either side of the spring tides in the August to November period. Spring tides on full moons have roughly twice as many biting midges as spring tides on new moons.[3]

Minimum pest problems occur in the June-July period during the mid dry season or in January and February in the middle of the wet season. During any month the least pest problems occur in the two to three days either side of the neap tide, particularly neap tides following a new moon. A calendar marked with the 4 days around full moons and new moons, with highlights of seasonal peaks of abundance, can serve as a good midge avoidance reminder.

Biting midges are active under calm conditions and are generally inhibited by wind. Wind protected areas adjacent to and within 1.5km of large expanses of mangroves should be avoided around the spring tide period. People in open areas exposed to winds will experience less pest problems compared to other areas.

Elevated houses and high rise buildings have less pest problems than ground dwellings. Although midges probably fly over dense tree canopies and can fly in appreciable numbers at least 3 metres above the landscape surface, they are generally more numerous lower to the ground surface.[11]

The worst pest problems around Darwin include areas include landward areas adjacent to the mangroves and tidal areas of Sadgroves and Reichardt Creeks, Hudson Creek, Elizabeth River, and Buffalo Creek.

The north shore of Frances Bay near Sadgroves Creek in the Charles Darwin National Park is a particularly troublesome area. This is due to the dendrite pattern of numerous narrow mangrove creeks and an extensive Sonneratia zone nearby. Urban areas of Stuart Park, the Narrows, and near Winnellie, which are closest to the Sadgroves creek mangroves, can experience seasonal moderate to minor pest problems. There are some minor pest problems near the lower reaches of Ludmilla creek and Alawa near Rapid Creek. Darwin city itself is relatively free from midges due to the relative lack of mangroves, the exposed cliffs, and the fact that the prevailing SE and NW winds do not blow from mangrove areas.

7.2 *Clothing and Netting*

Full-length trousers, socks and shoes, and long sleeved shirts will usually provide considerable protection from midge attack. Pale clothing is generally less attractive than dark clothing. Any exposed part of the body will still be subject to midge bites, with most bites occurring on the legs. Protective clothing should be supplemented with the application of repellants on exposed skin.

Clothing impregnated with permethrin or bifenthrin insecticide offers considerable protection for people continually exposed to biting midges. Impregnation involves soaking the clothing in a prescribed volume and concentration of certain formulations of the insecticide. Protective clothing such as overalls and mosquito nets impregnated with permethrin or bifenthrin will remain effective through one or two washes at the most, and will need reapplication. The insecticides in these treatments can kill the insects after they land on them, but they can also have the effect of interfering with the normal biting behaviour. Impregnated clothes with the additional use of insect repellents can provide extremely good protection.

Normal insect nets and screens are usually not adequate to restrict entry to midges unless the mesh is very fine. Tents screens in particular should have mesh diameter approximately half that of normal mosquito netting. Clothing, screens, netting or tents can be impregnated with permethrin or sprayed with permethrin, bifenthrin or repellents containing Deet to increase their efficiency.

Houses should have outward opening doors and insect screens to prevent entry when opening doors during midge activity.

7.3 *Repellents*

Most repellents have limitations because of their short duration of effectiveness (about 2-4 hours) and their irritability to mucous membranes around the eyes and mouth. Care is needed with young children to avoid the spread of repellent to their eyes or mouth. Repellents are also removed by perspiration.

Repellents that contain Deet (diethyl toluamide) or Picaridin as the active constituent offer considerable protection. Mixtures of natural oils or oils with natural ingredients such as herbs or antiseptics are not as effective as repellents containing Deet or Picaridin. In general effective repellents require above 10% Deet and 9% Picaridin. Repellents in lotions are more effective than alcohol based spray-ons, while gels are the most effective formulations. Repellents can also be applied to mosquito netting or insect screens, although a sample application on a small piece of netting is wise as some repellents affect synthetics. Repellents containing relatively high amounts of Deet can melt some plastics, although those containing Picaridin don't have the same effect.

Other methods of repelling biting midges include the use of coils, repellent oil lamps, and electric vapor pads impregnated with insecticide. These work satisfactorily in closed situations such as rooms, or sheltered patio and veranda situations out of the wind, where a cloud of vapour or smoke can build up. However they cannot provide satisfactory protection in windy and exposed situations.

Smoke from a fire with green leaves will give some protection in emergency situations. Burning aromatic and oil producing foliage of plants such as *Hyptis* (horehound), *Calytrix* (turkey bush), *Melaleuca* species (paperbark) and *Eucalyptus* species (gum trees) can give appreciable protection.

Rubbing the skin with the leaves of some of these plants can also provide some protection, but this is not as good as recommended repellents.

The so-called "electronic mosquito repellers" that emits a frequency that is supposed to repel biting midges by imitating the noise of males do not work and offer no protection against biting insect attack.

There is an urban myth that taking Vitamin B1 or thiamin can act as a repellent. There is no scientific evidence that Vitamin B1 acts as a repellent, or helps to reduce the reaction to insect bites by developing some immunity to the bites.[13] Other topical applications such as a Dettol™ and baby oil mixture do offer some physical barrier to biting midges, but are not as effective as Deet or Picaridin based repellents. The best protection from biting insects remains the avoidance of the problem areas at times of abundance and the use of protective clothing in combination with efficient repellents.

7.4 *Use of Lights*

Biting midges can be attracted to lights. Houses in biting midge problem areas should have dull outside lighting, with little internal light visible from outside. Lightproof curtains that can be drawn at night offer a good alternative. Outside lights should be away from insect screens, as the midges attracted to the light can then penetrate the screens. Outside lights should be yellow (or red, which is even better) to reduce their attractiveness to biting insects. Attractive lights such as large incandescent bulbs or white or ultra violet fluorescent tubes positioned a distance away from a house or building can deflect biting midges to some extent. However rows of streetlights positioned between mangroves and residential areas are not effective barriers to midge dispersal inland.[11]

7.5 *The reduction of vegetation*

The reduction of vegetation around houses or recreation areas can reduce problems by removing shelter for the midges. A buffer of clear open space between the mangroves and residential areas can reduce biting midge numbers in a residential area, as long as the buffer is wide and subject to winds. However clear open buffers by themselves offer little protection unless they are at least 1 km wide. Mowing a wide margin around houses to eliminate dense grass can help reduce the available areas where midges can harbor.

7.6 *The use of attractant traps*

There are a number of insect attracting traps on the market. They generally use light or carbon dioxide as an attractant and either trap the insect in a container, electrocute, or drown the insects. Some are more useful than others but can not be relied to give considerable protection from bites for unprotected people in close proximity to the traps. In most cases they attract biting insects to the general vicinity and these are then diverted to people, who are more attractive targets. Some traps can help to reduce the overall population, as long as there are enough traps, the biting insect population is relatively small, and the area is isolated from re-invasion from other areas. However most trapping techniques can not cope with the huge populations of midges at one time, and those not trapped still result in a pest problem.

8.0 Evaluation of Biting Midge Problems

The Medical Entomology Branch of the Department of Health and Community Services has conducted numerous investigations into biting midge problems in the Top End of the NT.[2,3,5] Potential problems have been investigated by trapping midges overnight using special carbon dioxide (CO_2) baited traps. The number of midges collected can be counted or estimated by weight or volume and identified to species under a microscope in the laboratory.

The number of bites by biting midges that constitute a pest problem will largely depend on an individual. It has been suggested that over 60 bites per hour for most experienced biting midge workers are the thresholds of acceptability. For people unaccustomed to biting midge bites, even 1 to 5 bites per hour may be considered unbearable.

There is an approximate relationship between the number of midges collected in a CO_2 trap and the number of bites that can be expected at the peak biting period. For an unprotected person, the number of bites in an hour at the peak biting time is approximately one quarter of the number collected in a CO_2 trap over one night at the same position. Thus CO_2 collections of over 240 per carbon dioxide trap per night are likely to represent a pest problem (equal to over 60 bites per hour) to unprotected people with prior experience of biting midges. Collections of over 1000 per trap per night represent over 250 bites in an hour and would constitute a major pest problem. Trap collections of over 5,000 per trap would constitute a severe pest problem.[3]

The numbers of *C. ornatus* collected by CO_2 traps in different locations can indicate the magnitude of the human pest problem in each location. Trapping on a constant day in relation to the tide cycle over every month in a year can give an indication of the seasonal population fluctuations. Trapping at different distances from the mangroves and in different vegetation types can give an indication of the dispersal of midges into various areas.

9.0 Control of *Culicoides ornatus*

9.1 *Insecticide fogging for Adult Midges*

Insecticide fogging is the application of aerosol size particles directed against active flying insects. Insecticide fogging operations in residential areas by vehicle or hand held equipment are usually not very effective measures to eliminate pest problems, due to the rapid re-infestation of midges from nearby breeding and harborage areas. Sometimes re-infestation occurs very soon after the fog has cleared, although up to 12 hours protection can be achieved in some localized situations.

For effective midge control, the entire midge breeding and harboring area near residential development needs to be fogged each day over the 3-4 day period of peak emergence. This has to be timed to coincide with the time just after the midges have emerged and before they begin to disperse out of their breeding areas. This area would also have to be relatively isolated from other such areas to prevent re-invasion. Fogging also has to be carried out during the peak activity period in the evening and early morning.

For vehicle ground based operations, the fog has to be able to drift into the target area on favorable winds of the right velocity and in the right direction. This often reduces the opportunity for effective fogging. Fogs do not usually penetrate more than 50m into dense forested areas such as mangroves, monsoon forests and other thick vegetation.

One of the major problems is determining the level of control required. A reduction of *C. ornatus* numbers by 99% may be required to reduce a large pest problem to an appreciable level. This may be impossible to achieve for various operational purposes, and if there were still any remaining pest problem, the control would not be cost effective.

In the Darwin situation, the mangrove breeding and harboring areas are generally inaccessible, too wide, or too extensive for ground based application methods to effectively reduce midge numbers, although some temporary relief would be possible in some areas.

Aerial application of insecticides aimed at adult midges in breeding and harborage areas has given the best results in overseas investigations, but in some instances there has been immediate re-infestation. It is a difficult practice, as the breeding grounds have to be closely delineated and fogging must be based

on an accurate forecast of adult emergence times. The fogging has to be with sufficient regularity to kill all the emerging dispersing females over the night and fog drift to nearby residential areas has to be avoided. Fogging is not carried out regularly for midge control in Australia and requires more local research. Fogging involves large continuing costs, which is often beyond the resources of many local authorities. Insecticide resistance and the killing of other insects pose additional potential problems.

9.2 *Barrier spraying*

The application of insecticides to create an artificial barrier or an insect killing zone around houses where biting insect harbor before biting offers some promise as a new control method. The application of residual insecticides to exterior walls, screens, patio plants, nearby hedging plants or lawns and other close vegetation may kill midges attracted to houses or people.[14] Insecticides that can be used include permethrin, deltamethrin and bifenthrin. Bifenthrin has the advantage over other similar insecticides, as it appears to have less of a repellent or agitation effect on insects, is less irritant to people, is ultra violet resistant, and binds very well to surfaces to give a good residual effect.[14] As with all synthetic pyrethroids, it must only be applied as per the label and kept out of fish habitats.

9.3 *Insecticide Control of Larval Habitats*

Breeding site treatment by applying insecticides to kill larvae before emergence of adults is a possible control method but there have been very few examples of successful larval treatment in mangrove areas. Larval habitat treatment involves considerable costs and organization, which is impractical in extensive breeding areas such as those surrounding Darwin. Insecticides would need to have good residual qualities and be able to penetrate dense mangrove tree cover and mud in a tidal situation. Most insecticides with these qualities would generally kill non-target insects. The problem of accurately delineating all the significant breeding sites and the seasonal fluctuation of breeding sites pose additional problems.

9.4 *Elimination of Breeding Habitats*

Reclamation of mangroves has been successful in eliminating biting midge breeding sites in various localized situations. This usually requires large amounts of fill material which is neither cheap or readily available. For *Culicoides ornatus*, the reclamation needs to extend from near the average high tide level to below the outer mangrove forest. This may involve significant engineering considerations posed by deep mud and erosion of the filled area.

Reclamation would not be practicable in most of the Darwin area because of the extensive areas involved. The destruction of large areas of mangroves would be environmentally undesirable and unacceptable to public opinion. This potential solution would only be practicable in localized areas if the breeding site was small, in close proximity to residential development, was regarded as an area of reduced environmental importance, and the filling could create a stable shore environment.

There should be conclusive evidence that the site to be reclaimed is a significant source of biting midges and that the midges are significant pests to nearby residential development. Mangroves can be an indicator of biting midge breeding sites, but the presence of mangroves does not confirm any site as the breeding place. Other specific factors such as substrate types are involved in productive breeding sites.

9.5 *Buffer zones*

There is some evidence that creating a buffer zone between urban residential development and mangrove areas can reduce the dispersal of biting midges into residential areas. Clearing of vegetation and mowing to allow wind disruption, or extensive streetlights or roads with active traffic in the buffer zone may enhance the buffer to some extent.[3] However extensive testing of a modified buffer with lights and

different vegetation types in Darwin have shown that unmodified buffers and lights by themselves are not effective barriers to *C. ornatus* dispersal from mangroves to urban areas. The effectiveness of buffers is generally related to the width of the buffer and the presence of blood sources or other attractions such as light in the buffer zone. However semi-urban residential or industrial development between mangroves and urban areas can reduce midge dispersal inland. In general, unmodified buffers need to be in the order of 1.5km, and modified buffers in the order of one kilometre to offer significant reduction in numbers.

10.0 Planning Guidelines To Prevent Biting Insect Problems

The Medical Entomology Branch is involved in the planning process to reduce the effects of biting insects. Guidelines have been prepared for preventing biting insect problems in new urban and semi rural residential developments, industrial, and other developments.

In 1974 the planning for the new satellite town of Palmerston near Darwin included a buffer of at least 1-km from the mangrove boundary to urban residential development.[12] Palmerston is one of the few urban areas in Australia that has been specifically designed to minimize biting insect problems.

Good urban planning is required to;

- reduce the risk of biting insect pests
- recognize and avoid areas of biting insect breeding or harborage
- avoid costly and environmentally undesirable rectification methods
- avoid costly and ongoing biting insect control programs

The Medical Entomology Branch gives advice on what may constitute a potentially significant biting insect breeding site. In some instances detailed entomological investigations are necessary to gather sufficient information before the detailed planning stage. The avoidance of biting insect problems can be achieved in the initial planning process by consideration of development location, easements, buffer zones, and sub division design.

Selected References

1. Marks, E.M. (1982), "An atlas of common Queensland mosquitoes" by Elizabeth Marks with "A guide to common Queensland biting midges" by Eric Reye, ", Q.I.M.R. Revised edition.

2. Whelan, P.I. (1991a), "Biting midge investigations near Darwin and their implications for urban planning", In Proc. Nat. Conf. on Biting Midge, Surfers Paradise, Qld., 8-9 Feb, 1990.

3. Whelan, P.I., Hayes, G., Montgomery, B.L. (1997), "Biting midge surveillance in Darwin Harbor, *Culicoides ornatus* (Diptera: Ceratopogonidae) abundance and dispersal", *Arbovirus Research in Australia,* vol. 7, pp.326-336.

4. Shivas M. (2000) "The Larval Biology of *Culicoides ornatus* Taylor in mangroves near Darwin, NT. PHD. Faculty of Science NTU Darwin Feb 2000.

5. Whelan, P.I., Booth, D. and Kelton, W. (1988), "Biting insect investigations and comment on the proposed Newtown (Weddell) Development, Darwin, N.T.", Department of Health and Community Services, Darwin NT.

6. Whelan, P.I. and Hayes, G.A. (1993), "Biting Insect Investigation Darwin South Stage I", Department of Health and Community Services, Darwin NT.

7. Whelan, P.I. (1995), "Biting insect investigation Darwin South Stage II", Department of Health and Community Services, Darwin NT.

8. Lee D.J. (1975), "Arthropod bites and stings and other injurious effects". SPHTM, Inst. of Public Health, Uni. of Sydney.

9. Shivas, M., Whelan, P.I., & Webb, C. (1997), "The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera: Ceratopogonidae) in mangroves near Darwin, NT, Australia", in *Arbovirus Research in Australia*, vol. 7.

10. Wightman, G.M. (1989), "Mangroves of the Northern Territory", Northern Territory Botanical Bulletin, No.7 Conservation Commission, Palmerston, N.T.

11. Shivas M and Whelan P.I. (2001), "Biting midge research project March 1999-March 2001". Study for DLP&E, Darwin NT on dispersal biology and effect of lights and vegetation. Department of Health and Community Services, Darwin NT.

12. Leihne, P.F. in association with Medical Entomology Branch DHCS (1985), "Mosquito and biting midge investigations, Palmerston 1982-85", Palmerston Development Authority.

13. Khan A.A., Maibach H.I., Strauss W.G. et al. "Vitamin B1 is not a systemic mosquito repellent in man". Trans St John Hosp Derm Soc 1969;55:99-102

14. Standfast H., Fanning I. Maloney L., Purdie D. and Brown M. "Field evaluation of Bistar 80SC as an effective insecticide treatment for biting midges (Culicoides) and mosquitoes infesting peri-domestic situations in an urban environment" Bulletin Mos Cont Assoc Aust Vol 15 (2) July 2003.

Appendix 7

Bull. Mosq. Control Assoc. Aust. Vol. 15 (2) 2003.

FIELD EVALUATION OF BISTAR 80SC AS AN EFFECTIVE INSECTICIDE HARBOURAGE TREATMENT FOR BITING MIDGES (*CULICOIDES*) AND MOSQUITOES INFESTING PERIDOMESTIC SITUATIONS IN AN URBAN ENVIRONMENT

By

H. Standfast[1], I. Fanning[2], L. Maloney[2], D. Purdie[3], & M. Brown[4]

1. **International Vector Consultants, 41 Henry St., Chapel Hill, Brisbane, Queensland 4069, Australia.**
2. **Hervey Bay City Council, Vector Control, PO Box 5045, Torquay, Queensland 4655, Australia.**
3. **Queensland Institute of Medical Research, PO Royal Brisbane Hospital, Queensland 4029, Australia.**
4. **Griffith University, Australian School of Environmental Studies, Nathan Campus, Brisbane, Queensland, Australia & FMC Chemicals, PO Box 329 Hamilton Central, Queensland 4007, Australia.**

Abstract

Excellent residual control of adult biting midges and mosquitoes was recorded at River Heads, Hervey Bay, by applying Bistar 80SC (FMC Chemicals) as a 0.1% bifenthrin in water mix to external resting surfaces in peri-domestic situations. Application of the mix as a coarse spray (150-200 micron droplets) resulted in a 97%-75% reduction in biting midge numbers in the first month of field evaluation, with a 65% mean reduction in numbers at six weeks post-treatment. Of the midge species controlled during this evaluation, 81% were *Culicoides ornatus*, and 19% *Culicoides subimmaculatus*.

With regards to the mosquitoes controlled during the evaluation, an even higher level of efficacy was achieved, with a 99%-94% reduction in numbers during the first month, and 94% mean reduction in numbers over the six week evaluation period. Of these, the saltmarsh arbovirus vector *Ochlerotatus vigilax* represented 78%.

These are significant results, as the authors are unaware of any other method which has achieved an effective, sustained reduction in adult biting midge numbers. Accordingly, the suitability of the method for provision of household protection and integration with existing vector control programs is discussed, and recommendations made for future management of this valuable insecticide.

Introduction

It is well documented that mosquitoes (Russell 1998) and biting midges (*Culicoides* spp.) (Kettle 1965, Howie 2002) seriously impact on human health in Australia. With respect to mosquitoes, several *Ochlerotatus*, *Aedes* and *Culex* species have been implicated in the transmission of arboviruses and canine filaria (Boreham and Marks 1986, Watson and Kay 1998, Hanna et al. 1999, Ryan et al. 1999, Boyd and Kay 2000). With biting midges, it is females from the genus *Culicoides* which impact most severely on the health and comfort of humans and animals (Kettle 1965, Linley et al. 1983, Kay and Standfast 1987). This biting behaviour can result in adverse economic effects on land development, property values, tourism, recreation and work-related activities (Linley and Davies 1971, Howie 2002). In Hervey Bay in 2002, the biting midge problem is estimated to have cost residents $61 million (Ratnayake et al. 2003). Additionally, *Culicoides* are also known to transmit protozoans, filarial worms, and viruses (Kettle 1965, Blanton and Wirth 1979, Linley et al. 1983).

In response to this threat, some larger coastal Queensland Local Governments allocate significant resources towards broadscale larviciding for mosquitoes (Brown et al. 1999). Unfortunately, there is no registered larvicide for biting midges. This is because the larvae occur in environmentally sensitive areas of the inter-tidal zone, and dispersal patterns are poorly know (Shivas 2001). Also, required dosages are environmentally damaging (Standfast unpub data). This leaves aerosol (thermal fogging and ULV) insecticide applications against adults as the only option available. The method only provides short-term relief from biting, and repeated applications are necessary and expensive. It is for these reasons that a sustained effective method is required, and one that provides household protection has been identified as a priority (Shivas 2001).

Accordingly, Bifenthrin (FMC Chemicals) was selected for evaluation as an effective insecticide surface treatment for biting midges and mosquitoes harbouring on ornamental plants, fences and walls surrounding domestic situations at River Heads, Hervey Bay (Queensland, Australia). This suburb was selected as a test site, as a recent public health study found that residents experience reduced health levels as a consequence of biting midges, and that an effective control method is desperately needed (Howie 2002). Bifenthrin, a non-alpha cyano (low skin irritant) synthetic pyrethroid, which is used world-wide against a range of agricultural pests, was considered an ideal candidate insecticide as it is characterized by:

1) low irritancy to mosquitoes, and thus increases mosquito-bifenthrin contact time (WHO 2002);
2) very low vapor pressure (1.81 10-7 mmHg);
3) low water solubility (<1 μg/litre) and good stability to hydrolysis and photolysis (2 years at 500C. under natural daylight); and
4) long residual efficacy against target insects (WHO 1998, 2002; Hougard et al. 2002; Yadav et al. 2003).
5) safety to humans: “Noting its safety and efficacy, Bifenthrin 10WP is recommended for indoor residual spraying” (WHO/CDS/WHOPES/2001.4).

In house-scale trials in India, Bifenthrin (10% wettable powder) applied at a rate of 25 mg/m^2 provided persistent (>80% mortality for 24 weeks) insecticidal activity against *Anopheles culicifacies* on mud and brick surfaces (Yadav 2003).

It was these characteristics that led to selection of an 8% water-based, no-odor, non-irritant, suspension concentrate (SC) formulation for evaluation in Queensland against biting midges. Although this FMC Chemicals formulation is registered in Australia as a surface treatment for mosquitoes, it has not been evaluated for efficacy against biting midges infesting domestic situations. Therefore, this study was undertaken to produce efficacy data for biting midges, and in doing so provide a tool for control of these insects of public health and economic importance. Additional efficacy data was also collected for mosquitoes.

Materials and Methods

Study Site. Public support for this evaluation at River Heads (Plate 1) was received at a River Heads public forum, held on the 2nd October 2002. There was 80% positive support from the public for this evaluation. The Environmental Protection Agency, and Department of Primary Industries – Fisheries, also supported the evaluation as it did not impact on the environmentally sensitive marine park surrounding River Heads. The evaluation was conducted under NRA Research Permit 5547.



Plate 1. River Heads, Hervey Bay, Queensland. Clean estuarine sand and muddy sand surrounding River Heads provides larval habitat for *Culicoides subimmaculatus* Lee & Reye, while estuarine mud produces *Culicoides ornatus* Taylor. Saltmarsh and mangrove habitats produce the mosquito arbovirus vector, *Ochlerotatus vigilax* (Skuse).

Once the above detailed approval had been obtained, eight houses comprised of four randomized pairs (1 treatment + 1 untreated control) were selected, and the householders consent obtained ca. 2 weeks prior to the treatment date (29th October, 2002).



Plate 2. On the properties selected for evaluation, external surfaces where mosquitoes and midges rest (fences, walls, ornamental plants and bushes) were identified for treatment.

Application of Bistar 80 SC (Active Ingredient: 8% bifenthrin). In order to obtain the required efficacy data for biting midges, the 8% SC formulation was applied as per the label directions for applications against mosquitoes under conditions of high pest pressure, and when maximum residual protection is desired. The label directions state that at a recommended rate of 125 mL/10L: "*on non-porous surfaces apply as a coarse spray at the rate of 1 litre of emulsion per 20 m^2. When treating non-porous surfaces do not exceed the point of run-off. On porous surfaces or use through power equipment, spray at the rate of 1 litre of emulsion per 10 m^2. When treating porous surfaces do not exceed the point of run-off. To control mosquitoes apply prepared emulsion to surfaces where insects rest or harbour. Reapply as necessary.*"

Accordingly, a 0.1% mix (125 mL/10L water) was applied as per the label instructions described above, to external building and ornamental plant surfaces (Plate 2). To do this a Solo Back Pack Sprayer (Solo, Germany) was calibrated by the Centre for Pesticide Application and Safety (University of Queensland, Gatton Campus) to deliver a dilute spray comprised of large (150-200 micron) droplets.

Table 1. Property treatment rates.

Treatment Property No.	Property Size	Volume of 8% SC Applied[1]
1	1012 m^2	875 ml
2	1012 m^2	750 ml
3	1012 m^2	500 ml
4	1012 m^2	625 ml

[1] The volume of 8% SC applied to the various properties varied according to house size and % ornamental coverage.

Surveillance and Identification. CDC-type light traps powered by a rechargeable 6 volt battery, were used to measure peri-domestic biting midge and mosquito populations in



Plate 3. Median midge and mosquito numbers caught overnight in unbaited vs baited light traps.

treatment and control properties. Light trap collections were made on the evening prior to treatment, and then each night for 9 nights post-treatment. Sampling frequency was then reduced to weekly collections for six weeks post-treatment.

To do this, one trap was hung from a tree within the fenced-off yard of each treatment and control property. On each sampling occasion, each trap was baited with 750 g dry ice and 2.5 ml Octenol (1 Octen-3-ol). The dry ice was housed in the purpose built 1 litre ice container, and the Octenol contained in a 4 ml microreaction vial. An exposed cotton pipe cleaner wick was used to release the Octenol. The traps were operated from 1500 to 0700 hours. Each day the collections were transported to the laboratory for sorting, counting, and identification according to the descriptions in Marks (1982). All collections were stored in 70% ethanol. The above described baited light trapping method was chosen on the basis of catches recorded in an evaluation of trapping efficacy conducted between 1500 and 0700 hours, 7 days prior to the application of the 8%SC formulation. In order to determine if un-baited traps would provide sufficient numbers for statistical analyses, the catches recorded from 5 x un-baited light traps were compared with what was caught in 5 x light traps baited with CO_2 and Octenol.

Environmental data. Environmental parameters in terms of wind speed, direction, temperature and humidity were measured on a vacant allotment at River Heads using a portable EnvironData Weather Master 2000 (EnvironData, 44 Percy St, Warwick, QLD. 4370 Australia).

Statistical Quantification of Treatment Efficacy. For both biting midges and mosquitoes, 12 hours pre-treatment and six weeks post-treatment field data, comprising 62 light trap collections were made. As the pre-treatment data was normally distributed, a t-test was used to test for significant differences between treatment and control properties. For the post-treatment data, and pre-treatment comparison of light trapping efficiency, a non-parametric Mann-Whitney Rank Sum Test was used to test for statistically significant differences in the median values between counts from treatment and control properties, and baited vs un-baited light-traps, respectively. This non-parametric test was utilized as the collected data failed a test for normality (see skewness values Table 5). We did not expect the long-term data to be normally distributed as biting midge and mosquito populations exhibit both spatial and temporal variability (Shivas 2001). Factors such as wind direction and speed, humidity, topography, harborage and emergence patterns all contribute to patchy distribution. Accordingly, we utilized the Henderson & Tilton (1955) formula to calculate weekly % reduction for fluctuating test populations:

$$\% \text{ control} = 100 \times \left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Where: Ta = population in treatment post-treatment
Tb = population in treatment pre-treatment
Ca = population in control post-treatment
Cb = population in control pre-treatment

Results

The field evaluation from late October to mid December was conducted in warm, humid, calm conditions (Table 2).

Table 2. Mean ± SD 24 hour environmental conditions during field evaluation.

Temperature ^{O}C.	% Relative Humidity	Wind Speed km/hr	Wind Direction (Degrees)
23 ± 3	78 ± 17	7 ± 3	118 ± 66

In the pre-treatment evaluation of trapping efficiency, baited light traps caught significantly (P<0.01) higher biting midge and mosquito numbers (Plate 3). On the night prior to treatment, there was no statistically significant difference in the numbers of biting midges (P<0.43) or mosquitoes (P<0.51) collected from properties identified for treatment or untreated controls (Table 3).

Table 3. 12-hour pre-treatment biting midge and mosquito numbers on properties selected for evaluation of Bistar 80SC efficacy.

Group	N	Mean	Std Dev	t	Df	95%CI	*P*
Pre-Treatment Biting Midges	4	51	81	0.84	6	-65 to 134	0.43
Control Biting Midges	4	17	11				
Pre-Treatment Mosquitoes	4	56	38	0.70	6	-408 to 227	0.51
Control Mosquitoes	4	147	257				

In contrast, over the six week post-treatment period, a statistically highly significant difference in the median numbers of biting midges (P<0.02) and mosquitoes (P<0.01) collected from treated and control properties was recorded (Table 4). In contrast to an average of 441 biting midges and 25 mosquitoes collected from treated properties, 2,989 biting midges and 169 mosquitoes were collected from untreated control properties (Table 5). In terms of species composition, 78% of the collected mosquitoes species were the saltmarsh *Oc. vigilax*, with *C. ornatus* and *C. subimmaculatus* representing 81% and 19% of the collected biting midge species, respectively.

Table 4. Mann-Whitney Rank Sum analysis for six weeks biting midge and mosquito field data.

Group	N	Median Number	25%	75%	T	*P*
Biting Midge						
Treatments	54	276	66	682	2652	<0.02
Controls	54	425	122	1856		
Mosquitoes						
Treatments	54	8	4	34	1802	<0.01
Controls	54	106	46	210		

Table 5. Descriptive Statistics for 6 weeks field Data.

Biting Midge (n = 54 trap collections)

	Skewness	Range	Max	Min	Median	Mean
Treatment	1.46	2,011	2,012	1	276	441
Control	2.21	21,914	21,948	34	425	2,989

Mosquitoes (n = 54 trap collections)

	Skewness	Range	Max	Min	Median	Mean
Treatment	2.50	186	186	0	8	25
Control	2.40	875	879	4	106	169

In terms of % reduction over time, biting midge numbers were reduced by 97% to 75% in the first month, with a 65% mean reduction over the 6 week study period (Fig. 1). Mosquito numbers were reduced by 99% to 94% in the first month, with a 94% mean reduction over the 6 week study period. Rainfall events were recorded in the first, third, fifth and sixth weeks of the study (Hervey Bay Airport Meteorological Data) (Fig. 1).

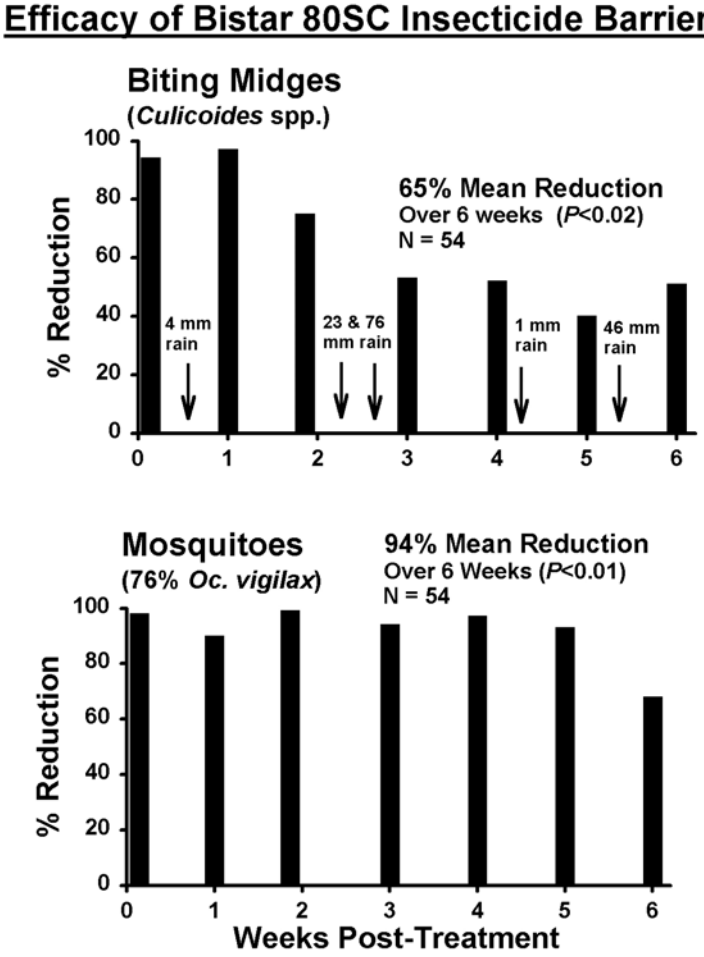


Fig. 1. % Reduction of peri-domestic biting midge and mosquito numbers over a six week study period. Rainfall events are also recorded.

Discussion

The authors are unaware of any other study which details effective, sustained reduction in adult biting midge numbers. The successful Bistar 80SC application was achieved during periods of peak biting midge and saltmarsh mosquito emergence, and despite rainfall events on six occasions. In doing so, the method meets Shivas (2001) recommendation for biting midge control, in that a sustained, effective method is required, and one that provides household protection is a priority. The peri-domestic applications also satisfied the EPA and Fisheries concerns, as they provide a safe alternative to broadscale application of organophosphates to sensitive estuarine habitats, at rates that would be ecologically disastrous. Also, in terms of comfort to the Local Government personnel

applying the product, and the residents of treated properties, the bifenthrin molecules non-alpha-cyano characteristics were appreciated. No skin or eye irritation characteristics occurred, and as expected with a bifenthrin SC formulation, no staining of peoples properties or phyto-toxic effects were recorded.

This study also highlights the fact that harborage treatments are suitable for integration with existing Local Government vector control programs. Mosquito arbovirus vectors such as *Oc. vigilax* and *Culex annulirostris* Skuse have the ability to disperse over great distances (Johansen et al. 2001). This makes thorough treatment of the numerous and often unidentified larval habitats expensive, problematic, and often impossible. Effective vector control programs are required, as arboviruses such as dengue in north Queesland, and West Nile in the USA are increasing in prevalence.

In refining this method, accurate laboratory determination of the Bistar 80SC concentration-mortality relationship for major biting midge and mosquito species of public health importance is essential. The incorporation of a discriminating dose test (2x LC_{95}) in routine monitoring programs will aid early detection of developing bifenthrin tolerance if it occurs. Future research efforts should also be dedicated towards determination of the longevity of control effected by Bistar 80SC applications on various resting surfaces. Surfaces such as treated and untreated wood, bricks, and waxy leaf surfaces would all retain bifenthrin at differing concentrations over time. Re-treatment strategies could vary depending on the predominant harborage or resting surface present in a given domestic situation. Accordingly, the authors recommend that a resistance management strategy be developed to safeguard the longevity of this valuable formulation. Bistar 80SC is one of the few effective options we have available for control of these adult insects of major public health significance.

Acknowledgements

Dr Pat Dale (Griffith University – Australian School of Environmental Studies), Darran Thomas (Gold Coast City Council - Entomology) and Mike Muller (Brisbane City Council – Mosquito & Pest Services) reviewed this article. The Hervey Bay City Council, River Heads Community and the Biting Midge Research and Management Committees provided guidance and encouragement. Ian Francis, Kim Watson (FMC), Nicholas Woods, Gary Dorr (Centre for Pesticide Application & Safety), and Darryl McGinn (Mosquito Consulting Services) provided technical guidance and useful discussion. Garrard’s Pesticides Pty Ltd provided the Solo Backpack sprayer.

References

Blanton, F. S., and W. W. Wirth. 1979. The Sand Flies (*Culicoides*) (Diptera: Ceratopogonidae) of Florida. Gainsville, FL, Florida Department of Agriculture and consumer Services. Arthropods of Florida and Neighboring Land Areas. 10: 1-204.

Boreham, P., and E. Marks. 1986. Human filariasis in Australia: introduction, investigation, and elimination. Proc. R. Soc. Qld. 97: 23-52.

Boyd, A. M., and B. H. Kay. 2000. Vector competence of *Aedes aegypti*, *Culex sitiens*, *Culex annulirostris*, and *Culex quinquefasciatus* (Diptera: Culicidae) for Barmah Forest virus. J. Med. Entomol. 37: 660-663.

Brown, M. D., D. Thomas, P. Mason, J. G. Greenwood and B. H. Kay. 1999. Laboratory and field evaluation of the efficacy of four insecticides for *Aedes vigilax* (Diptera: Culicidae) and toxicity to the non-target shrimp *Leander tenuiornis* (Decapoda: Palaemonidae). J. Econ. Entomol. 92: 1045-1051.

Hanna, J. N. S., S. A. Ritchie, D. A. Phillips, J. M. Lee, S. L. Hills, A. F. van den Hurk, A. T. Pyke, C. A. Johansen, and J. S. Mackenzie. 1999. Japanese encephalitis in north Queensland, Australia. Med. J. Aust. 170: 533-536.

Henderson, C. F., and E. W. Tilton. 1955. Tests with acaricides against the brow wheat mite. J. Econ. Entomol. 48: 157-161.

Hougard, J. M., S. Duchon, M. Zaim and P. Guillet. 2002. Bifenthrin: a useful pyrethroid insecticide for treatment of mosquito nets. J. Med. Entomol. 39: 526-533.

Howie, J. 2002. The public health impacts associated with biting midge (Diptera: Ceratopogonidae) in Hervey Bay, Queensland, Australia. Honors Thesis, University of the Sunshine Coast.

Johansen. C.A., R.A. Farrow, A. Morrisen, P. Foley, A.F. van den Hurk, H. Seriat, B. Montgomery, J.S. Mackenzie, and S.A. Ritchie. 2001. Wind-borne mosquitoes: Could they be a mechanism of incursion of Japanese encephalitis virus into Australia? Arbovirus Res. Aust. 8: 180-186.

Kay, B. H. and H. A. Standfast. 1987. Ecology of arboviruses and their vectors in Australia. Current Topics in Vector Research. 3: 1-36.

Kettle, D. S. 1965. Biting ceratopogonids as vectors of human and animal diseases. Acta Trop. 22: 356-362.

Linley, J. R. and J. B. Davies. 1971. Sandflies and tourism in Florida and the Bahamas and Caribbean area. J. Econ. Entomol. 64: 264-278.

Linley, J. R., A. L. Hoch, and F. P. Pinheiro. 1983. Biting midges (Diptera: Ceratopogonidae) and human health. J. Med. Entomol. 20: 347-364.

Marks, E. N. 1982. An atlas of common Queensland mosquitoes. Queensland Institute of Medical Research, Brisbane, Australia.

Ratnayake, J., P. Dale, P. Daniels, and N. Sipe. 2003. Economic impact of biting midges in Hervey Bay. Report for Hervey Bay City Council, Griffith University, Faculty of Environmental Sciences, Nathan Campus, Australia.

Russell, R. C. 1998. Vectors vs. humans in Australia: Who is on top down under? An update on vector-borne disease and research on vectors in Australia. J. Vect. Ecol. 23: 1-46.

Ryan, P. A., K. A. Do, and B. H. Kay. 1999. Definition of Ross River virus vectors in Maroochy Shire, Australia. J. Med. Entomol. 37: 146-152.

Shivas, M. 2001. Hervey Bay Biting Midge Review 2001: Previous studies and research priorities. Hervey Bay City Council, PO Box 5045, Torquay, Hervey Bay, Queensland, 4655, Australia.

Watson, T. M., and B. H. Kay. 1998. Vector competence of *Aedes notoscriptus* (Diptera: Culicidae) for Ross River virus in Queensland, Australia. J. Med. Entomol. 35: 508-514.

WHO. 1998. The WHO recommended classification of pesticides by hazard and guidelines to classification 1998-1999. WHO/PCS/98.21/Rev.1 World Health Organization, Geneva, Switzerland.

WHO. 2002. Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4

Yadav, R. S., H. C. Srivastava, T. Adak, N. Nanda, B. R. Thapar, C. S. Pant, M. Zaim, and S. K. Subbarao. 2003. House-scale evaluation of bifenthrin indoor residual spraying for malaria vector control in India. J. Med. Entomol. 40: 58-63.

Appendix 8

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT
OF HEALTH
AND COMMUNITY
SERVICES

EXOTIC MOSQUITOES ARRIVING ON SEAGOING VESSELS

RECOMMENDED INSPECTION & ERADICATION PROCEDURES

Published in (1998) '*Bulletin of the Mosquito Control Association of Australia'*, Vol 10, (2)
Amended July 2002

P. I. Whelan
Senior Medical Entomologist
Department of Health and Community Services
July 2002

For more information contact:
Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@.nt.gov.au

EXOTIC MOSQUITOES ARRIVING ON SEAGOING VESSELS
RECOMMENDED INSPECTION & ERADICATION PROCEDURES

P. I. Whelan, Department of Health and Commuity Services

Published in (1998) '*Bulletin of the Mosquito Control Association of Australia'*, Vol 10, (2)
Published in amended version in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale.Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.
Amended July 2002

1.0 INTRODUCTION

Various States in Australia are concerned about the possible importation and subsequent introduction of *Aedes aegypti* (the dengue fever mosquito), *Aedes albopictus* (The Asian tiger mosquito) and other exotic *Aedes* mosquitoes (such as the *Ae. scutellaris* group which occur in South East Asia, New Guinea and the Pacific) from interstate or overseas. *Aedes aegypti* is only established in northern Queensland (Sinclair 1992) but importation of this species from overseas to areas where it is already established could introduce new strains of the species or exotic viruses. Any measures to prevent the importation of *Ae. albopictus* into Queensland should also intercept *Ae. aegypti,* as Queensland (and the rest of Australia) is free of *Ae. albopictus* (Kay et al. 1990). One of the demonstrated methods of importation of these mosquitoes is via seagoing vessels, including commercial vessels, refugee vessels, fishing vessels and seagoing yachts (Whelan 1981, Kay et al. 1990).

In northern Australia the greatest potential risk arises by importing drought resistant eggs that have been deposited on the inside of drinking water storage containers. The containers likely to contain larvae or eggs are open jars or stoppered containers for transporting drinking water, such as drums or jerry cans, vehicle tyres used for packaging, spare tyres that are exposed to the rain, and deck stored machinery and equipment. The most frequent mode of importation has been on illegal fishing vessels intercepted in Australian waters. Vessels with refugees or illegal migrants, smaller trading vessels and barges, and private yachts, have also been sources of exotic mosquitoes (Whelan 1991).

An active inspection program of overseas vessels is currently being performed by Quarantine authorities in at least major ports. The intensity of inspection or the emphasis on detecting mosquitoes is probably variable between States. These, and additional inspections of other risk areas, are vital in excluding these vectors from Australia. The procedures outlined below are a guide to carrying out the inspection and eradication measures to ensure that Australia remains free of additional vectors or disease problems.

2.0 EQUIPMENT

The collecting equipment required includes a torch, a bulb pipette attached to a flexible clear hosing, white painted ladle, bucket, sample bottles, tissues, labels, pens, pipette, forceps, insect collection containers, aerosol knockdown insecticide spray, white sheets, and record forms. All this equipment should be readily available for each inspection. Control operations usually necessitate a return to a vessel for thorough treatment, and require cans of aerosol insecticide, a pressure sprayer with a residual pyrethroid insecticide and a 1 kg quantity of granular pool chlorine.

Onshore eradication procedures require a supply of granular pool chlorine, liquid insecticide application equipment, marker paint spray cans, recording equipment, and a mobile water supply (usually a trailer or truck mounted tank) of tap water.

3.0 VESSEL INSPECTION PROCEDURES

1. All vessels should be inspected for adult or larval mosquitoes. If possible all vessels should be inspected for adult mosquitoes before the vessels enter a harbour.

2. All inspections should be carried out in a specific quarantine area that should be at least 1 km from shore. If the vessel is brought direct to a landing, the inspection and control of adult mosquitoes should be carried out en route before any landing is made.

3. Any adult mosquitoes observed flying in any areas, such as holds or cabins, should be knocked down with aircraft disinsection spray. Attempts should be made to collect the knocked down mosquitoes by laying out white sheets in closed areas before spraying. Any insects collected from the sheets should be packaged in a secure container with a light packaging of tissue paper. The container should be labelled and forwarded as soon as possible to a specialist for identification.

4. The vessels containing live mosquitoes should be completely sprayed with aircraft disinsection sprays. Any intercepting vessel capable of offering mosquito harbourage that has been alongside a foreign vessel with adult mosquitoes should also be sprayed after leaving the intercepted vessel. Holds and other dark humid areas, including under beds and in cupboards, should be sprayed with aircraft disinfection spray. Any vessels with adult mosquitoes should be thoroughly searched to establish the source of the mosquitoes. Any vessel on which 4th instar larvae and pupae, or pupal skins are detected, should be sprayed on the presumption that live adult mosquitoes are present.

5. Any receptacles capable of holding or collecting water should be inspected for water and mosquito larvae. In most instances this will require the use of a torch and a white ladle. Receptacles needing examination will include bottles, cans, tyres, machinery parts, drums, and drinking water storages such as jars, jerry cans, and large water tanks. A large bulb pipette or siphon should be used for difficult to access receptacles or water tanks. Any receptacle used to carry water, irrespective of whether it is sealed, should be inspected for larvae. Water from water holding tanks should be sampled for mosquito larvae by net or by filling a bucket of water via a drain tap, or by using a large bulb pipette, or manual suction pump. Hygiene precautions should be taken when sampling drinking water to ensure water is not contaminated by the ladle or other sampling techniques.

6. All mosquito larvae or larval and pupal skins detected in any receptacles should be collected into labelled vials of 70 % alcohol and forwarded to a specialist for identification on the day of collection, together with collection details and a report form.
   Where there are secure facilities, larvae and pupae in receptacles arriving from South East Asia, New Guinea and the Pacific should be collected live, placed in labeled secure containers with original water, and transported immediately to the State Health entomologist or entomology specialist, so that the larvae and pupae can be link reared to adults. This is to clarify the identity of possible unknown *Aedes* species entering Australia from the above areas. Secure facilities

and ready access to a mosquito specialist is required to prevent the escape of live exotic mosquitoes.

7. For larger vessels, built-in freshwater tanks should be inspected to ensure that all openings are sealed or mosquito proof. Any filling points should be made mosquito proof (at least temporarily) with the aid of materials such as insect netting, until examination and treatment are complete, or the vessel leaves port.

4.0 ERADICATION PROCEDURES ON VESSELS

1. Once examined for mosquito larvae, all water in any containers (except that in built-in water storages) should be emptied into the sea or the containers sealed until the vessel leaves port.

2. Any vessel on which adult mosquitoes, live larvae or pupae, or pupal skins are detected, should have all containers on board that are either holding water, or likely to have recently been mosquito breeding sites, treated with granular pool chlorine (100 g in 20 litres of water, approximately one full plastic 70 ml urine sample jar), or sprayed with deltamethrin, permethrin or lambdacyhalothrin to the point of run off.

4. Receptacles which held water or dry containers likely to have been a mosquito breeding site, should be stored under cover if the vessel is due to remain in port for more than one week.

5. No receptacle which held water or dry containers likely to have been a mosquito breeding site should be allowed off a vessel until it has been steam cleaned or super chlorinated or treated with a residual insecticide.

6. If the vessel is due to go to another Australian port and has receptacles which hold water, those containers should be steam cleaned, chlorinated, treated with residual insecticide, sealed or stored under cover. Authorities in the next port of call should be advised of potential risk problems.

5.0 ONSHORE ERADICATION MEASURES

1. Onshore inspection and eradication measures should be carried out within one day of detection of live exotic *Aedes* adults, or larvae in association with pupae in any receptacle on an overseas vessel that has docked at a port or landing facility. Onshore inspection and eradication should also be carried out immediately if any exotic mosquito larvae are detected in the onshore ovitraps.

2. All property owners and businesses in the immediate area of importation (generally 500 m is sufficient) should be briefed on the importation and the importance and details of the eradication measures. No potential receptacles, particularly tyres, should be allowed to be removed from the premises until treated.

3. Adult mosquito fogging operations should be carried out within 500 m of the importing vessel or ovitrap site, with particular attention to the interior of warehouses and sheltered areas, or areas that contain potential breeding and harbouring sites. The fogging should be done in the late evening when mosquitoes are likely to be most active.

4. A receptacle search should be done within 500 m of the landing site or ovitrap site. All containers with water should be located, with each container marked to indicate orientation. The number and location of each container, and the presence of water and larvae, should be documented.

5. All larvae in each receptacles should be collected and placed in individual labelled collection vials of 70 % alcohol. Pupae should be transferred live to secure vials with adequate breeding site water and hatched in a secure laboratory. All larvae and pupae should be identified on the day of collection to locate the highest risk containers.

6. All water holding receptacles should be filled completely with tap water and super chlorinated or treated with residual insecticide to the whole interior surface. Receptacles with exotic larvae should be highlighted to prevent movement and ensure additional scrutiny.

7. If time and resources allow, an evaluation of the presence of exotic eggs in any container could be made before super chlorination or insecticide treatment. For this procedure every receptacle with water should be completely emptied and dried. This is to ensure that no late instar larvae or pupae inadvertently missed can later develop to maturity and emerge. All previously wet receptacles or receptacles likely to have held water at the time of importation are then completely filled with tap water and left for 3 days before reinspecting for mosquito larvae. Each water filled receptacle should then be treated with a super chlorine solution or residual insecticide.

8. When using super chlorine the super chlorine solution should be left in place for 3 hours to kill any unhatched *Aedes* eggs.

9. The super chlorine solution should be completely emptied from all the containers within one day of treatment.

10. Additional ovitraps should be placed in the detection area and inspected weekly for two months and again after the start of the next rain season.

11. The public and local businesses should be informed of the results of the inspection and eradication measures.

12. The procedures and the results of the inspections should be completely documented, and the report should be forwarded to the relevant authorities.

6.0 CONCLUDING REMARKS

These inspection and eradication procedures should be supplemented by an *Aedes* ovitrap surveillance program at least around international port areas. The possibility of the introduction and establishment of *Ae. albopictus* and *Ae. aegypti* to various States in Australia is very real. There have been instances of the interception of these vectors in Darwin, Broome, Townsville, Cairns and Brisbane (Whelan 1991). If the vectors are introduced, particularly to the northern areas of Australia, there will be new pest mosquito problems and additional risks of dengue outbreaks and epidemics (Kay et al. 1984). Failure to detect an importation very early, and to react immediately

and thoroughly, could result in the establishment of these vectors, ongoing and expensive control operations, and increased mosquito borne disease.

7.0 REFERENCES

Kay, B. H., Barker-Hudson, P., Stallman, N. D., Weimers, M. A., Marks, E. N. M., Holt, P. J., Muscio, M., Gorman, B. M., (1984), 'Dengue Fever - Reappearance in northern Queensland after 26 years', *Medical Journal of Australia*, vol. 140, pp. 264-268.

Kay, B. H., Ives, W. A., Whelan, P. I., Barker-Hudson, P., Fanning, I. D. & Marks, E. N. M., (1990), 'Is *Aedes albopictus* in Australia?', *MJA*, vol.153, pp.31-34.

Sinclair, D. P., (1992), 'The distribution of *Aedes aegypti* in Queensland, 1990-1992', *Bull of the Mos Cont Assoc of Aust*, vol. 4, no. 2, pp. 17-24.

Whelan, P. I., (1981), 'The vulnerability and receptivity of the NT to mosquito borne disease', *Trans Menzies Found*, vol. 2, pp. 165-171.

Whelan, P. I., (1991), 'Northern Territory remains free of dengue fever', *Bull Mos Control Assoc Aust*, vol. 3, no. 1, pp. 7-9.

Appendix H

Environmental Impact Statement for Proposed Blacktip Terrestrial Fauna Study prepared by EcOz Environmental Services






This page has been left intentionally blank

Environmental Impact Statement for the proposed Blacktip Project

Terrestrial Fauna Study

Prepared for: Woodside Energy Ltd.

Prepared by: EcOz Environmental Services

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

ABN 59 009 613 030

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

Environmental Impact Statement for the proposed Blacktip Project

Terrestrial Fauna Study

Prepared for: Woodside Energy Ltd.

Prepared by: EcOz Environmental Services

Project number:	Wood0303
File ref:	Z:\OldServer\Documents\ecoz_projects\WOOD0303 - Blacktip\03 Flora & Fauna\Fauna Report\Final\Blacktip Terrestrial Fauna Study vFinal.doc
Report by:	Kylie Harvey, Stephanie Myles
Reviewed by:	Noel Preece
Date:	29th June 2004
Document distribution:	Ceri Morgan, Woodside Energy Ltd.

Disclaimer:
This study, report and analyses have been based on the information available to EcOz at the time of the study. We take responsibility for the report and its conclusions to the extent that the information was sufficient. EcOz does not take responsibility for errors and omissions due to information not available to EcOz at the time of the study.

EXECUTIVE SUMMARY

This report documents baseline information on terrestrial vertebrate fauna for the Blacktip Project area, and assesses the potential impacts associated with the following onshore project activities:

- *construction and operation of the onshore processing plant.*
- *construction and operation of a buried onshore pipeline.*
- *construction and operation of associated roads and access routes (land only).*
- *construction camps and lay-down areas.*

Methodology
All known information sources were reviewed and relevant aspects documented to provide an historical background database. The area of study was assessed during several vegetation surveys during 2003 and 2004 (see EcOz Vegetation and Flora Study 2004, this volume), and a fauna habitat map was developed. Six sites were selected for the fauna surveys. Methodologies to survey the sites were development in consultation with NT Government authorities and followed the currently accepted practices for the region. The faunal sites were surveyed by trapping, observation and active searching for 3 days and nights by a team of two faunal experts.

Statutory obligations
Statutory obligations in relation to the protection of vegetation and flora apply to the project under the following NT and Commonwealth legislation:

- *Territory Parks and Wildlife Conservation Act 2000.*
- *Environment Protection and Biodiversity Conservation Act 1999.*

International Treaties and obligations apply to a number of faunal species. These are identified and addressed in the report.

Fauna habitats
Four fauna habitats were mapped in and immediately adjacent to the onshore project area based on amalgamation of vegetation communities interpreted from high resolution satellite imagery and field surveys. The habitats are:

- *eucalyptus forests to woodlands;*
- *sand dunes;*
- *monsoon vine forest; and*
- *mangroves.*

Only the Eucalyptus forest to woodlands and sand dune habitats are directly in the onshore development footprint as it stood at the time this report was prepared. Surveys were conducted in the eucalyptus forests and woodlands, and in the monsoon vine forests.

Faunal species
Sixty fauna species, including 2 frogs, 11 reptiles, 46 birds and one mammal species, were recorded during field surveys of the project area. The NT Fauna Atlas records for the project area documented 134 species within 20 km of the project area. The surveys added 28 species (2 frogs, 6 reptiles, 19 birds and one mammal) to the NT Fauna Atlas records.

Communities of conservation significance
Monsoon vine forest communities *occur at the northern and southern ends of Yelcher Beach where the pipeline shore crossing is located. The monsoon forests were surveyed for fauna because all monsoon vine forests are considered significant in a regional context due to their restricted size, and their high level of patch interdependence, although the project is unlikely to affect them.*

Species of conservation significance
None of the species recorded during surveys of the onshore project area are classified as 'threatened' under NT or Commonwealth legislation. Fourteen species of fauna classified as 'threatened' in the NT, including 4 bird species, 2 fishes, 1 mammal, 1 reptile and 6 marine turtles, are known to occur in the wider Darwin Coastal bioregion. The nationally 'threatened' mammal, the False Water Rat Xeromys myoides*, also occurs in the bioregion, but probably not in the project area. The conservation status and range of each of these species, and the likelihood of animals occurring in habitats in or near the project area are addressed in the report.*

Two of the listed 'threatened' species, the Red Goshawk Erythrotriorchis radiatus *and Brush-tailed Tree-rat* Conilurus penicillatus*, have a known range that extends to the onshore project area. These species were not recorded in the current field surveys and there are no previous records within a 20 km radius of the project area. This does not preclude their presence in the onshore project area where suitable tall forest habitats exist, however, it does indicate that:*

- *the presence of sensitive Red Goshawk nesting sites in the area is unlikely; and*
- *there is unlikely to be significant populations of the Brush-tailed Tree-rat present.*

A further 'threatened' fauna species, the Northern Brush-tailed Phascogale Phascogale tapoatafa pirata *has been identified as potentially occurring in the region. The Northern Brush-tailed Phascogale could potentially occur in the tall forest habitats in and surrounding the onshore project area, although the closest confirmed recent records are from Litchfield National Park some 160 km north-east of the project area. In the region where the project area is located, habitats of this species are extensive and largely unaffected by development.*

No migratory species have been recorded in the onshore project area in field surveys, but eight species have been identified as likely to occur. The species include the Saltwater Crocodile Crocodylus porosus*, three migratory wetland bird species, and four migratory terrestrial bird species. No waterbird roosting sites have been recorded in the onshore project area and the area is not considered to be significant for waterbirds.*

Eleven 'near-threatened' and regionally restricted species could potentially occur in the project area, although none were recorded in surveys. The known range of five terrestrial fauna species that are endemic to the Top End Coastal bioregion (combined Darwin Coastal and Arnhem Coast) extends to the project area, but none have been recorded for the area.

The monsoon rainforests north and south of the Yelcher Beach area at the pipeline landfall site have some conservation significance in a regional context. They are unlikely to be disturbed by the project. Seven species of bird which are typically associated with monsoon vine forests were recorded in the monsoon forests during the field surveys.

Potential Environmental Effects

The majority of the potential environmental effects on fauna associated with the Blacktip Project will be as a result of the disturbance and removal of native vegetation during the construction phase of the project. The main potential impacts of the project on fauna have been identified as:

- *short-term disturbance to the animals and habitats;*
- *habitat loss;*
- *impacts on species of conservation significance;*
- *fauna capture in open trench; and*
- *weeds and exotic species.*

There is significant scope for reducing the potential ecological impacts of the project by incorporating fauna considerations in the construction specifications. There are also opportunities to mitigate some of the potential adverse effects by implementing management actions before, during and after construction. Recommendations on management measures that should be implemented to minimise impacts on fauna are identified in this report. Additional measures for minimisation of site specific impacts should be developed following determination of the final design specifications.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **III**

1. INTRODUCTION **1**

2. METHODOLOGY **2**

2.1. Desktop literature review 2

2.2. Fauna habitat map 2

2.3. Field surveys 2

2.4. Evaluation of conservation significance 3

3. RESULTS **5**

3.1. Fauna habitats 5

3.2. Fauna species 5

3.3. Introduced species 6

4. CONSERVATION SIGNIFICANCE **7**

4.1. Threatened species 7

4.2. Migratory species 10

4.3. Near-Threatened and regionally restricted species 10

4.4. Significant sites and habitats 11

5. POTENTIAL ENVIRONMENTAL EFFECTS AND MANAGEMENT RECOMMENDATIONS **13**

5.1. Short-term loss of species from area 13

5.2. Habitat loss and reduced connectivity 14

5.3. Impacts on species of conservation significance 15

5.4. Fauna capture in open trench 16

5.5. Introduction and spread of weeds and exotic fauna species 17

6. REFERENCES AND BIBLIOGRAPHY **19**

TABLES

Table 1 Fauna survey sites. 3

Table 2 Conservation status and distribution of 'threatened' species known to occur in the wider Darwin Coastal bioregion. Species lists are taken from Woinarski (2002) but have been updated to reflect recent changes to the conservation status of some species..... 8

Table 3 Near-Threatened fauna species with a known range that extends to the project area. 10

Table 4 Regionally endemic fauna species with a known range that extends to the project area. 11

Table 5 Recommendations to reduce capture and mortality of fauna in pipeline trench. 16

FIGURES

Figure 1 Location of fauna survey sites.

APPENDICES

Appendix 1 Images of fauna survey sites

Appendix 2 Field survey results.

Appendix 3 List of fauna species recorded or likely to occur in or near the project area.

ACKNOWLEDGEMENTS

We would like to thank Alex Dudley and Ron Firth for undertaking the fauna surveys and the NT Museum and NT Herbarium for their assistance in identification of voucher specimens. The Department of Infrastructure, Planning and Environment is acknowledged for the provision of data to the project. Specifically, Peter Krause is acknowledged for collating the NT Fauna Atlas data for us.

1. INTRODUCTION

EcOz Environmental Services has been contracted by Woodside Energy Ltd. (WEL) to undertake studies of the terrestrial fauna at the project area proposed for the Blacktip Project. A detailed overview of the proposed project is provided in the referral documents submitted to the NT and Commonwealth Governments and in preliminary drafts of the EIS documents. These documents form the current design specifications on which the assessment of terrestrial fauna is based.

The proposed project has both onshore and offshore components. Assessment of the potential environmental impacts of the project will therefore consider interactions with both the marine and terrestrial environments in, and surrounding, the project area. This report is concerned with documenting baseline information on terrestrial fauna and assessing the potential impacts associated with the following onshore project activities:

- construction and operation of the onshore processing plant.
- construction and operation of a 3 km buried onshore pipeline.
- construction and operation of associated roads and access routes (land only).
- construction camps and laydown areas.

The last 2 points in the above list can only be partially assessed at this point in time as site selection and design specifications have not been finalised.

The marine environment in and surrounding the offshore project area is the subject of separate studies. For the purpose of this report, 'project area' refers to the onshore project area only.

The "Guidelines for Preparation of a Draft Environmental Impact Statement on the Proposed Blacktip Gas Project (Department of Infrastructure, Planning and Environment, March 2004)" detail the specific requirements of the EIS document that is to be prepared for the Blacktip Project in accordance with Clause 8 of the Environmental Assessment Administrative Procedures of the *Environmental Assessment Act (1982)* and Chapter 4 Division 6 of the *Environment Protection and Biodiversity Conservation Act (1999)*. The terrestrial fauna study was designed to satisfy the requirements of the Guidelines, and specifically to provide baseline information on which to base an assessment of potential impacts and development of appropriate mitigations measures for the project.

The aims of the fauna study are to:

- Undertake a desktop study to identify vertebrate fauna species and habitats that occur, or are likely to occur in areas that may be affected by the Project.

- Undertake a survey of key fauna habitats and areas likely to contain habitat for 'threatened' fauna species.

- Assess the conservation significance of fauna species and habitats that may be affected by the project in a local, regional and national context with specific reference to species listed under the provisions of the *Territory Parks and Wildlife Conservation Act 2000* and the *EPBC Act 1999*.

- Provide management recommendations and safeguards to minimise the impacts of the project on vertebrate fauna.

This report documents the findings of field surveys, consultations and reviews of existing information undertaken to assess the potential impacts of the Blacktip Project on terrestrial fauna.

2. METHODOLOGY

2.1. Desktop literature review

To identify the range of fauna species and habitats, and other environmental constraints that may occur in the project area, reviews of relevant literature and databases, and consultations with regional fauna experts from the NT Parks and Wildlife Commission were initially undertaken.

The main data sources utilised in the desktop review are listed below.

- NT Fauna Atlas records, provided by the Parks and Wildlife Commission, for the region (defined as within a 20 km radius of the onshore project area).
- EPBC Act Protected Matters Search Tool (search area defined as within a 10 km radius of the processing plant).
- Darwin Coastal Bioregion Summary (Woinarski 2002a).
- Recent data from surveys on seabirds (Chatto 2001), shorebirds (Chatto 2003) and waterbirds (Chatto 2000) in the region.
- Key scientific papers.

Fauna species and habitats of conservation significance identified from these data sources are discussed in section 5 of this report.

2.2. Fauna habitat map

A fauna habitat map was developed based on amalgamation of vegetation communities interpreted from high resolution satellite imagery. The habitat map was verified using vegetation survey data collected during 3 separate visits to the project area in May 2002, August 2003 and December 2003. The resultant map stratified the project area into four habitat types.

2.3. Field surveys

Field surveys of fauna were undertaken from the 1st to 5th of June 2004. A one day reconnaissance survey was undertaken to identify the most suitable survey sites for each habitat type based on representativeness, the presence of microhabitats and accessibility. Four survey sites were established at sites representative of the most dominant habitat types in the project area, eucalyptus open forest\woodland and coastal sand dunes. A further two sample sites were established in monsoon vine forest habitats near to the project area as they are considered as those most likely to support species of conservation significance. Table 1 summarises the locations of the fauna survey sites, which are shown in Figure 1.

Table 1 Fauna survey sites.

Fauna habitat	Site no.	Zone WGS 84	Easting	Northing
Eucalyptus woodland\forest	5A1	52	547034	8425889
Eucalyptus woodland\forest	5A2	52	545880	8426413
Monsoon vine forest	5B1	52	544477	8425760
Monsoon vine forest	5B2	52	544358	8425026
Eucalyptus woodland\forest	5C1	52	544699	8425747
Eucalyptus woodland\forest	5C2	52	545076	8426016

At each survey site the following environmental information was recorded:

- GPS coordinates;
- site photo;
- landscape position;
- soils and geology;
- presence\absence of water;
- evidence of fire, weeds and feral animals; and
- vegetation community structure and dominant species in each stratum.

The fauna surveys followed the widely accepted Bioregional Assessment Unit methods developed by the NT Parks and Wildlife Commission. At each survey site a 50 m x 50 m quadrat was established with each of 20 Elliott (box) traps, 4 cage traps and 4 pit traps. Each Elliot and cage trap was baited with a mixture of peanut butter and oats. All traps were opened for 3 consecutive nights and checked early each morning. The pitfall traps were left open for the entire trapping period with each trap being checked at least twice during the day to avoid animal deaths.

At each survey site, 3 diurnal and 2 nocturnal active searches, involving raking leaf litter, spot lighting and checking under bark and logs, were conducted. Eight diurnal 'instantaneous' bird counts were also conducted in each quadrat. Opportunistic observations were made along Yelcher Beach to identify any seabirds and shorebirds using the area. Opportunistic observations made whilst travelling around the project area between the survey sites were also recorded. Mangrove areas near the beach were surveyed for evidence of the False Water Rat *Xeromys myoides*. The False Water Rat lives on mud flats in mangrove habitat and evidence of its presence is given by distinctive holes in the mud, usually associated with fine remnants of crab shell, and in areas of high crab density (Woinarski *et al.* 2000; Woinarski pers. comm. 2004).

The surveys were conducted by a team of two experienced fauna surveyors with two local Aboriginal assistants from the nearby Wadeye community. Parks and Wildlife Commission Permit Number 17901 applied to the survey and appropriate Animal Ethics Clearance was obtained from Charles Darwin University Animal Ethics Committee.

Species were identified in the field by sight and expert identification, using a range of technical reference works, listed in the reference list. Animals that were unable to be identified in the field were taken as voucher specimens and lodged with the NT Museum for identification, where their identities were confirmed.

2.4. Evaluation of conservation significance

The conservation significance of fauna and habitats in and surrounding the project area was assessed with reference to the following:

- Threatened species listed under the *Territory Parks and Wildlife Conservation Act 2000* and\or *Environment Protection and Biodiversity Conservation Act 1999.*

'Threatened' species are those classified as extinct in the wild, critically endangered, endangered or vulnerable as assessed against IUCN categories. The *Territory Parks and Wildlife Conservation Act 2000* gives protected status to all species classified as 'threatened' in the NT and requires a person to apply for a permit to take or interfere with these species. Nationally 'threatened' species are a Matter of National Environmental Significance under the *Environment Protection and Biodiversity Conservation Act 1999*. In accordance with this Act, a person cannot take an action that will have a significant impact on a 'threatened' species without prior approval of the Commonwealth.

- Migratory species listed under the *Environment Protection and Biodiversity Conservation Act 1999.*

Listed migratory species include species listed in:

- to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals) for which Australia is a Range State under the Convention;
- the Agreement between the Government of Australia and the Government of the Peoples Republic of China for the Protection of Migratory Birds and their Environment (CAMBA); and
- the Agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA).

Australia has an international obligation to protect species listed under these agreements. Migratory species as a Matter of National Environmental Significance under the *Environment Protection and Biodiversity Conservation Act 1999.*

- Species that are classified as Near-Threatened and\or have a regionally restricted distribution in the Northern Territory.

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the future. Near Threatened species are not protected under legislation, however, the potential for these species to become more rare in the future has been identified and establishes a need to implement conservation measures to protect them.

Regionally restricted species for the purpose of this report are those that are endemic to the Top End Coastal Bioregion (Connors *et al*. 1996). This bioregion has recently been split into the Darwin Coastal and Arnhem Land bioregions by Environment Australia (2000), but is used here as endemic species lists have not been developed for the new bioregions.

The known range and habitat requirements of Near Threatened and regionally endemic species were identified with reference to Churchill (1998) for bats; Cole and Woinarski (2000) and Woinarski (2000) for mammals, Garnett and Crowley (2000) and Readers Digest (1997) for birds and Cogger (2000), Barker *et al.* (1995), and Wilson & Swan (2003) for amphibians reptiles. Identified species which appeared to occur outside their known ranges were referred to the NT Museum for verification that they were likely to occur in the location, or to verify that the record for the species was a new range extension.

- Habitats of listed 'threatened' species or habitats possessing outstanding biodiversity values.

Habitats of listed 'threatened' species or possessing outstanding biodiversity values are generally those identified from published literature, and from an assessment of habitat values in the project area.

3. RESULTS

3.1. Fauna habitats

Four fauna habitats were mapped in and immediately adjacent to the onshore project area based on amalgamation of vegetation communities interpreted from high resolution satellite imagery and field surveys. The habitats are:

- eucalyptus forests to woodlands;
- sand dunes;
- monsoon vine forest; and
- mangroves.

Only the Eucalyptus forest to woodlands and sand dune habitats are directly in the onshore development footprint as it stood at the time this report was prepared. Surveys were conducted in the eucalyptus forests and woodlands, and in the monsoon vine forests. Images of each of the six surveyed sites are provided in Appendix 1.

3.2. Fauna species

Sixty fauna species, including two frogs, 11 reptiles, 46 birds and one mammal species, were recorded during field surveys of the project area (Appendix 2).

The NT Fauna Atlas documented 134 species within 20 km of the project area. The surveys added 28 species (two frogs, six reptiles, 19 birds and one mammal) to the NT Fauna Atlas records. The species listed on the Atlas may or may not occur on the project area, depending on habitat availability, which is discussed to some extent in the following sections. A full list of species recorded in field surveys and from the desktop review is provided at Appendix 3.

3.2.1. Amphibians

Two frog species were recorded during the survey. Another seven were listed on the NT Fauna Atlas. The low numbers trapped and found during the survey probably reflect the habitats surveyed (woodland and closed and open forest), and the cooler weather. The frog species recorded in the NT Fauna Atlas records for the region are widespread and common species. During wetter times of year these species are likely to be encountered in limited numbers in the onshore project area. None of the frog species are of conservation significance. The Cane Toad appears to not have reached the Wadeye area at the time of the survey.

3.2.2. Reptiles

Eleven species of reptiles were recorded during the surveys, including two snakes, two geckoes, five skinks and two goannas. The two snakes, three of the skinks and one goanna were new records for the region, although were not range extensions. Most of the species identified in the NT Fauna Atlas are likely to occur in the vicinity of the project area, provided that suitable habitat is available. Some species, for instance Mitchell's Water Monitor, require fresh water for survival, so are not likely to occur near the project. Others are wide-spread and some are wide-ranging species which occur in a range of habitats, and could occur in the area from time to time. None of the species are listed as threatened.

A separate survey of marine turtles was undertaken for the project, and, therefore, this report will not discuss these species.

3.2.3. Birds

Forty six bird species were observed during the surveys, including 19 not previously recorded for the local area. None of the species recorded during the surveys are listed as being of conservation significance. Most of the common bird species recorded in previous regional records (Appendix 3) could be found in the area. A number of species which are listed as being of conservation significance (Appendix 3) could potentially be found in the project area. These are discussed below in section 4.

3.2.4. Mammals

The only mammals observed during the surveys were Agile Wallabies *Macropus agilis*. No mammals were trapped during the surveys. As the surveys were of short duration, this result is not unexpected, although it is usual to catch at least one or two mammals during surveys. The desktop studies suggested that a number of mammals could be expected to occur in the region, including some vulnerable species. These species are discussed below in section 4. Searches specifically for these species were conducted, and habitats suitable for the species were assessed and investigated. None were found in the onshore project area. This study was the first formal fauna study for the region, so there was no prior expectation that these vulnerable species would be present.

3.3. Introduced species

No introduced species were recorded in the project area during field surveys. Species that are likely to occur include the Feral Pig *Sus scrofa*. Signs of pigs were recorded in the area during previous investigations (Noel Preece, pers. comm. 2003), and they are likely to be present from time to time.

Feral animals, mainly pigs and buffalo, are identified as a key threatening process in the Darwin Coastal bioregion where the onshore development will be located. The monsoon rainforest patch network is being degraded by feral animals (principally pigs), the extensive eucalypt forests are broadly affected by feral animals and livestock, and the condition of riparian zones is generally declining because of damage associated with proliferation of feral pigs and buffalo, and (in some cases) unrestricted access by livestock (Woinarski 2002a). The effects of pigs and buffalo in the project area are minimal due to the lack of preferred wet habitats and the low numbers of animals likely to be present.

The Cane Toad *Bufo marinus* is an introduced species that now occupies much of Queensland, northern New South Wales and the Top End of the Northern Territory. Concern about the ecological impacts of Cane Toads is widespread and predation, competition and lethal toxic ingestion caused by Cane Toads is currently nominated for listing as a 'key threatening process' under the Commonwealth EPBC Act. Cane Toads are not yet present in the onshore project area, however, it is expected that they will naturally move into the area in the next few years. Their current range extends west of Katherine, and sightings have been reported in the Lower Daly River region (Frogwatch NT [Accessed 14 May 2004] http://www.frogwatch.org.au/canetoads/index.cfm). Movement of construction materials, vehicle and plant from infested areas to the onshore project area has potential to speed up the spread of Cane Toads, as does the creation of a cleared corridor for the onshore pipeline route.

4. CONSERVATION SIGNIFICANCE

There are a small number of regionally restricted and 'threatened' species that potentially occur in the project area as identified from the desktop review. Significant populations of these species are unlikely given their absence during the surveys, although their possible presence in the project area cannot be discounted. There are a number of fauna species, habitats and areas of conservation significance to fauna that occur in the wider region. These have been described in this section in recognition of the fact that project related activities, such as construction of access routes and sourcing of construction materials, will take place in the wider region, and potential project impacts are not restricted to the onshore project area.

4.1. Threatened species

None of the species recorded during surveys of the onshore project area are classified as 'threatened' under NT or Commonwealth legislation. Fourteen species of fauna classified as 'threatened' in the NT , including four bird species, two fishes, one mammal, one reptile and six marine turtles, are known to occur in the wider Darwin Coastal bioregion (Woinarski 2002a). The nationally 'threatened' mammal, the False Water Rat *Xeromys myoides,* also occurs in the bioregion. Table 2 documents the conservation status and range of each of these species, and the likelihood of animals occurring in habitats in or near the project area. The marine turtles are not covered here as they are outside of the scope of this study.

Two of the listed 'threatened' species included in Table 2, the Red Goshawk *Erythrotriorchis radiatus* and Brush-tailed Tree-rat *Conilurus penicillatus*, have a known range that extends to the onshore project area. These species were not recorded in the current field surveys and there are no previous records within a 20 km radius of the project area. This does not preclude their presence in the onshore project area where suitable tall forest habitats exist, however, it does indicate that:

- the presence of sensitive Red Goshawk nesting sites in the area is unlikely; and
- there is unlikely to be significant populations of the Brush-tailed Tree-rat present.

A further 'threatened' fauna species, the Northern Brush-tailed Phascogale *Phascogale tapoatafa pirata* has been identified by the NT Parks and Wildlife Commission (Woinarski and Fisher pers. comm. 2003) as potentially occurring in the region. The Northern Brush-Tailed Phascogale is a strongly arboreal dasyurid marsupial that typically inhabits open forest with sparse ground cover. The Northern Brush-tailed Phascogale could potentially occur in the tall forest habitats in and surrounding the onshore project area (Alaric Fisher pers. comm. 2004), although the closest confirmed recent records are from Litchfield National Park some 160 km north-east of the project area. Formerly, this species was widespread throughout the dry sclerophyll forest and woodlands of tropical and temperate Australia (Strahan 1995). Although much of its habitat has been reduced for agriculture on a national scale, the records of the tropical sub-species indicates that the range is widespread but sparse, making it vulnerable to localised extinction. In the region where the project area is located, habitats of this species are extensive and largely unaffected by development.

Table 2 Conservation status and distribution of 'threatened' species known to occur in the wider Darwin Coastal bioregion. Species lists are taken from Woinarski (2002) but have been updated to reflect recent changes to the conservation status of some species.

Species name	NT listing	EPBC listing	Distribution and likelihood of occurrence in the project area
Mammals			
Brush-tailed Tree-rat *Conilurus penicillatus*	VUL	-	The preferred habitat of the Brush-tailed Tree-rat *Conilurus penicillatus* is tall eucalypt forests with a shrubby understorey, although in some locations within its range it also occurs on coastal grasslands (Woinarski 2002c). The project area is well south of the known distribution of this species. Advice from the NT Bioregional Assessment Unit (Alaric Fisher pers. comm.) is that survey effort in the near-coastal tall open forest habitats in the west of the NT has been low and this species may occur in these habitats. On the basis of this advice, the possibility of this species occurring in the project area can not be discounted.
False Water Rat *Xeromys myoides*	NT	VUL	A poorly known native rodent, the False Water Rat *Xeromys myoides* is found to inhabit a variety of well-watered habitats from mangrove forests to sedged lakes (Strahan 1995). The species has previously been recorded in the Northern Territory from the South Alligator River, Daly River and most recently from the Glyde River in north-east Arnhem Land (Woinarski *et* al. 2000). The False Water Rat could potentially occur in the estuarine environments surrounding the project area (Woinarski pers. comm. 2004). Surveys in mangrove habitats on the headlands that flank the northern and southern end of Yelcher Beach near the project area, failed to find this species. This does not preclude its presence in the more well developed mangrove and saline grassland habitats that occur further to the north and south of the project area. In the event that *X. myoides* does occur in these habitats it is considered unlikely that they will be affected by the project which is at least 2 to 3 km away.
Birds			
Yellow chat *Epthianura crocea tunneyi*	EN	EN	The Yellow Chat is typically nomadic and inhabits the open, well-grassed swamplands of Northern Australia particularly those semi-arid regions that are prone to drying out where they frequent the edges of surface water bodies (Readers Digest 1997). The subspecies *Epthianura crocea tunneyi* is restricted to a small geographic area encompassing the floodplains from the Mary River to the East Alligator River (Schodde and Mason 1999), and within this area it is known from only about 12 sites (Woinarski 2002b). The known range of this species does not extend to the project area, and given the lack of suitable floodplain habitats in proximity to the project area it is considered unlikely that this species would occur there.
Red Goshawk *Erythrotriorchis radiatus*	VUL	VUL	The Red Goshawk occurs across much of northern Australia, from near Broome in the south-west Kimberley to south-eastern Queensland (Woinarski, 2001). This species lives in coastal and sub-coastal tall open forests and woodlands, tropical savannas traversed by wooded or forested rivers, and along the edges of rainforest (Marchant & Higgins 1993). The range of this species extends to the project area and there is potential for this species to occur in tall forest habitats in and surrounding the project area. Nest sites of this species are particularly vulnerable (Garnett and Cowley, 2000). No nest sites have been identified during field surveys of the project area.
Gouldian Finch *Erythrura gouldiae*	EN	VUL	Gouldian Finches occupy two different regions of the landscape on an annual cycle. In the dry season and part of the late wet season, between Feb and Oct, they live within wooded hills that contain a group of Eucalyptus species commonly referred to as "snappy gum" (*Eucalyptus tintinnans, E. brevifolia*). These species of trees provide nesting sites. During this period they feed upon native Sorghum and find water at small rocky waterholes that remain in the hills until next wet season. In the wet season Gouldian Finches move from the hills into the lowland drainage lines to feed upon perennial grasses that begin to seed mid Dec (Lewis, 2001). Gouldian Finches have not previously been recorded in proximity to the project area and the preferred habitats of this species do not occur there.
Partridge Pigeon *Geophaps smithii smithii*	VUL	VUL	The Partridge Pigeon (subspecies *Geophaps smithii smithii*) lives primarily in open forest and woodland dominated by Darwin Stringybark *Eucalyptus tetrodonta* and Darwin Woollybutt *E. miniata* that has a structurally diverse understorey (F. Fraser pers. comm.. cited in Garnett and Crowley 2000). The species is now recorded only in sub-coastal NT, principally from Kakadu and between Katherine and Darwin and the Tiwi Islands; also recorded near the McKinley, Daly and Finniss Rivers and west of Katherine (Garnett and Crowley 2000). The known range of this sub-species of the Partridge Pigeon does not extend as far west as the project area, and it was not recorded during field surveys of the project area.
Reptiles			

Species name	NT listing	EPBC listing	Distribution and likelihood of occurrence in the project area
Yellow-snouted Ground Gecko *Diplodactylus occultus*	VUL	-	The Yellow-snouted Ground Gecko *Diplodactylus occultus* is the only 'threatened' terrestrial reptile species known to occur in the Darwin Coastal bioregion. It is known from only a few localities, almost entirely from the northwest areas of Kakadu National Park and appears to occur in well-developed leaf litters and grasses in open Eucalyptus dominated forests (Beggs and Armstrong 2001). The known range of this species does not extend to the project area and it is considered highly unlikely that the species would occur there.
Fishes			
Speartooth Shark *Glyphis sp. A*	-	EN	In the Northern Territory, the Speartooth Shark is known only from the Adelaide-Alligator Rivers region (Stirrat and Larson, 2002). The known range of this species does not extend to the project area, and given that there are no permanent fresh water-bodies, it is considered that this species will not occur there.
Freshwater Sawfish *Pristis microdon*	VUL	DD	Freshwater Sawfish *Pristis microdon* is the largest fish found in Australia's fresh waters. Its range now appears to be extremely restricted, and it is now known only from a few northern Australian river systems. In the NT the species is known to occur in the Adelaide, Victoria and Daly Rivers (Pogonoski *et al.* 2002). Its know range does not include the project area and there are no permanent freshwater habitats nearby.

4.2. Migratory species

No migratory species (as defined by the *EPBC Act 1999*) have been recorded in the onshore project area in field surveys, but eight species have been identified as likely to occur. The species include the Saltwater Crocodile *Crocodylus porosus,* the migratory wetland bird species Oriental Pratincole *Glareola maldivarum,* Oriental Plover *Charadrius veredus,* Little Curlew *Numernius minutes*, and the migratory terrestrial bird species Melville Cicadabird *Coracina tenuirostris,* White-bellied Sea Eagle *Haliaeetus leucogaster,* Barn Swallow *Hirundo rustica,* Rufous Fantail *Rhiphidura rufifrons* (Appendix 3). A number of 'migratory' marine turtles and mammals may inhabit the surrounding marine environments. The potential occurrence of these species in the offshore project area is the subject of a separate report.

The Saltwater Crocodile *Crocodylus porosus* is unlikely to be present in the onshore project area due to the lack of permanent waterbodies. This species is likely to be present in the marine environments surrounding the project area and also in the coastal estuarine environments and larger freshwater rivers and creeks.

No waterbird roosting sites have been recorded in the onshore project area and the area is not considered to be significant for waterbirds (Chatto, pers. comm. 2004). There are some seabird breeding roosts (ie. Terns) recorded in proximity to the proposed pipeline landfall site, however, these are considered to have a low significance as groups typically consist of numbers in the low hundreds (Chatto pers. comm. 2004). The proposed onshore development is considered unlikely to cause significant impacts on these colonies (Chatto pers. comm. 2004) as suitable habitats are abundant in the region away from the project area. No shorebird roosts have been identified in the area.

4.3. Near-Threatened and regionally restricted species

Fifty-five terrestrial fauna species are classified as Near-Threatened in the Northern Territory. The known range of 20 of these species extends to the project area (Table 3). Of these species, 11 could potentially occur in habitats in the project area.

Table 3 Near-Threatened fauna species with a known range that extends to the project area.

Species	Range extends to project area	Suitable habitats may exist in or near project area
Mammals		
Northern Quoll *Dasyurus hallucatus*	YES	YES
Lesser Wart-nosed Horseshoe Bat *Hipposideros stenotis*	YES	YES
Ghost Bat *Macroderma gigas*	YES	NO
Black-footed Tree-rat *Mesembriomys gouldii*	YES	YES
Northern Nailtail Wallaby *Onychogalea unguifera*	YES	YES
Narbarlek *Petrogale concinna*	YES	NO
Western Chestnut Mouse *Pseudomys nanus nanus*	YES	NO
Pale Field-rat *Rattus tunneyi*	YES	NO
Orange Horseshoe Bat *Rhinonicteris aurantius*	YES	YES
False Water Rat *Xeromys myoides*	YES	YES
Birds		
Australian Bustard *Ardeotis australis*	YES	NO

Species	Range extends to project area	Suitable habitats may exist in or near project area
Bush Stone-curlew *Burhinus grallarius*	YES	YES
Emu *Dromaius novaehollandiae*	YES	YES
Yellow-rumped Mannikin *Lonchura flaviprymna*	YES	NO
Square-tailed Kite *Lophoictinia isura*	YES	YES
Grass Owl *Tyto capensis*	YES	NO
Masked Owl *Tyto navaehollandiae kimberli*	YES	YES
Clamorous Reed Warbler *Acrocephalus stentoreus*	YES	NO
Reptiles		
Chameleon Dragon *Chelosania brunnea*	YES	YES
Worrell's Turtle *Emydura subglobosa worrelli (listed as E. worrelli)*	YES	NO

The known range of five terrestrial fauna species that are endemic to the Top End Coastal bioregion (combined Darwin Coastal and Arnhem Coast) extends to the project area (Table 4). There are a number of endemic sea snakes and marine turtles that are not listed as they are outside of the scope of this study.

Table 4 Regionally endemic fauna species with a known range that extends to the project area.

Species	Range extends to project area	Suitable habitats may exist in or near project area
Mammals		
False Water Rat *Xeromys myoides*	YES	YES
Birds		
Chestnut Rail *Eulabeornis castaneoventris*	YES	NO
Barn Swallow *Hirundo rustica*	YES	YES
Asian Dowitcher *Limnodromus semipalmatus*	YES	NO
Reptiles		
Glaphyromorphous nigricaudis	YES	YES

Species that occur in eucalyptus open forest habitats, like those that dominate the project area, typically occupy extensive areas (Woinarski [Accessed 14 May 2004] http://savanna.ntu.edu.au/information/dk/dk_pa.html) as this vegetation community is widely distributed in the Top End. The habitats that dominate the onshore project area are well represented in the region. In this context the project area is considered to have low regional conservation significance for fauna.

4.4. Significant sites and habitats

Habitats with special biodiversity conservation values that occur in proximity to the project area include monsoon vine forest and coastal estuarine systems dominated by mangroves. There are no sites with special conservation significance to fauna that have been identified in proximity to the onshore project area. However, the wider Darwin Coastal bioregion does contain some ecologically significant sites worthy of mention. This section provides a brief description of the significance of the monsoon rainforest habitats that occur in proximity to the project area, and some sites with regional

and national conservation significance. The significance of the coastal estuarine systems in the region is being investigated as part of a separate study.

Dry monsoon rainforest habitats

The closest monsoon vine forest communities to the onshore project area occur at the northern and southern ends of the section of Yelcher Beach where the pipeline will come on-shore. The patch to the south is located 320 m from the seaward end of the export pipeline corridor and the patch to the north is located approximately 250 m from the seaward end of the export pipeline corridor. Monsoon vine forests are also likely to occur in association with the estuarine systems that occur along the coast to the north and south of the project area. Woinarski (http://savanna.ntu.edu.au/information/dk/dk_pa.html) considers monsoon rainforests to be a highly significant environment for wildlife in the region, supporting a distinctive fauna. Fauna species typically associated with monsoon rainforests (Bach *et al.* 1999; Price *et al.* 1998; Woinarski 1993) that were recorded during field surveys near the project area include:

Emerald Dove[2]	*Chalcophaps indica*
Rose-crowned Fruit-Dove[1] [2] [3]	*Ptilinopus regina*
Varied Triller[2]	*Lalage leucomela*
Little Shrike-thrush[2]	*Colluricincla megarhyncha*
Yellow Oriole[1] [2] [3]	*Oriolus flavocinctus*
Green-backed Gerygone[2]	*Gerygone chloronota*
Spangled Drongo[2]	*Dicrurus bracteatus*

Bach *et al.* 1999[1]; Woinarski 1993[2]; Price *et al.* 1999[3]

Especially in the wet season, the rainforests provide concentrations of fruit far greater than those across the rest of the landscape, and these attract flying-foxes and fruit-eating pigeons, orioles, cuckoos and figbirds. Many of these animals move between rainforest patches and the surrounding open forest, and the conservation of this rainforest environment is probably dependent upon the maintenance of as many patches as possible and extensive areas of their surrounding habitats (Price *et al.* 1999; Woinarski http://savanna.ntu.edu.au/information/dk/dk_pa.html).

Waterbird habitats

The sub-coastal wetlands of the monsoonal wet-dry tropics of the Top End are recognised for their high conservation value (Whitehead & Chatto 1996). The Darwin Coastal bioregion contains all or part of several nationally important wetland systems (Woinarski 2002a). The nearest 'important wetland' to the project area is the Moyle Floodplain and Hyland Bay system, which is located 50 km to the east. These floodplains are most notable for their waterbird fauna and are considered to be one of the most important areas for colonial breeding waterbirds in the NT (Chatto 2000).

5. POTENTIAL ENVIRONMENTAL EFFECTS AND MANAGEMENT RECOMMENDATIONS

The potential effects of the Blacktip Project on fauna have been minimised as much as possible during the design phase by locating major project infrastructure to avoid impacts on key fauna habitat areas such as monsoon rainforests, mangroves, wetlands, and rivers and creeks. The majority of the potential environmental effects on fauna associated with the project will be associated with the short-term disturbance of animals and habitats during the construction phase. The main potential longer-term impacts of the project on fauna have been identified as:

1. habitat loss;
2. impacts on species of conservation significance;
3. fauna capture in open trench; and
4. weeds and exotic species.

Other potential impacts, such as those associated with changes to hydrology, water quality, effluent and waste management, hazardous substances and increased risk of fire, are considered to have a lower potential impact on fauna, and therefore are not discussed in detail in this report. Impacts associated with the onshore gas flare will be mainly on shorebirds, seabirds and marine turtles, which are being considered in a separate study.

There is significant scope for reducing the potential ecological impacts of the project by incorporating fauna considerations in the construction specifications. There are also opportunities to mitigate some of the potential adverse effects by implementing management actions before, during and after construction. Recommendations on management measures that should be implemented to minimise impacts on fauna are identified in this section. Additional measures for minimisation of site specific impacts should be developed following determination of the final design specifications.

5.1. Short-term loss of species from area

5.1.1. Potential Effects

Short-term disturbance and possible loss of species in and adjacent to the project area during the construction phase is likely to represent the major environmental effect of the project on terrestrial fauna. The project area is located in a substantially natural and remote area, which is generally visited only by local Aboriginal people, and where there is no industrial development for hundreds of kilometres. The increased activity in the area during the construction phase will represent a substantial deviation from the ambient environmental conditions. Construction activities will involve a large number of personnel, vehicles and plant moving around the project area, and along access tracks that presently receive very little traffic. This will result in increased noise levels, creation of dust and generally high levels of disturbance for the period in which construction will take place.

The disturbance caused by construction activities will likely be sufficient to cause some fauna to avoid using the surrounding areas for the duration of construction and possibly longer. High levels of vehicle traffic during the construction phase will likely result in increased numbers of road casualties. During the operational phase when activity levels in the area decrease, fauna may move back into the areas adjacent to the project area. Overall, it is considered that long-term impacts on fauna will be negligible due to the widespread availability of similar habitats in the surrounding areas.

5.1.2. Management

The following recommendations should be considered to minimise the loss of fauna from the area:

1. Develop a noise reduction strategy for the construction and operational phases of the project.

2. Implement dust minimisation strategies.

3. Restrict vehicle travel on access routes to daylight hours, avoiding dusk and dawn in particular and between sunset and sunrise where possible to minimise fauna casualties.

5.2. Habitat loss and reduced connectivity

5.2.1. Potential Effects

Construction in areas of intact native vegetation may cause a decline in the physical condition of fauna habitats both directly through removal or disturbance of vegetation, and indirectly through general changes to environmental conditions that extend beyond the actual zone of disturbance. Construction of the shore crossing (working width currently 60 m) and onshore pipeline (2.2 km x 40 m) will be via an 'open cut' technique, which will result in the clearing of sand dune and eucalyptus woodland habitats. A further 56 ha of eucalyptus woodland to forest habitat will be cleared for the gas plant, and associated lay-down and camp areas. In the context of the large areal extent of eucalyptus woodland habitats in the region, it is considered that the extent of clearing associated with the project is unlikely to have a significant long-term impact on habitat availability for fauna.

Additional clearing of habitats will be associated with the:

- construction of an access route from Wadeye to the onshore plant site;
- sourcing of construction materials; and
- potentially the construction of a beach barge landing and heavy vehicle access road from the beach landing to the plant site.

The details of these aspects of the project are yet to be finalised and therefore the habitat types and extents that will be affected by the project cannot be determined. However, it can be established at this stage that there is potential for adverse effects on sensitive fauna habitats, especially riparian zones, as a result of these activities.

Construction of the onshore pipeline, gas plant and access roads will result in changed environmental conditions at the edges of the cleared areas (edge effects) (Ford *et al.* 2001; Hobbs, 2001) and may create a barrier to the movement of some fauna species. Barriers can act as impediments to animal movement between habitat patches (Kozakiewicz 1993), or can affect animal movement by creating more complex movement paths as individuals approach a barrier, withdraw, and approach again (McDonald and St Clair 2003). The magnitude of barrier effects will depend on species behaviour and mobility (Goosem *et al*. 2001). Species of fauna that are habitat specialists or that move amongst several habitats are particularly at risk (Ford *et al*. 2001; Harrington *et al*. 2001). A study into the effects of habitat fragmentation on selected species of mammals, birds and reptiles in the NT, found that certain species were excluded from areas where less than a 30% of bush remained within a 4 km radius (Parks and Wildlife Commission of the Northern Territory 2001). Whilst most species of fauna at the project area will move across areas cleared of vegetation in the onshore project area, some species will not, or will reduce their level of movement.

5.2.2. Management

The following management measures should be considered to minimise the effects of habitat loss and fragmentation associated with the project:

4. Keep the extent of the working footprint for all project components, including access tracks and borrow pits, to the minimum area necessary for construction activities. This is particularly important at the shore crossing and at riparian areas where habitats are particularly sensitive to disturbance.

5. Consult with Traditional Owners and other Aboriginal representative groups, to develop appropriate mitigation strategies.

6. Avoid clearing of large mature fruiting trees (such as *Ficus virens*, *Terminalia microcarpa*, *Syzygium nervosum* and *Canarium australianum*), which provide important habitat and act as a stepping stone between fragmented habitats.

7. Clearly mark the work area using construction pegs, construction flagging, or other temporary measures, and identify areas requiring special protection as 'no-go' areas on construction plans and on the ground.

8. Undertake construction in the vicinity of watercourses as early as possible in the dry season and ensure that appropriate rehabilitation or erosion control structures are in place prior to the first wet season rains.

9. Stage clearing of vegetation in accordance with the construction schedule to minimise the time between clearing and rehabilitation.

10. Design additional project infrastructure, including access routes, vehicle and plant storage and turn-around areas, borrow pits etc. so that:

    a. previously disturbed areas are used where possible;

    b. areas of sensitive vegetation are avoided; and

    c. low impact construction techniques are used in environmentally sensitive areas.

11. Develop a rehabilitation plan prior to construction. Include a rehabilitation schedule, proposed techniques, species proposed for use, and the following general principles:

    a. Stockpile top soil and suitable vegetative matter near to the area from which it was taken so that it can be respread over the area during rehabilitation.

    b. Locate stockpiles within the marked working width.

    c. Store excavated soil on-site in an area previously cleared of vegetation, or remove to an appropriate area off-site. Any on-site or off-site location needs to be approved by DIPE prior to dumping.

    d. Clearly mark appropriate locations for dumping of spoil.

12. Brief all construction staff on the importance of protecting fauna species and habitats.

5.3. Impacts on species of conservation significance

5.3.1. Potential Effects

Two listed 'threatened' species, the Red Goshawk *Erythrotriorchis radiatus* and Brush-tailed Tree-rat *Conilurus penicillatus*, have a known range that extends to the onshore project area. The tall forest habitats typically utilised by the Red Goshawk and Brush-tailed Tree-rat are found in and around the project area, however, these species were not recorded during field surveys and there are no previous records within a 20 km radius of the project area. A further two 'threatened' mammals, the Brush-tailed Phascogale *Phascogale tapoatafa* (in suitable tall forest) and False Water Rat *Xeromys myoides* (in suitable mangrove habitats) may occur in the project area, although this would represent a substantial expansion to their known ranges.

Nesting sites of the Red Goshawk *Erythrotriorchis radiatus* are highly susceptible to disturbance and the bird's tolerance to habitat fragmentation is yet to be determined (Garnett and Crowley 2000). If a nest site was to occur in proximity to locations where construction activities were taking place this could result in failure of the nest. Surveys of the onshore project area did not identify any nest sites of

this species. Given that nests are large and are typically located in tall trees, it is considered highly likely that any nest sites that did occur in the project area would have been identified during the field surveys.

There is unlikely to be significant populations of the Brush-tailed Tree-rat or Brush-tailed Phascogale in proximity to the project area. The tall forest habitats that are typically the habitat of the Brush-tailed Tree-rat and Brush-tailed Phascogale, are well represented in coastal NT and in areas adjacent to the project area. Given that high quality habitats for these species are widely available in the region, it is considered unlikely that the project will cause long-term impacts to any populations.

There is unlikely to be significant populations of the False Water Rat *Xeromys myoides* in close proximity to the project area. The more extensive mangrove and saline grassland habitats that occur in association with Injin Beach (north of the project area) and Yelcher Beach (south of the project area) are considered more likely to provide suitable habitat. In the event that *Xeromys myoides* does occur in these habitats it is considered unlikely that they will be affected by the project, which is at least 2 to 3 km away.

The project area does not occur in close proximity to any significant shorebird or waterbird colonies (Chatto 2003, 2000). Seabird breeding roosts (ie. Terns) have been recorded in proximity to the proposed pipeline landfall site, although these are considered to have a low significance (Chatto 2001). The proposed onshore development is considered unlikely to cause significant impacts on shorebirds or waterbirds in the region (Chatto, pers. comm. 2004).

5.3.2. Management

The following management recommendations should be considered, in addition to measures1-11, to minimise the potential impacts of the project on fauna species of conservation significance:

12. Contractors to report all large bird nesting sites (e.g. large single nests like those typically built by Red Goshawks and Sea Eagles, or nesting colonies) so that they can be assessed prior to disturbance.

13. Assess the conservation significance to fauna, i.e. near riparian areas, prior to siting of additional project infrastructure.

5.4. Fauna capture in open trench

5.4.1. Effect

Construction of the shore crossing and onshore pipeline has the potential to cause fauna mortality due to capture in the open trench during construction. Animals that are captured in trenches are exposed to various elements such as stress, predators, effects from the sun and subsequent dehydration (Woinarski *et al.,* 2000). The pipeline route has been designed to avoid areas of high faunal conservation value such as monsoon vine forests, wetlands and riparian areas, a strategy recommended by Woinarski *et al*. (2000). Whilst this design measure will hopefully minimise the number of animals that become trapped in the open trench, a large number of animals will still get trapped, and will die unless appropriate measures are in place to facilitate their escape or removal

5.4.2. Management

Investigations of wildlife mortality in a pipeline trench in the NT (Woinarski *et al.* 2000) resulted in a series of recommendations to reduce capture and mortality during trench construction (Table 5). The procedures recommended by Woinarski *et al.* (2000) should be considered as a way to minimise fauna mortality associated with the project.

Table 5 Recommendations to reduce capture and mortality of fauna in pipeline trench.

Type of measure	Recommended procedure	Explanation
Construction operational	14. Undertake operations in the most benign season (i.e. in the second and third quarters).	Wildlife mortality is likely to be highest in hot (or very cold) weather; Wildlife activity may also be higher in warm weather than cool weather, so capture rates would be greater
Construction operational	15. Interrupt trench with frequent "escape ramps" for captured wildlife	Exit points from the trench will enable trapped animals to leave the trench: sloping ramps away from the trench every 200-500m should be sufficient for most species
Construction operational	16. Minimise the time the trench is opened, through careful planning of construction and pipe laying	Fewest animals will be trapped if pipe laying (and immediately thereafter trench filling) occurs within 24 hrs of trench opening
Construction operational	17. Site pipeline route to avoid areas of exceptional conservation values (eg. remnant bushland, essential habitat for threatened species, etc.)	These areas are likely to contain species of high conservation value, so they should be avoided.
Inspection	18. Ensure that trenches are inspected frequently (by a wildlife handler)	Animals captured in the trench should be removed, identified and released in a vegetated area near to where it was captured. Trench inspections and collection and removal of species must be undertaken by an experienced wildlife handler to facilitate accurate identification and minimise stress to the animal. The data obtained from these collections will form a valuable information source, and may be a condition of approval by the NT Govt.

Source: Adapted from Woinarski *et al.* (2000).

5.5. Introduction and spread of weeds and exotic fauna species

5.5.1. Effect

Activities associated with the construction and operation stages have a high potential to introduce weeds and feral animals into remote areas that are currently relatively unaffected by exotic species. The greatest risk of weeds and feral animals being introduced and spread will occur during the construction phase of the project when plant and equipment sourced from elsewhere in the region and Australia may act as vectors of exotic species introduction to the project area. Road access routes to the project area from Darwin and Katherine traverse areas where infestations of declared weed species are present, and where the Cane Toad *Bufo marinus* is currently found. The construction and maintenance of a right of way (ROW) cleared of tall vegetation may also facilitate movement of feral grazing animals (i.e. cattle, donkey, buffalo), and the dispersal of Cane Toads.

If exotic species become established in the project area they will compete with native species of flora and fauna. In the case of the grassy weed species, especially Gamba Grass *Andropogon gayanus* and Mission Grasses *Pennisetum polystachion* and *P. pedicellatum* which are present along access routes to the project area, they can also create conditions for hot, intense fires that adversely impact on native vegetation and fauna. Cane Toads may cause a decline in numbers of some native fauna species that eat the Toad, or through competition for resources.

5.5.2. Management

The following management measures are recommended to minimise the introduction and spread of exotic plants and animals during project construction and operation:

19. Identify and treat existing weed infestations at the project area, along access routes and at borrow pits prior to construction activities.

20. Consult with the Department of Infrastructure, Planning and Environment - Weeds Branch to develop an exotic species management programme for construction and operation, incorporating the following elements:

    a. Inspections of vehicles, plant and equipment for Cane Toads prior to crossing the Daly River;
    b. wash-down and inspection of vehicles, plant and equipment prior to moving off main roads to remove weed propagules;
    c. Inspection of construction materials sourced outside the project lease area;
    d. Requirements for providers of construction materials to certify their 'weed free' status;
    e. Weed and exotic fauna awareness training and inductions, including Cane Toad recognition;
    f. A weed monitoring and treatment programme that commences immediately following construction and continues throughout the operation stage of the project;
    g. A Cane Toad reporting strategy.

21. Only use species native to the area in rehabilitation and landscaping.

22. Determine species suitability for use in consultation with experts in rehabilitation techniques in tropical environments.

23. Prohibit taking of domestic animals to the project area.

6. REFERENCES AND BIBLIOGRAPHY

Bach C., Price O., Shapcott A. & Palmer C. (1999) Fruit resources, frugivore movements and landscape scale conservation in monsoon rainforests of northern Australia. In: *Australian Wildlife Management Society Conference*, Darwin, Australia.

Barker J., Grigg G. & Tyler M. J. (1995) *A Field Guide to Australian Frogs*. Surrey Beatty & Sons, Chipping Norton, NSW.

Barrett G., Silcocks A., Barry S., Cunningham R. & Poulter R. (2003) *The New Atlas of Australian Birds*. Royal Australian Ornithologists Union, Hawthorn East, Vic.

Beggs, K. and Armstrong, M. (2001) *Threatened Species Information Sheet – Yellow-snouted Gecko* [online]. Available from: http://www.nt.gov.au/ipe/pwcnt/reptiles/yel_snout_gecko_vu.pdf [Accessed 20 April 2004].

Chatto, R. (2000) *Waterbird breeding colonies in the Top End of the Northern Territory*. NT Parks and Wildlife Commission, Palmerston. Technical Report No. 69.

Chatto, R. (2001) *The distribution and status of colonial breeding seabirds in the Northern Territory*. NT Parks and Wildlife Commission, Palmerston, Technical Report No. 70.

Chatto, R. (2003) *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. NT Parks and Wildlife Commission, Palmerston, Technical Report No. 73.

Chatto, R. 2004. Personal communication.

Cogger, H. (2000) *Reptiles & Amphibians of Australia*. Reed, NSW.

Cole, J. and Woinarski, W. (2002) *Field Guide to the Rodents and Dasyurids of the Northern Territory*. Surrey Beatty and Sons, NSW.

Connors G., Oliver B. & Woinarski J. (1996) *Bioregions in the Northern Territory*. Parks and Wildlife Commission Northern Territory, Palmerston.

Churchill, S. (1998) *Australian Bats*. Reed Books, Sydney.

Environment Australia, (2000) *Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the Development of Version 5.1. - Summary Report*. Department of Environment and Heritage, Canberra.

Fisher, A. 2003. Personal communication.

Ford, H.A., Barrett, G.W., Saunders, D.A. and Recher, H.F. (2001) Why have birds in the woodlands of Southern Australia declined? *Biological Conservation*, 97(1):71-88.

Frogwatch NT. Cane Toads [online]. Available from: http://www.frogwatch.org.au/canetoads /index.cfm [Accessed 14 May 2004].

Garnett S. & Crowley G. (2000) *The Action Plan for Australian Birds*. Environment Australia, Canberra.

Goosem M., Izumi Y. and Turton S. (2001) Efforts to restore habitat connectivity for an upland tropical rainforest fauna: a trial of underpasses below roads. *Ecological Management and Restoration*, 2(3): 196-202.

Harrington, G.N., Freeman and Crome, F.H.J. (2001) The effects of fragmentation of an Australian tropical rain forest on populations and assemblages of small mammals, *Journal of Tropical Ecology*, 17(2): 225-240.

Hobbs, R.J. (2001) Synergisms among Habitat Fragmentation, Livestock Grazing, and Biotic Invasions in Southwestern Australia, *Conservation Biology*, 15(6): 1522-1528.

Kozakiewicz M. (1993) Habitat isolation and ecological barriers – the effect on small mammal populations and communities. *Acta Theriol,* 38: 1-30.

Lewis, M. (2001) *Threatened species information sheet – Gouldian Finch* [online]. Available at: http://www.nt.gov.au/ipe/pwcnt/birds/gouldian_finch_en.pdf [Accessed 20 May 2004].

Marchant S. and Higgins P. J. (1993) *Handbook of Australia, New Zealand and Antarctic Birds. Vol 2. Raptors to Lapwings*. Oxford University Press.

McDonald W. and St. Claire C. (2003) The effects of artificial and natural barriers on the movement of small mammals in Banff National Park, Canada. *OIKOS*, 105: 397-407.

Parks and Wildlife Commission of the Northern Territory. (2001) *Guidelines for the retention of native vegetation in Top End woodlands.*

Pogonoski J. J., Pollard D. A. & Paxton J. R. (2002) *Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes*. Environment Australia, Canberra.

Price O., Bach C., Shapcott A. & Palmer C. (1998) Design of Reserves for Mobile Species in Monsoon Rainforests. Parks and Wildlife Commission of the Northern Territory, Darwin.

Price O., Woinarski J. & Robinson D. (1999) Very large area requirements for frugivorous birds in monsoon rainforests of the Northern Territory , Australia. *Biological Conservation* 91: 169-180.

Readers Digest (1997) *Complete Book of Australian Birds*. Readers Digest (Australia) Pty Ltd, Sydney.

Schodde R. & Mason I. J. (1975) Occurrence, nesting and affinities of the White-throated Grasswren *Amytornis woodwardi* and White-lined Honeyeater, *Meliphaga albilineata*. *Emu* 75: 12-18.

Stirrat, S. and Larson, H. (2002) *Threatened Species Information Sheet – Speartooth Shark* [online]. Available from: http://www.nt.gov.au/ipe/pwcnt/fish/speartooth_shark_en.pdf [Accessed 20 April 2004].

Strahan, R. (1995) *The Mammals of Australia.* Reed Books, NSW.

Whitehead P. & Chatto R. (1996) A Directory of Important Wetlands in Australia - Northern Territory. In: *A Directory of Important Wetlands in Australia* (ed. A. N. C. Agency). Australian Nature Conservation Agency, Canberra.

Wilson S. & Swan G. (2003) *A Complete Guide to Reptiles of Australia*. Reed New Holland, Sydney.

Woinarski J. C. Z. (1993) A Cut-and-paste Community: Birds of monsoon rainforests in Kakadu National Park, Northern Territory. *Emu* **93**: 100-120.

Woinarski J. C. Z. (2000) The conservation status of rodents in the monsoonal tropics of the Northern Territory. *Wildl. Res* 27: 421-435.

Woinarski, J. (2002a) *Compilation of individual summaries for the National Land and Water Resources Audit*. NT Parks and Wildlife Commission, Palmerston.

Woinarski, J. (2002b) *Threatened species information sheet – Yellow Chat (Alligator Rivers subspecies)* [online]. Available at: http://www.nt.gov.au/ipe/pwcnt/birds/yellow_chat_en.pdf [Accessed 20 May 2004].

Woinarski, J. (2002c) *Threatened species information sheet – Brush-tailed Tree Rat* [online]. Available at: http://www.nt.gov.au/ipe/pwcnt/mammals/brush_tailed_tree_rat_vu.pdf [Accessed 20 May 2004].

Woinarski J. C. Z., Armstrong M., Brennan K., Connors G., Milne D., McKenzie G. & Edwards K. (2000) A different fauna?: captures of vertebrates in a pipeline trench, compared with conventional survey techniques; and a consideration of mortality patterns in a pipeline trench. *Australian Zoologist* 31: 421-431.

Woinarski, J.C.Z., Brennan, K., Dee, A., Njudumul, J., Guthayguthay, P. and Horner, P. (2000) Further records of the False Water Rat *Xeromys myoides* from coastal Northern Territory. *Australian Mammalogy* 21:221-223.

Woinarski, J. Darwin-Kakadu – Plants and Animals [online]. Available from: http://savanna. ntu.edu.au/information/dk/dkpa.html [Accessed 14 May 2004].

Woinarski, J. 2004. Personal communication.

Appendix 1

Figures





Site 5A1 Eucalyptus woodland/forest



Site 5A2 Eucalyptus woodland/forest





Site 5B1 Monsoon vine forest north





Site 5B2 Monsoon vine forest south



Site 5C1 Eucalyptus Woodland



Site 5C2 Eucalyptus Woodland

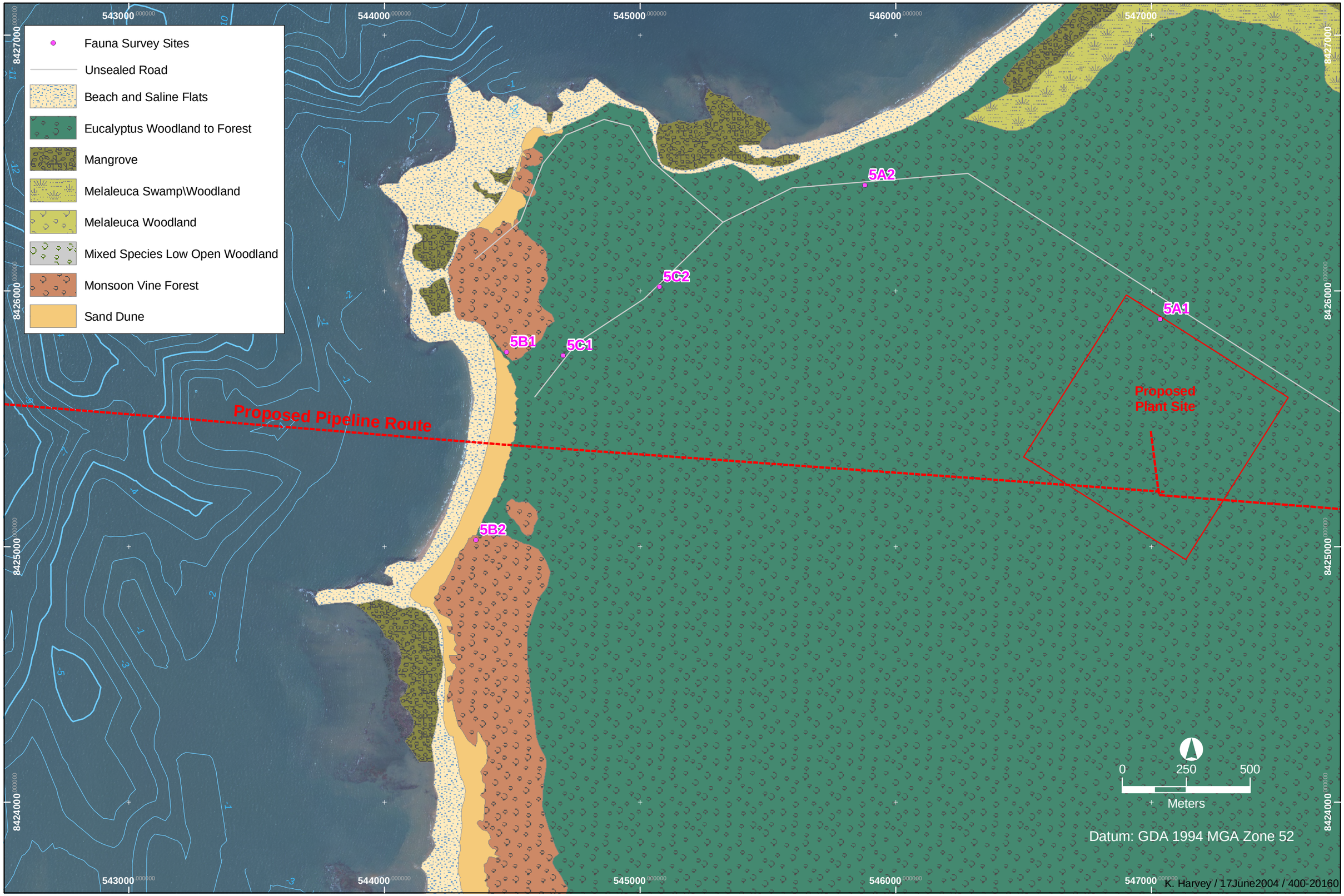


FIGURE 1: FAUNA HABITATS AND SURVEY SITES

WOODSIDE AUSTRALIAN ENERGY

Appendix 2

Results of fauna survey undertaken 2nd to 6th June 2004

Family	Common name	Scientific name	5A1	5A2	5B1	5B2	5C1	5C2
			Total	Total	Total	Total	Total	Total
Frogs								
MYOBATRACHIDAE	Marbled Frog	*Limnodynastes convexiusculus*		1				
MYOBATRACHIDAE	Ornate burrowing frog	*Limnodynastes ornatus*			9			1
Reptiles								
BOIDAE	Children's Python	*Antaresia childreni*		1				
COLUBRIDAE	Common Tree Snake	*Dendrelaphis punctulata*					1	
GEKKONIDAE	Gecko	*Gehyra australis*	1	1	1	1	2	3
GEKKONIDAE	Bynoe's gecko	*Heteronotia binoei*	2	5			1	2
SCINCIDAE	Skink	*Carlia munda*	4	5	5		16	7
SCINCIDAE	Skink	*Cryptoblepharus plagiocephalus*		2	1		5	2
SCINCIDAE	Skink	*Ctenotus essingtonii*	1		3		1	3
SCINCIDAE	Skink	*Menetia alanae*	3					
SCINCIDAE	Skink	*Morethia storri*						2
VARANIDAE	Spotted Tree Monitor	*Varanus scalaris*		1				
VARANIDAE	Yellow-spotted Monitor	*Varanus panoptes*			1			
Birds								
ACCIPITRIDAE	Brahminy Kite	*Haliastur indus*			1	1		
ACCIPITRIDAE	Whistling Kite	*Haliastur sphenurus*		1				
ACCIPITRIDAE	Osprey	*Pandion haliaetus*		1				
AEGOTHELIDAE	Australian Owlet-nightjar	*Aegotheles cristatus*	1					
ARTAMIDAE	Pied Butcherbird	*Cracticus nigrogularis*	5	1			2	4
ARTAMIDAE	White-breasted Woodswallow	*Artamus leucorhynchus*						2
CACATUIDAE	Red-tailed Black-cockatoo	*Calyptorhynchus banksii*		1			3	1
CACATUIDAE	Sulphur-crested Cockatoo	*Cacatua galerita*	1				1	1
CAMPEPHAGIDAE	Varied Triller	*Lalage leucomela*			1	4		
CAMPEPHAGIDAE	White-bellied Cuckoo-shrike	*Coracina papuensis*	3				1	2
CAMPEPHAGIDAE	White-winged Triller	*Lalage sueurii*			1			
CENTROPODIDAE	Pheasant Coucal	*Centropus phasianinus*					1	
COLUMBIDAE	Bar-shouldered Dove	*Geopelia humeralis*	1		2	6	4	6
COLUMBIDAE	Emerald Dove	*Chalcophaps indica*				1		
COLUMBIDAE	Rose-crowned Fruit-Dove	*Ptilinopus regina*				3		
CORVIDAE	Torresian Crow	*Corvus orru*		2			1	1
DICAEIDAE	Mistletoebird	*Dicaeum hirundinaceum*	2	1				2
DICRURIDAE	Leaden Flycatcher	*Myiagra rubecula*	1				1	
DICRURIDAE	Magpie-lark	*Grallina cyanoleuca*		2			3	
DICRURIDAE	Spangled Drongo	*Dicrurus bracteatus*	2		1	1	3	2
DICRURIDAE	Willie Wagtail	*Rhipidura leucophrys*						1
FALCONIDAE	Australian Hobby	*Falco longipennis*						1
HALCYONIDAE	Blue-winged Kookaburra	*Dacelo leachii*	1	1	3	1	2	
MELIPHAGIDAE	Bar-breasted Honeyeater	*Ramsayornis fasciatus*		2				
MELIPHAGIDAE	Blue-faced Honeyeater	*Entomyzon cyanotis*	1					
MELIPHAGIDAE	Brown Honeyeater	*Lichmera indistincta*	2	1			1	2

Family	Common name	Scientific name	5A1	5A2	5B1	5B2	5C1	5C2
			Total	Total	Total	Total	Total	Total
MELIPHAGIDAE	Helmeted Friarbird	*Philemon buceroides*		1		2		
MELIPHAGIDAE	Little Friarbird	*Philemon citreogularis*			1			
MELIPHAGIDAE	Silver-crowned Friarbird	*Philemon argenticeps*	3	4	1		3	3
MELIPHAGIDAE	White-throated Honeyeater	*Melithreptus albogularis*	4	4			5	5
MEROPIDAE	Rainbow Bee-eater	*Merops ornatus*	1	2			1	2
ORIOLIDAE	Olive-backed Oriole	*Oriolus sagittatus*			1	3		
ORIOLIDAE	Yellow Oriole	*Oriolus flavocinctus*				1		
PACHYCEPHALIDAE	Little Shrike-thrush	*Colluricincla megarhyncha*				1		
PACHYCEPHALIDAE	Rufous Whistler	*Pachycephala rufiventris*	2	1				
PARDALOTIDAE	Green-backed Gerygone	*Gerygone chloronota*			1	3		
PARDALOTIDAE	Striated Pardalote	*Pardalotus striatus*	6	3			4	4
PARDALOTIDAE	Weebill	*Smicrornis brevirostris*	2					
PODARGIDAE	Tawny Frogmouth	*Podargus strigoides*	1	1				
POMATOSTOMIDAE	Grey-crowned Babbler	*Pomatostomus temporalis*	1				6	1
PSITTACIDAE	Northern Rosella	*Platycercus venustus*	2				1	
PSITTACIDAE	Rainbow Lorikeet	*Trichoglossus haematodus*	7	1		2		
PSITTACIDAE	Red-winged Parrot	*Aprosmictus erythropterus*	2		1			
PTILONORHYNCHIDAE	Great Bowerbird	*Chlamydera nuchalis*			1			
STRIGIDAE	Barking Owl	*Ninox connivens*	1					
STRIGIDAE	Southern Boobook	*Ninox novaeseelandiae*	1					
Mammals								
MACROPODIDAE	Agile wallaby	*Macropus agilis*			3	2	2	4

Floral species on survey sites

Family name	Species name	Common name	5A1	5A2	5B1	5B2	5C1	5C2
Dominant								
ACANTHACEAE	*Hypoestes floribunda*				G			
ANACARDIACEAE	*Buchanania obovata*	Green Plum	M	M/G			G	
ARECACEAE	*Livistona humilis*	Sand Palm	M				M	M
BOMBACACEAE	*Bombax ceiba*					G		
CAESALPINIACEAE	*Erythrophleum chlorostachys*	Ironwood	G				U/G	U/G
CAESALPINIACEAE	*Tamarindus indicus*	Tamarind			U	U		
COMBRETACEAE	*Terminalia ferdinandiana*	Billy-goat Plum	M	M	M		M	M/G
CYCADACEAE	*Cycas maconochiei*		M	M			M	M
EUPHORBIACEAE	*Petalostigma pubescens*	Quinine Tree	M					
LECYTHIDACEAE	*Planchonia careya*	Cocky Apple	M	M/G			M/G	G
LOGANIACEAE	*Strychnos lucida*	Strychnine Tree			M	M		
MALVACEAE	*Hibiscus tiliaceus*				M			
MIMOSACEAE	*Acacia difficilis*				M			
MIMOSACEAE	*Acacia dimidiata*		M					
MORACEAE	*Ficus aculeata*	Sandpaper Fig					M	
MYRTACEAE	*Corymbia confertiflora*	Broad-leaved Carbeen			M		M	M
MYRTACEAE	*Corymbia porrecta*	Grey Bloodwood	U/M	U			U	
MYRTACEAE	*Eucalyptus miniata*	Darwin Woollybutt	U	U			U	U
MYRTACEAE	*Eucalyptus spp (seedlings)*		G	G			G	G
MYRTACEAE	*Eucalyptus tetrodonta*	Darwin Stringybark	U	U			U	U
OPILIACEAE	*Opilia amentacea*							G
POACEAE	*Cymbopogon bombycinus*				G			
POACEAE	*Cymbopogon sp.*							G
POACEAE	*Eragrostis cumingii*				G			
POACEAE	*Eriachne triseta*				G			
POACEAE	*Heteropogon triticeus*		G	G			G	G
POACEAE	*Sarga sp.*		G	G			G	G
POACEAE	*Setaria apiculata*		G				G	G
POACEAE	*Themeda triandra*	Kangaroo Grass						
PROTEACEAE	*Grevillea decurrens*		M	M			M	
PROTEACEAE	*Grevillea goodii*		M					
PROTEACEAE	*Persoonia falcata*		G					M
RHAMNACEAE	*Alphitonia excelsa*	Milkwood						G
RUBIACEAE	*Spermacoce sp.*							G
SANTALACEAE	*Exocarpos latifolius*				M	M		
STERCULIACEAE	*Brachychiton diversifolius*	Kurrajong		M		M	G	M/G
STERCULIACEAE	*Brachychiton megaphyllus*	Large-leaved Kurrajong						G
STERCULIACEAE	*Brachychiton paradoxus*	Red-flowered Kurrajong					G	G
VERBENACEAE	*Vitex glabrata*						M	
Other sub-dominant species								
ACANTHACEAE	*Dicliptera ciliata*						G	
AMARANTHACEAE	*Gomphrena sp.*				G			
ANACARDIACEAE	*Buchanania obovata*	Green Plum						M
ANNONACEAE	*Polyalthia nitidissina*					M		
APOCYNACEAE	*Alstonia spectabilis*					M		
APOCYNACEAE	*Wrightia pubescens*				M			
ARECACEAE	*Livistona humilis*	Sand Palm		M				
ASTERACEAE	*Blumea saxatilis*						G	
BURSERACEAE	*Canarium australianum*	Melville Is White Beech					M	
CAPPARACEAE	*Capparis umbonata*	Wild Orange		M				M

Family name	Species name	Common name	5A1	5A2	5B1	5B2	5C1	5C2
CELASTRACEAE	*Denhamia obscura*						M	M
COMBRETACEAE	*Terminalia canescens*	Winged Nut Tree		U				
COMBRETACEAE	*Terminalia pterocarya*			U				
CONVOLVULACEAE	*Jacquemontia paniculata*				G			
DILLENIACEAE	*Hibbertia muelleri*		G					
DILLENIACEAE	*Pachynema sphenandrum*			M				
EUPHORBIACEAE	*Drypetes deplanchei*				M	M		
EUPHORBIACEAE	*Mallotus nesophilus*				M			
FABACEAE	*Abrus precatorius*	Crab-eye Vine			G			
FABACEAE	*Desmodium pullenii*			G				
FABACEAE	*Flemingia sp.*							G
FABACEAE	*Indigofera saxicola*		G					
FABACEAE	*Milletia pinnata*				M			
FABACEAE	*Plagiocarpus axillaris*		5A1					
FLAGELLARIACEAE	*Flagellaria indica*					M		
GOODENIACEAE	*Goodenia sp.*						G	
LAMIACEAE	*Anisomeles malabarica*						M	
LAURACEAE	*Litsea glutinosa*				M			
LAURACEAE	*Neolitsea brassii*					M		
LILIACEAE	*Protasparagus racemosa*	Asparagus Fern			M			
LORANTHACEAE	*Amyema sanguinea var. pulchra*	Mistletoe		U/M				
MIMOSACEAE	*Acacia lamprocarpa*			M				M
MIMOSACEAE	*Acacia sp.*			M				
MORACEAE	*Ficus aculeata*	Sandpaper Fig						M
MYRISTICACEAE	*Myristica insipida*					M		
OLEACEAE	*Jasminum molle*	Native Jasmine			M			
OPILIACEAE	*Cansjera leptostachya*					M		
OPILIACEAE	*Opilia amentacea*					M		
ORCHIDACEAE	*Dendrobium affine*	Orchid					U	U
PANDANACEAE	*Pandanus spiralis*	Screw Palm						G
PLUMBAGINACEAE	*Plumbago zeylanica*					M		
POACEAE	*Cymbopogon sp.*							G
POACEAE	*Panicum sp.*						G	
POACEAE	*Sarga plumosum*	Perennial sorghum					M	
POACEAE	*Sarga timorense*	Annual sorghum	G					
POACEAE	*Themeda triandra*	Kangaroo Grass					M	
RUBIACEAE	*Gardenia megasperma*	Gardenia		M			M	M
RUBIACEAE	*Ixora timorensis*					M		
RUBIACEAE	*Timonius timon*					M		
RUTACEAE	*Glycosmis trifoliata*					M		
RUTACEAE	*Micromelum minutum*					M		
SAPINDACEAE	*Distichostemon hispidulus*		M					
SCROPHULARIACEAE	*Buchnera linearis*		G	G				
STERCULIACEAE	*Waltheria indica*		G					
TILIACEAE	*Grewia breviflora*				M	M		
TILIACEAE	*Grewia oxyphylla*				M			
TILIACEAE	*Grewia retusifolia*							M
TILIACEAE	*Triumfetta sp.*				M			
ULMACEAE	*Celtis philippensis*					G		
VERBENACEAE	*Premna acuminata*				M			
VERBENACEAE	*Vitex glabrata*						M	
VITACEAE	*Cissus reniformis*						M	
XANTHORRHOEACEAE	*Lomandra tropica*		G					

U = Upper storey M = Middle storey G = ground and climbing & scrambling species

Appendix 3

List of vertebrate fauna species recorded from the project area and region

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
AMPHIBIANS						
Bilingual Froglet *Crinia bilingua*				✓		
Marbled Frog *Limnodynastes convexiusculus*			✓			
Ornate burrowing frog *Limnodynastes ornatus*			✓			
Northern Dwarf Tree-frog *Litoria bicolor*				✓		
Copland's Rock Frog *Litoria coplandi*				✓		
Rockhole Frog *Litoria meiriana*				✓		
Rocket Frog *Litoria nasuta*				✓		
Pale Frog *Litoria pallida*				✓		
Roth's Tree-frog *Litoria rothii*				✓		
Uperoleia sp. (inornatus?)			✓			
REPTILES						
Family Agamidae						
Two-lined Dragon *Diporiphora bilineata*				✓		
Northern Water Dragon *Lophognathus temporalis*				✓		
Family Boidae						
Children's Python *Antaresia childreni*			✓			
Family Colubridae						
Common Tree Snake *Dendrelaphis punctulata*			✓			
White-Bellied Mangrove Snake *Fordonia leucobalia*				✓		
Slaty-Grey Snake *Stegonotus cucullatus*				✓		
Keelback *Tropidonophis mairii*				✓		
Family Crocodylidae						
Saltwater Crocodile *Crocodylus porosus*		Migratory			✓	
Family Elapidae						

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Olive Whip Snake *Demansia olivacea*				✓		
Orange-naped snake *Furina ornata*				✓		
Family Gekkonidae						
Diplodactylus immaculatus				✓		
HouseGecko *Gehyra australis*			✓	✓		
Bynoe's Gecko *Heteronotia binoei*			✓	✓		
Family Pygopodidae						
Burton's Legless Lizard *Lialis burtonis*				✓		
Family Scincidae						
Slender Rainbow Skink *Carlia gracilis*				✓		
Robust Rainbow Skink *C. longipes*				✓		
Skink *Carlia munda*			✓			
Three-spined Rainbow Skink *C. triacantha*				✓		
Arboreal Snake-eyed Skink *Cryptoblepharus plagiocephalus*			✓	✓		
Northern Ctenotus *Ctenotus borealis*				✓		
Skink *Ctenotus essingtonii*			✓			
Douglas' Skink *Glaphyromorphus douglasi*				✓		
Dark-tailed Skink *G. nigricaudis*				✓		
Skink *Menetia alanae*			✓			
Storr's Snake-Eyed Skink *Morethia storri*			✓	✓		
Family Varanidae						
Sand Goanna *Varanus gouldii*				✓		
Mitchell's Water Monitor *V. mitchelli*				✓		
Yellow-spotted Monitor *Varanus panoptes*			✓			
Spotted Tree Monitor *V. scalaris*			✓	✓		
Black-headed Monitor *V. tristis*				✓		
BIRDS						
Family Anatidae						

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Grey Teal *Anas gracilis*				✓		
Family Accipitridae						
Letter Winged Kite *Elanus scriptus*				✓		
Red Goshawk *Erythrotriorchis radiatus*	Vulnerable	Vulnerable			✓	
Brahminy Kite *Haliastur indus*			✓			
Whistling Kite *Haliastur sphenurus*			✓	✓		
White-bellied Sea-Eagle *Haliaeetus leucogaster*		Migratory			✓	
Osprey *Pandion haliaetus*			✓			
Black Kite *Milvus migrans*				✓		
Family Ardeidae						
Great Egret *Ardea alba*						Chatto (2000)
Little Egret *A. garzetta*						Chatto (2000)
Cattle Egret *A. ibis*						Chatto (2000)
Pied Heron *A. picata*						Chatto (2000)
Nankeen Night Heron *Nycticorax caledonicus*						Chatto (2000)
Family Artamidae						
Black-faced Woodswallow *Artamus cinereus*				✓		
White Breasted Woodswallow *A. leucorynchus*				✓		
Little Woodswallow *A. minor*				✓		
Pied Butcher-bird Cracticus nigrogularis			✓			
Family Burhinidae						
Beach Thick-knee *Esacus magnirostris*						Chatto (2000)
Family Cacatuidae						
Sulphur-crested Cockatoo *Cacatua galerita*			✓	✓		
Galah *Eolophus roseicapilla*				✓		
Red-tailed Black Cockatoo *Calyptorhynchus banksii*			✓	✓		
Family Campephagidae						
Melville Cicadabird *Coracina tenuirostris melvillensis*		Migratory			✓	

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Black-faced Cuckoo-shrike *C. novaehollandiae*				✓		
White-bellied Cuckoo-shrike *C. papuensis*			✓	✓		
White-winged Triller *Lalage sueurii*			✓			
Varied Triller *Lalage leucomela*			✓	✓		
Family Campephagidae						
Pheasant Coucal *Centropus phasianinus*			✓			
Family Charadriidae						
Greater Sand Plover *Charadrius leschenaultii*						Chatto (2003)
Lesser Sand Plover *C. mongolus*						Chatto (2003)
Red-capped Plover *C. ruficapillus*						Chatto (2003)
Oriental Plover *C. veredus*		Migratory			✓	Chatto (2003)
Grey Plover *Pluvialis squatarola*						Chatto (2003)
Masked Lapwing *Vanellus miles miles*				✓		
Family Columbidae						
Emerald Dove *Chalcophaps indica*			✓	✓		
Bar-shouldered Dove *Geopelia humeralis*			✓	✓		
Peaceful Dove *G. striata*				✓		
Rose-crowned Fruit-Dove *Ptilinopus regina*			✓			
Family Corvidae						
Torresian Crow *Corvus orru*			✓	✓		
Family Cracticidae						
Pied Butcherbird *Cracticus nigogularis*				✓		
Family Cuculidae						
Common Koel *Eudynamys scolopacea*				✓		
Family Dicaeidae						
Mistletoebird *Dicaeum hirundinaceum*			✓	✓		
Family Dicruridae						
Spangled Drongo *Dicrurus bracteatus*			✓	✓		

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Leaden Flycatcher *Myiagra rubecula*			✓			
Magpie-lark *Grallina cyanoleuca*			✓			
Willie Wagtail *Rhipidura leucophrys*			✓			
Family Epthianuridae						
Yellow Chat *Epthianura crocea tunneyi*	Endangered					
Family Falconidae						
Nankeen Kestrel *Falco cenchroides*				✓		
Australian Hobby Falco longipennis			✓			
Family Glareolidae						
Oriental Pratincole *Glareola maldivarum*		Migratory			✓	
Family Grallinidae						
Magpie lark *Grallina cyanoleuca*				✓		
Family Gruidae						
Brolga *Grus rubicunda*				✓		
Family Haematopodidae						
Pied Oystercatcher *Haematopus longirostris*						Chatto (2000)
Family Halcyonidae						
Blue-winged Kookaburra *Dacelo leachii*			✓	✓		
Collared Kingfisher *Todiramphus chloris*				✓		
Red-backed Kingfisher *T. pyrrhopygia*				✓		
Family Hirundinidae						
Tree Martin *Hirundo nigricans*				✓		
Barn Swallow *H. rustica*		Migratory			✓	
Family Laridae						
Little Tern *Sterna albifrons*						Chatto (2001)
Family Meliphagidae						
Rufous-banded Honeyeater *Conopophila albogularis*				✓		
Rufous-throated Honeyeater *Conopophila rufogularis*				✓		

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Blue-Faced Honeyeater *Entomyzon cyanotis*			✓	✓		
White-gaped Honeyeater *Lichenostomus unicolor*				✓		
Brown Honeyeater *Lichmera indistineta*			✓	✓		
White-throated Honeyeater *Melithreptus albogularis*			✓	✓		
Red-headed Honeyeater *Myzomela erythrocephala*				✓		
Dusky Honeyeater *M. obscura*				✓		
Silver-crowned Friarbird *Philemon argenticeps*				✓		
Helmeted Friarbird *Philemon buceroides*			✓			
Little Friarbird *P. citreogularis*				✓		
Bar-breasted Honeyeater *Ramsayornis fasciatus*			✓			
Family Meropidae						
Rainbow bee-eater *Merops ornatus*			✓	✓		
Family Muscicapidae						
Lemon Bellied Flycatcher *Microeca flavigaster*				✓		
Shining Flycatcher *Myiagra alecto*				✓		
Rufous Fantail *Rhipidura rufifrons*		Migratory			✓	
Northern Fantail *R. rufiventris*				✓		
Family Oriolidae						
Yellow Oriole *Oriolus flavocinctus*			✓	✓		
Olive-backed Oriole *Oriolus sagittatus*			✓			
Family Pachycephalidae						
Little Shrike-thrush *Colluricincla megarhyncha*			✓			
Rufous Whistler *Pachycephala rufiventris*			✓	✓		
Grey Whistler *P. simplex*				✓		
Family Pardalotidae						
Striated Pardalote *Pardalotus striatus*			✓	✓		
Weebill *Smicrornis brevirostris*			✓	✓		
Green-backed Gerygone *Gerygone chloronota*			✓	✓		

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Mangrove Gerygone *G. levigaster*				✓		
Large Billed Gerygone *G. magnirostris*				✓		
Family Phalacrocoraxidae						
Little Pied Cormorant *Phalacrocorax melanoleucos*				✓		Chatto (2000)
Little Black Cormorant *P. sulcirostris*				✓		Chatto (2000)
Family Podargidae						
Tawny Frogmouth *Podargus strigoides*			✓			
Family Pomatostomidae						
Grey-crowned Babbler *Pomatostomus temporalis*			✓			
Family Psittacidae						
Red-winged Parrot *Aprosmictus erythropterus*			✓			
Northern Rosella *Platycercus venustus*			✓			
Varied Lorikeet *Psitteuteles versicolor*						
Rainbow Lorikeet *Trichoglossus haematodus*			✓	✓		
Family Ptilonorhynchidae						
Great Bowerbird *Chlamydera nuchalis*			✓	✓		
Family Scolopacidae						
Common Sandpiper *Actitis hypoleucos*				✓		
Ruddy Turnstone *Arenaria interpres*						Chatto (2003)
Sharp-tailed Sandpiper *Calidris acuminata*						Chatto (2003)
Sanderling *C. alba*						Chatto (2003)
Red Knot *C. canutus*						Chatto (2003)
Great Knot *C. tenuirostris*						Chatto (2003)
Red-necked Stint *C. ruficollis*						Chatto (2003)
Bar-tailed godwit *Limosa lapponica*						Chatto (2003)
Black-tailed godwit *L. limosa*						Chatto (2003)
Little Curlew *Numenius minutus*		Migratory			✓	
Whimbrel *N. phaeopus*				✓		Chatto (2003)

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
Eastern Curlew *N. madagascariensis*						Chatto (2003)
Grey-tailed tattler *Tringa brevipes*						Chatto (2003)
Common Greenshank *T. nebularia*				✓		Chatto (2003)
Marsh Sandpiper *T. stagnatilis*						Chatto (2003)
Terek Sandpiper *Xenus cinereus*						Chatto (2003)
Family Strigidae						
Barking Owl *Ninox connivens*			✓			
Southern Boobook *Ninox novaeseelandiae*			✓	✓		
Family Sylviidae						
Goldern Headed Cisticola *Cisticola exilis*				✓		
Family Threskiornithidae						
Royal Spoonbill *Platalea regia*						Chatto (2000)
Australian White Ibis *Threskiomis molucca*				✓		Chatto (2000)
Straw-necked Ibis *T. spinicollis*				✓		
Family Zosteropidae						
Yellow White-eye *Zosterops luteus*				✓		
MAMMALS						
Family Macropodidae						
Agile wallaby *Macropus agilis*			✓			
Family Muridae						
Brush-tailed Tree-Rat *Conilurus penicillatus*	Vulnerable			✓		Parks and Wildlife Commission pers. comm
Delicate Mouse *Pseudomys delicatulus*				✓		
False Water Rat *Xeromys myoides*	Near Threatened	Vulnerable			✓	
Family Phalangeridae						
Northern Brushtail Possum *Trichosurus vulpecula arnhemensis*				✓		
Family Pteropodiae						
Black Flying Fox *Pteropus alecto*				✓		

Species	Conservation status		Data source			
	NT	Comm	Field surveys	NT Fauna Atlas	EPBC Act Report	Other
FISHES						
Freshwater Sawfish *Pristis microdon*	VUL	DD			✓	

Appendix I

Environmental Impact Statement for the Proposed Blacktip Gas Project Archaeology and Historic Heritage prepared by Begnaze






This page has been left intentionally blank

Environmental Impact Statement for proposed Blacktip Gas Project

Archaeology and Historic Heritage

Prepared for: EcOz Environmental Services

Prepared by: Begnaze Pty. Ltd.

Begnaze Pty. Ltd.
ABN 16 050 796 131

8 Wanguri Tce, Wanguri NT 0810
Phone: (08) 8927 5019
Fax: (08) 8984 4626

Begnaze Pty. Ltd.
ABN 16 050 796 131

8 Wanguri Tce, Wanguri NT 0810
Phone: (08) 8927 5019
Fax: (08) 8984 4626

Environmental Impact Statement for proposed Blacktip Gas Project

Archaeology and Historic Heritage

Prepared for: EcOz Environmental Services

Prepared by: Begnaze Pty. Ltd.

DOCUMENT CONTROL:

Project number:	Wood0303
File ref:	Z:\OldServer\Documents\ecoz_projects\WOOD0303 - Blacktip\05 Archaeological and cultural heritage\Reports\Final\Blacktip Archaeology and Historic Heritage vFinal .doc
Report by:	Christine Crassweller
Reviewed by:	Noel Preece (EcOz Environmental Services)
Date:	17th June 2004
Document distribution:	Ceri Morgan

Disclaimer:
This study, report and analyses have been based on the information available to Begnaze and EcOz at the time of the study. We take responsibility for the report and its conclusions to the extent that the information was sufficient. Begnaze and EcOz do not take responsibility for errors or omissions due to information not available to us at the time of the study.

EXECUTIVE SUMMARY

The consultant was engaged by EcOz Environmental Services to identify any archaeological and historic sites that may be impacted upon by the proposed development of the Blacktip Gas Plant and on-shore pipeline near Wadeye, Northern Territory. The report includes a description of the findings, and recommendations are made for the mitigation of any archaeological or historic sites that may be disturbed during the design, construction and operational phases of the project.

Background research was carried out to find any previously recorded archaeological and heritage sites in the area of the proposed development and in 2003 archaeological surveys were carried out over the areas that will be disturbed by the development. The surveys consisted of pedestrian transects over the Blacktip gas plant area and pedestrian and vehicle transects along the proposed pipeline alignment.

No previously recorded archaeological or heritage sites were identified in the project area. One archaeological site, Shell Midden 1, was located during the field survey. This site will be disturbed during the construction of the on-shore pipeline. No archaeological or historic sites or objects were located in the vicinity of the proposed Blacktip Gas Plant.

There are three recommendations for ensuring the protection of unidentified archaeological material during the construction stage of the on-shore pipeline. Firstly, an archaeologist should be present during the flagging of the pipeline alignment from the seabed to the proposed gas plant and full survey of the construction corridor should be undertaken. Secondly, before areas are selected for access roads, borrow pits etc, it is recommended that the predictive model developed in this report for the location and frequency of archaeological sites is used to avoid areas that have a high probability for the presence of archaeological sites, and all sites chosen should be surveyed by an archaeologist. Thirdly, it is possible that during the construction stage of both the on-shore pipeline and the gas plant subsurface archaeological material may be located. It is recommended that response mechanisms are set up to ensure that this material is protected.

As Shell Midden 1 has been attributed a high level of archaeological significance, the following mitigation procedures are recommended:

Design stage.

- *The pipeline should be located so that it leaves the seabed in the northern section of the beach so that it crosses the sand dunes at approximately 8425488N.*

- *The site should be formally recorded and described in detail by an archaeologist prior to any works being undertaken.*

Construction stage.

- *Permission is obtained from the Heritage Conservation Services NT to disturb the site only after a thorough recording of the site has been completed.*

- *The boundary of the pipeline alignment through the dune and midden site is fenced and no activity occurs outside this area.*

Operational stage.

- *The sides of the sand dune on either side of the pipeline are stabilised so that no further damage occurs through erosion.*

- *All appropriate personnel are notified of the site's location and all operations occur within the pipeline's boundary fences.*

TABLE OF CONTENTS

1. INTRODUCTION 1

2. HERITAGE LEGISLATIVE FRAMEWORK 2

2.1. Northern Territory legislation 2

2.1.1. Declared heritage places and objects. 2
2.1.2. Prescribed archaeological places and objects. 2

2.2. Commonwealth legislation 2

2.2.1. Register of the National Estate 3
2.2.2. National Heritage List 3

3. ENVIRONMENTAL SETTING 4

3.1. Moyle Land System 4

3.2. Littoral Land System 4

3.3. Possible influences of environmental factors on locating archaeological material 4

4. CULTURAL SETTING 6

4.1. Ethnographic background 6

4.2. Historic record 6

4.3. Archaeological background 7

4.4. Possible cultural factors influencing the presence of archaeological or historic material 8

5. METHODOLOGY 9

5.1. Preliminary survey 2003 9

5.2. Survey procedures 9

5.2.1. Blacktip Gas Plant survey 10
5.2.2. Onshore pipeline survey 10
5.2.3. Types of archaeological sites 11
5.2.4. Site definition 11
5.2.5. Artefact identification 12
5.2.6. Assessment of significance and heritage management principles 12

6. RESULTS 14

6.1. Summary 14

6.2. Sites of heritage significance 14

6.2.1. Register of National Estate 14
6.2.2. Sites recorded on Commonwealth and/or NT Heritage Registers 14
6.2.3. Macassan sites and Aboriginal and ATSI archaeological and heritage places and objects . 14
6.2.4. European historic sites 15

6.3. Blacktip Gas Plant survey 15

6.4. On-shore pipeline survey 15

6.4.1. Relationship to proposed development 17

6.5. Assessment of heritage significance 17

7. POTENTIAL PROJECT IMPACTS 19
7.1. Design phase 19
7.2. Construction phase 19
7.3. Operational phase 19
8. RECOMMENDATIONS 20
8.1. Design phase 20
8.2. Construction phase 20
8.3. Operational phase 21
9. REFERENCES\BIBLIOGRAPHY 22

TABLES

Table 1 Site status on the Northern Territory Heritage Register database.
Table 2 Site status on the Register of the National Estate database.
Table 3 The co-ordinates of the four corners of the gas plant site.
Table 4 Location of pedestrian transect made between the gas plant site and the coast.
Table 5 Location of vehicular transects made between the gas plant site and the coast.
Table 6 Details of pedestrian transects made between the gas plant site and the coast.

FIGURES

Figure 1 Location of archaeological site, Shell Midden 1.
Figure 2 Sketch map of Shell Midden 1.

APPENDICES

Appendix 1 Plates referred to in text.

1. INTRODUCTION

This report describes the archaeological component of an environmental assessment for the proposed Blacktip Project that is located west of the town of Wadeye. As part of the environmental assessment a preliminary survey was carried out to define a suitable plant site near Wadeye and a 100 metre wide pipeline corridor from the plant to the coast, a distance of approximately 2kms. Included in this report are the findings of archaeological surveys made over the above areas, and assessments of any sites identified from previous archaeological research that may be impacted upon by the development.

To ensure that archaeological and historic sites and objects are not damaged or destroyed during the proposed development and are protected within the terms of the *NT Heritage Conservation Act 1991*, the aims of the archaeological and cultural heritage project are:

1. To develop a predictive model of the distribution of archaeological places and objects to guide the archaeological survey strategy for the on-shore gas plant and pipeline route.
2. To locate and record archaeological and historic objects or places.
3. To assess the nature, distribution and cultural significance of the materials within a regional, Territory and national context.
4. To provide recommendations for the management of particular archaeological or historic places or objects.
5. To provide recommendations for generalised mitigation procedures and management of prescribed archaeological places and objects.
6. To carry out mitigation and conservation strategies designed to minimise loss of heritage values to the Northern Territory.

This report is only a preliminary assessment as the archaeological survey was carried out prior to finalisation of the site layout. The aim for the 2003 survey team was to identify a 100 metre wide pipeline corridor within the already identified 10 kilometre wide corridor, and a location for the gas plant that is acceptable from the view of the potential impacts of the project on archaeological and historic heritage. Consequently the area surveyed by the archaeological team did not cover the entire project footprint.

2. HERITAGE LEGISLATIVE FRAMEWORK

2.1. Northern Territory legislation

There are two kinds of heritage sites protected under the *NT Heritage Conservation Act (1991)* that places legal constraints on owners of private property, local government and the Crown. These are:

- places or objects listed on the Northern Territory Heritage Register are declared heritage places and objects that are protected under section 33 of the Act; and
- prescribed archaeological places and objects that are protected under sections 29 and 39 of the Act.

It is an offence under the Act to damage, destroy, alter or carry out work of any sort on declared or prescribed sites without the written consent of the Minister or Minister's delegate.

2.1.1. Declared heritage places and objects.

To date there have been more than three hundred nominations to the Northern Territory Heritage Register, leading to the registration of more than 150 places. Categories which describe the status of each site on the Northern Territory Heritage Register database are listed in Table 1.

Table 1 Site status on the Northern Territory Heritage Register database.

Status	Description
D	Declared heritage place.
NR	Not recommended. HAC* determined that the place did not meet heritage assessment criteria and did not hold sufficient value to warrant declaration under the act.
RF	Refused by the Minister. HAC* recommended for declaration and minister refused to do so.
P	Proposed. HAC* has determined that the place warrants declaration under the Act but has not yet made its recommendations to the minister.
RV	Revoked. Declaration as a heritage place pursuant to Section 26(1) of the Act is revoked.
N	Nominated. HAC* has yet to complete its assessment of the heritage value of the place.

*Heritage Advisory Council

The Northern Territory Heritage Register contains places which have been recognized for a wide range of natural and cultural values. As a result it includes places specifically recognized as significant owing to their environmental characteristics (e.g. Alcoota Fossil Beds) and prehistoric sites (e.g. N'dhala Gorge). For the purposes of the current report, only places of historic or archaeological significance have been included.

2.1.2. Prescribed archaeological places and objects.

The NT Heritage Conservation Services, Department of Infrastructure Planning and Environment (DIPE) holds the Archaeological Sites Register. Listing on this register does not necessarily mean that a site is protected or holds legal significance under the *NT Heritage Conservation Act 1991*. Included in this register are the protected prescribed sites that consist of all archaeological sites and objects pertaining to the past occupation by Aboriginal or Macassan people.

2.2. Commonwealth legislation

The Commonwealth Government protects heritage sites under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Environment and Heritage Legislation Amendment Act (No 1) 2003*. There are two lists of protected heritage sites that may be relevant to this study. The lists are available on the internet at http://www.deh.gov.au and they are:

- *The Register of the National Estate* which consists of "…an inventory of places in Australia with aesthetic, historic, scientific, or social significance or other special value for present and future generations" (Pearson and Sullivan 1995:45). It represents a national database of places with significant Aboriginal, historic or environmental values.

- *The National Heritage List* that protects places of exceptional natural and cultural significance with penalties for any breaches. Approval by the Minister of Environment and Heritage is needed before any sites are disturbed.

2.2.1. Register of the National Estate

The Register of the National Estate database contains not only places that are registered but also places that have been nominated to the register and are yet to be assessed, as well as nominated places which have been rejected or removed from the Register of the National Estate (Table 2). Sites are divided into places of historic, Aboriginal or environmental significance. A total of 290 places of historic significance are listed on the Register of the National Estate database for the Northern Territory, of which approximately 150 are registered (February 2004). The entry of a place on the Register of the National Estate does not place any direct legal constraints or control over the actions of state or local government or private owners, but does impose other legal obligations.

Table 2 Site status on the Register of the National Estate database.

Status	Description
R	*Registered.* The place is listed on the Register of the National Estate.
ID	*Identified.* The Commission has formally considered the values of this place and decided that it should be publicly proposed for entry in the Register. The place is awaiting publication in the gazette and the press to give full effect to this decision.
RE	Removed from the Register or Interim List. The place has been removed from the Register or list via a public process that provides for the submission of objections.
IL	*Interim list.* The place has been publicly proposed for entry in the Register and the AHC may be awaiting objections, considering objections, or seeking other data before making a decision on whether the place should be entered on the Register proper.
IP	*Indicative place.* Data provided to or obtained by the Commission has been entered into the database and the place is at some stage in the assessment process. The AHC has not made a decision on whether the place should be entered into the Register.
D	*Destroyed.* The place has been destroyed before being assessed or listed.
REJ	*Rejected*. The AHC has assessed the place and found that it does not warrant entry in the Register in its own right.

While the database is large, relatively comprehensive and national in focus, individual site listings vary enormously in terms of the amount and the accuracy of information contained with them. Some site listings contain no information other than a site name and approximate location, while other listings contain inaccurate information or represent duplicate listings. Only places of historic or archaeological significance have been included in this current report.

2.2.2. National Heritage List

This list commenced on 1st January 2004, and as at April 2004 there were only two heritage or Indigenous sites recorded in the Northern Territory (being Kakadu National Park and Uluru-Katatjuta National Park). This will probably change as the Australian Heritage Council enters more sites onto the list.

3. ENVIRONMENTAL SETTING

There have been several archaeological studies in the Top End that have used environmental and archaeological data to predict the type and distribution of sites using factors such as climate, landforms geology, soils and vegetation. (Hiscock and Mitchell 1992, Hughes and Baker 1983, Heritage Surveys 1997, Gregory 1998, Guse 2001, Thorley 2002). The environmental setting of the onshore project area is described in this section along with a discussion of the implications for the distribution and visibility of archaeological and heritage sites.

The region is under the influence of the northwest monsoons, with a summer wet season and a dry winter from May to October. In the Wadeye area the average rainfall is approximately 1210 mm, most of which falls in the months of January and February (Aldrich et al. 1977). This can lead to severe flooding of the lowland areas around rivers and creeks during this period. In the dry season smaller creeks in the region are dry while others may have become a series of billabongs.

The area around the proposed gas plant lies on part of the tectonic unit of the Bonaparte Gulf Basin, which is a deep structural and sedimentary basin containing thick Palaeozoic and Mesozoic sediments. Overlaying the basin is the Cambridge Gulf Lowlands that form the Western Plains geomorphological region, a coastal strip up to 55 kilometres wide (Wilson et al. 1990, Morgan 1972). Within approximately 20 kilometres of the proposed gas plant there are outcrops of the Permian Port Keats Group that consist of siltstone, silty sandstone, mica, limestone and basal conglomerate (Morgan 1972).

The proposed gas plant and the majority of the on-shore pipeline are located on the Moyle Land System. The section of the pipeline that crosses the coast is located on the Littoral Land System. A brief description of each of these is provided below.

3.1. Moyle Land System

The Moyle Land system consists of gently undulating plains and sandy/laterised soils and occasional isolated mesa-like hills of the Mullaman Land System. The geology consists of sandstones, limestones and shales. The area is drained by small mature creeks with their flat areas prone to flooding in the wet (Christian and Stewart, 1953). Tall open forest of Woolly butt, *Eucalyptus miniata,* and Stringy bark, *Eucalyptus tetrodonta* with some Ironwood *Erythrophleum chlorostachys,* dominate the area (Wilson et al. 1990). The grass *Sorghum intrans* (recently changed to *Sarga intrans*) is the dominant grass (Aldrich et al.1977) and there are areas with a dense understorey of *Livistona sp.* palms. The creeks are lined with narrow Melaleuca fringing forests. Near the coastward edge of the plain the communities change to Pandanus and *Eucalyptus grandiflora.*

3.2. Littoral Land System

This narrow coastal land system in the area of the pipeline alignment contains mangrove mud flats, sand beaches and low sand dunes above the beaches. The vegetation on the sand dunes consists of spinifex grass and *Ipomoea* vines. Fresh water can occasionally be found in soaks behind the sand dunes (Christian and Stewart 1953). The mudflats and saltpans are recent saltwater deposits and the sand dunes are windblown marine deposits.

3.3. Possible influences of environmental factors on locating archaeological material.

There have been several archaeological studies in the Top End that have used environmental and archaeological data to predict the type and distribution of sites using factors such as climate, landforms geology, soils and vegetation. (Hiscock and Mitchell 1992, Hughes and Baker 1983, Heritage Surveys 1997, Gregory 1998, Guse 2001, Thorley 2002). Environmental factors also affect the visibility of archaeological remains.

As the Moyle land system has only isolated mesas that could provide terrain suitable for rock shelter sites or as a source of raw material for the manufacture of stone artefacts, it is expected that any sites that may be impacted by the development will be open artefacts scatters.

Environmental factors also affect the visibility of archaeological remains. Archaeological material tends to be visible on either eroding surfaces where the soil has been removed exposing the artefacts or stable surfaces where sediments have not accumulated over the artefacts. In the area of the proposed gas plant and on-shore pipeline artefacts will be exposed on creek banks that have been significantly eroded or on gravelly laterised surfaces that are indicative of an erosional surface (Thorley 2002:21). Artefacts will not be exposed in the sandy surfaces located near the coast or lowlands around creeks as they tend to move downward through the sand. Ground visibility is expected to be low in areas where the grass understorey has not been burnt.

4. CULTURAL SETTING

The data sources used for this section have been compiled from four principle sources:

1. The archaeological sites register held by the Heritage Branch, (DIPE).
2. The Register of the National Estate, maintained by the Australian Heritage Council.
3. The register of significant places maintained by the National Trust of Australia (Northern Territory Branch).
4. The Northern Territory Heritage Register held by the Heritage Branch (DIPE).

In addition to these sources published and unpublished documents and reports describing Northern Territory historic places were used. These documents are held by the State Library of the Northern Territory, the Darwin office of the National Trust, Heritage Branch (DIPE) and the Northern Territory Museum.

4.1. Ethnographic background

Stanner (1933a & b) who carried out ethnographic research in the region in the 1930s, noted that economic life and subsistence strategies for the Aboriginal people around the Daly were somewhat controlled by seasonal changes which changed the availability of water and food resources. The wet season made the flood plains inaccessible and by the end of the dry season people were forced to congregate around permanent waters. Ceremonial life was mainly confined to the dry season when traditional food such as macropods, waterfowl, fish, turtle and snake were plentiful.

When Gregory (1998:65-66) compiled ethnographic and historic evidence to investigate hunter-gatherer settlement patterns in the Ord-Victoria River region she concluded that coastal areas may have been quite densely populated during the early years of European settlement with sites situated on sand hills, shorelines, mangroves, rocky points, headlands, lagoons and swamps. The resources used were both marine and terrestrial and included fish, shell, turtles, crabs, flying foxes, crocodiles and their eggs. Fish were caught by hand, with spears or fish traps. Water lilies, palm nuts, grass seeds long yams and mangroves supplemented their dietary needs. In the lowland area Gregory (1998:66-68) noted that swamps, lagoons, grassy plains and woodland areas were exploited for resources such as yams, berries, lilies, freshwater mussels, water rats, geese, crocodiles, emus, pandanus nuts and cattle.

4.2. Historic record

Port Keats, now Wadeye, was discovered by Europeans in 1819 as King explored the coastline, however Europeans did not settle the Port Keats area until 1935 when a Catholic mission was set up just behind Lounga (Docherty Island), (Pye n.d.).

In 1939 the mission moved to the present location of the town of Wadeye. An airstrip was built in 1939 mainly for emergency use and the first vehicle to arrive was not until 1950 when the drivers followed the foot track used by Aborigines to reach the Daly River. The closest European settlement was in the Daly River Region approximately 150kms to the north. The Daly was first briefly occupied in the late 1880s by missionaries and European and Chinese farmers. Since 1881 there has been various European activity in the Daly River area such as sugar and peanut farming, and in 1880-90s there was a copper mine (Forrest 1994).

While the European settlement in the Port Keats area was much later than in the Daly River, European influence was still felt by Aboriginals in the region (Stanner 1933a, 1933b and Gleeson and Richards 1985). Aboriginal people were displaced from the Daly and moved into areas south of the Daly River while others moved onto the European settlements. Their numbers were decreased by disease in 1890 and their traditional way of life was weakened by their dependence on European goods especially opium, alcohol and tobacco.

The region south of the Daly including the Port Keats area was made an Aboriginal Reserve in 1885. In 1948 and 1963 this Reserve was increased and in 1976, under the *Aboriginal Land Rights (Northern Territory) Act 1976*, ownership was handed over to the Aborigines living in the reserve, (Stanley 1985).

4.3. Archaeological background

The Heritage Branch (DIPE) have only three archaeological sites recorded in the Port Keats region. Yarrar, located approximately 12 kms south of the proposed pipeline, is a rock shelter that contains rock art, rock engravings, stone artefacts and a low stone wall. Most of the paintings are of abstract designs in red and white pigment and there are also a series of short parallel lines engraved on the rock surface. Papangarla is a rock art shelter located in a dissected weathered sandstone scarp southwest of Wadeye. The main designs at this shelter are parallel red and white lines. There are also five grinding hollows. The third, approximately 30 kms north of the proposed pipeline alignment consists of a tamarind tree, a jetty and a fish trap. An artefact scatter, Nyik (Gregory 1998), has also been located 2-3 kms southwest of Yarrar, however this site has not been registered with DIPE.

Stanner excavated both Yarrar and Nyik in the late 1950s and the excavated material was re-analysed by Flood (1967) and Gregory (1998). Both sites would have been occupied in the late wet to early dry, as they are located near creeks that contain water only in the wet season.

At Nyik the majority of stone artefacts were manufactured from quartzite with minor quartz, silcrete and volcanic material. Types of artefacts identified were cores, retouched flakes and points. Gregory (1998) proposed that this site was used as a base camp or procurement site.

Yarrar also had a similar assemblage of stone tool types and raw materials. A radiocarbon date of approximately 3400 years BP was obtained from the middle parts of the excavated deposit. The patterns of the archaeological material found indicate that occupation intensity was greater after this date than in the lower part of the deposit (Gregory 1998:162). There were also changes in the raw stone material types with locally found quartz, silcrete and fine sedimentary rock in the lower levels and dolerite, a raw material found further a field, identified in the upper levels of the excavation. Gregory (1998:180) suggests that this indicates that there was either an expanding territorial range which was a reaction to either environmental changes occurring during this period or because there was an expansion of trade activities.

Gregory (1998:124-130) also appraised archaeological data to explain hunter-gatherer settlement patterns on coastal areas and the adjacent lowlands around the Cambridge Gulf. Only three sites, two fish traps and one shell midden were located on coastal areas (the Littoral Land System) in the regional archaeological record. Two were more than 2km from the nearest freshwater and the other was within 200m of a swamp. Ninety four sites have been recorded in the coastal lowland plain areas. Most were located in rock shelters (67%) and along rivers and streams (13%) and only 5% were located on the open plains. The majority of sites were located within 200 metres of either an ephemeral or permanent water source.

An archaeological survey (Crassweller 2001) located a highly disturbed shell scatter on a grass-covered coastal sand dune on the northern end of Munda Beach approximately 15 kilometres north of the proposed pipeline alignment. This scatter consisted of a low density (12 shells/ square metre) of mostly highly fragmented *Telescopium telescopium* and a few *Anadara granosa* and *Terebralia sp.* The dimensions of the shell scatter were 22 x 10 metres. The presence of a green coloured glass flake on the shell scatter indicates that this is a contact site. Crassweller (2001:8) also noted four large shell scatters of mostly *Terebralia sp.* on sand dunes that ran south along the back of Munda Beach for approximately 5 kilometres.

4.4. Possible cultural factors influencing the presence of archaeological or historic material

As entry into the area around Port Keats has been restricted to Europeans since 1885 there has only been minor physical European intrusions, mainly related to the mission located north east of the development and therefore it is highly unlikely that any historic sites will be located in the area of the proposed gas plant or on shore pipeline.

Previous archaeological research in the north Australian coastal areas (Bourke 2000) indicate that there was a high reliance by Aborigines on marine resources, the most visible of which are the shell middens and scatters. The presence of shell scatters located north of the study area indicates that Aboriginal people in the area also used shell food.

The ethnographic evidence by Stanner and archaeological research into environments similar to that around the Port Keats (Gregory 1998) indicate that fresh water sources were a focal point for past Aboriginal activities and are the most likely location for the presence of archaeological sites. The sites will most likely be located less than 200 metres from the water source.

The only items that had been used by Aboriginals in the past that are likely to have survived in the archaeological record are shell fish hooks, hearths, stone tools such as spear heads, axes, and grindstones and shells used either in the manufacture of implements or large shells such as *Melo amphora*, used as water vessels Brockwell (1995). After the arrival of Europeans the raw materials used in the manufacture of these items were substituted with iron, porcelain, glass and wire.

5. METHODOLOGY

The archaeological and historic heritage survey scope of works submitted to the NT Office of Environment and Heritage for the proposed project divided the archaeological and heritage component into several stages of survey intensity. Overall the stages will result in full coverage of the project area ensuring that heritage sites are not damaged or destroyed.

Stage 1. ~ Use previous archaeological research to prepare a predictive model of archaeological distribution along the pipeline alignment. The predictive model will use Land Systems or Land Units to target sections of the proposed alignment for further archaeological inspection.

Stage 2. ~ An archaeological inspection of portions of the proposed pipeline alignment that cross Land Systems that are predicted to have high densities of archaeological materials. The results of this initial survey will detect the variability and density of archaeological material that will be used to test the predictive model and identify areas that will need a more intensive archaeological inspection.

Stage 3. ~ Inspect the entire pipeline alignment at the time the centre line is cleared for survey pegging.

Stage 4. ~ Archaeological surveys will be made over areas that are located beyond the centre line. The selection of these areas will be based on previous survey results and the refinement of the predictive model. This stage will include an assessment of the likelihood of encountering sub-surface materials.

As noted in Section 1 of this report, the timetable for the archaeological assessment, as set out by the scope of works, has altered slightly. As the preliminary survey of the proposed pipeline required the presence of an archaeological team, a vehicular survey with pedestrian transects (a modified Stage 2 process) was carried out before the first stage.

5.1. Preliminary survey 2003

The 2003 survey was carried out to identify the physical location of the Blacktip Gas Plant and a 100 metres wide pipeline corridor that would not adversely impact upon sacred sites, cultural heritage places or the environment. The survey group included archaeologists, flora specialists, geo-technical terrain specialists, and Aboriginal traditional owners. The geo-technical team was required to drill holes a maximum of five kilometres apart along the route to assess soil depth and structure. In reality the distances between drill holes was less than five kilometres as holes were also drilled when the geomorphology of an area changed. The flora specialists were required to note vegetation changes along the route and the traditional owners were required to identify areas of cultural significance.

Begnaze was required to carry out two archaeological undertakings. The first was to ensure that the area to be drilled by the geo-technical team contained no archaeological material that would be disturbed by the drilling. The second was to identify any archaeological sites or objects located on or near the proposed pipeline route and gas plant. The findings from the survey were then used to identify archaeologically sensitive areas to be avoided, or when avoidance is not possible, to recommend alternate routes or mitigation strategies to lessen the impact of the loss or damage of archaeological and heritage places and objects.

5.2. Survey procedures

The aims of the fieldwork were to locate and record any archaeological objects or places to ensure that the provisions of the *Northern Territory Heritage Conservation Act 1991* are not contravened. The archaeological survey was to be carried out as follows:

- The archaeological and heritage study will identify archaeological material within the designated area by means of a survey carried out in a manner that will ensure the highest possible coverage of the area.

- Any archaeological or heritage places, objects or classes of objects located during the survey will be recorded in such detail as to permit independent assessment of their significance. The location of any archaeological places and objects will include coordinates obtained by a Global Positioning System. All sites will be named in order to identify the sites on the ground.

- After assessing the significance of the archaeological place or object, recommendations will be made regarding compliance with the provisions of the *Northern Territory Heritage Conservation Act 1991.*

The archaeological survey of the pipeline section between the coast and the proposed gas plant consisted of both vehicular and pedestrian transects. The vehicular transects were made as close as possible to the centre of the pipeline alignment. Pedestrian transects were made every time the survey party stopped, that is every time a hole was drilled, when the flora survey crew found vegetation of interest, when mechanical failures occurred, or when there was a location where there was a higher potential for locating archaeological sites, such as areas adjacent to waterways, higher ground or eroded areas. This method resulted in both random and purposive pedestrian transects. The archaeological survey of the gas plant area was carried out using pedestrian transects only. The surveys were carried out by Christine Crassweller and Helen Haritos.

5.2.1. Blacktip Gas Plant survey

Pedestrian transects by two archaeologists walking approximately 20 metres apart were made over the 750 x 750m proposed gas plant area (Table 3) and included one transect around the border of the area to be disturbed, transects between four drill holes and six transects across the area in a northeast to southwest direction. This method resulted in an average of one transect by one archaeologist every 50 metres across the gas plant area.

Table 3 The co-ordinates of the four corners of the gas plant site.

	GDA 1994		1:100,00 map sheet, Pearce 4769	
Corner	East	South	Easting	Northing
W	$129^0$25'52.09"	$14^0$14'33.60"	546 509	8 425 392
N	$129^0$26'05.87"	$14^0$14'13.22"	546 924	8 426 018
E	$129^0$26'26.77"	$14^0$14'26.66"	547 549	8 425 603
S	$129^0$26'12.99"	$14^0$14'47.04"	547 135	8 424 978

5.2.2. Onshore pipeline survey

A vehicular survey (Table 4) was made as near as possible to the pipeline alignment from the gas plant site to the coast where the pipeline emerges from the sea. Two pedestrian transects (Transects 1 and 2) (Table 5) were also made along the pipeline. The coastal area was surveyed in a north-south along the length of the sand dunes behind the beach (Transect 3) and another transect was made 250 metres inland from the sand dunes in an east-west along the pipeline alignment (Transect 4). The location given in Table 4 for Transect 3 and 4 represents a point on the sand dunes from which the transects were made.

Table 4 Location of vehicular transects made between the gas plant site and the coast.

	1:100,00 map sheet, Pearce 4769 Datum: WGS84			
Transect	**Lat**	**Long**	**Easting**	**Northing**
From	-14.5861	132.1298	52 546773	8425279
To	-14.2430	129.4123	52 544475	8425359

Table 5 Location of pedestrian transects made between the gas plant site and the coast.

	1;100,00 map sheet, Pearce 4769 Datum: WGS84			
Transect	**Lat**	**Long**	**Easting**	**Northing**
1	-14.5861	132.1298	546773	8425279
2	-14.5859	132.1298	545525	8425371
3 & 4	-14.5809	132.1218	545459	8425283

The following sections contain information about fieldwork methods employed in this study including the identification and recording of archaeological sites and materials and the criteria used for the assessment of their significance.

5.2.3. Types of archaeological sites

There are five types of sites previously recorded in the region and they can broadly be defined as follows:

- *Artefact scatters.* These may contain flaked or ground artefacts and hearthstones. They occur as surface scatters of materials or as stratified deposits when there has been repeated occupations.

- *Shell middens* contain mollusc material in the form of surface scatters or mounded deposits (Gregory 1998:222), which represent the remains of human meals.

- *Stone arrangements* range from simple cairns to more elaborate arrangements. These stone arrangements were used in ceremonial activities and represent sacred or totemic sites. Other stone arrangements were constructed for route or territory markers, the walls of huts, fish traps or small walls to stop water from entering a rock shelter or to retain the floor.

- *Art sites* include stencils and paintings where material was added to the rock surfaces or engravings or poundings where the pictures or designs are produced by the removal of material from the rock surface (Clegg 1983).

- *Rockshelter sites* contain a deposit of cultural material that has built up over time and contain flaked or ground stone artefacts, faunal material and other Aboriginal cultural remains.

- *Stone quarries* are generally sites where stone for flaked or edge ground artefacts has been extracted from an outcropping source of rock (Hiscock and Mitchell 1993).

5.2.4. Site definition

An archaeological site is defined for this survey as a concentration of artefactual material with an average density that is 5 times greater than the average density of the background scatter and there are more than five artefacts or shells which cover an area of at least $1m^2$. A site will have an identifiable boundary where either artefact densities decrease to the extent as to be classified as background scatter or environmental features determine the boundary.

Background scatter is generally a very low density, more or less continuous distribution of isolated artefacts over the landscape. Although these artefacts do not constitute a site they are still protected under the *NT Heritage Conservation Act (*1991) as prescribed objects and will be given location details and general descriptions for research purposes.

5.2.5. Artefact identification

A requirement for a successful archaeological project involves the accurate identification of archaeological materials. For an object to be identified as a flaked object it needs to possess one or more of the following:

- a positive or negative ring crack.
- a distinct positive or negative bulb of percussion.
- a distinct eraillure scar in an appropriate position below the platform.
- definite remnants of flake scars on dorsal surface or ridges.

Stone artefacts are divided into four main types of cores, unretouched flakes, retouched flakes and flaked pieces (Hiscock 1984:128-129). They are defined as follows:

- *cores* are pieces of stone that have one or more negative flake scars and the absence of positive scars.
- *unretouched flakes* are pieces of stone that have been struck off another piece of stone and ideally possess platforms, positive bulbs of percussion, concentric ripples, ring cracks and /or eraillure scars on the ventral surface.
- *retouched flakes* are flaked flakes. They are identified by the presence of negative scars that must have been created after the ventral surface of the flake had been created. There will be either negative scars on the ventral surface or negative scars on the dorsal surface, which have been formed by the flake being hit on the ventral surface.
- *flaked piece*s are stone artefacts that have been formed by knapping but cannot be identified as either a core or a flake.

Other artefact and implement types that have been identified in the top end of the Northern Territory are listed below following characteristics outlined by McCarthy (1976).

- *Unifacial points* are flakes that have been retouched along the margins from one surface, either ventral or dorsal to give or enhance its pointed shape. They are sometimes symmetrical or leaf shaped.
- *Bifacial points* are retouched along both ventral and dorsal surfaces of a flake to enhance or give the artefact its pointed shape. They may have the platform removed and the proximal end rounded.
- *Edge ground axes* have been shaped by the process of flaking, pecking and polishing. They generally have only one working edge that has been ground to a sharp margin although occasionally they may have two leading edges.
- *Grindstones* are characterized by a worn and abraded surface or surfaces. There also may be a concave surface.
- *Hammerstones* have use wear on the surface in the form of abrasion, pitting, and edge fracturing with some negative scarring.
- *Manuports* are stone material that are not found naturally in an area and must have been carried in by humans.

5.2.6. Assessment of significance and heritage management principles

According to Sullivan and Bowdler (1984) archaeological significance means that it has scientific, archaeological or research value, that is, it has the potential to assist current or future research into problems of human history or other areas of enquiry. The Australian ICOMOS Charter for the Conservation of Places of Cultural Significance, otherwise known as the Burra Charter (Maquis-Kyle

and Walker 1992:73) states that the scientific value or research potential of a place depends upon the importance of the data involved, on its rarity, quality or representativenesss, and on the degree to which the place or object may contribute to further substantial information.

Therefore the significance of a site is firstly related to the intactness or integrity of a site, and the state of preservation of the archaeological material. Secondly, if the site has stratigraphic reliability then it may be possible to use the cultural material for dating which will provide a chronology extending back into the past. Thirdly, the representativeness of a site is important either because a site is unusual or because the site has research potential when taken in conjunction with other sites.

6. RESULTS

6.1. Summary

As a result of the archaeological survey over the proposed Blacktip Gas Plant and on-shore pipeline one archaeological site a shell midden, was located on the sand dunes behind the beach where the pipeline emerges from the sea. The presence of the shell midden suggests that marine resources were as important in this region as other coastal areas in the Top End.

No other archaeological or historic sites or objects were located in the area of the gas plant or along the pipeline alignment. As there has been very little impact by European developments or settlement around the proposed gas plant and on-shore pipeline it is highly unlikely that any historic sites or objects are located in the area.

The archaeological and environmental background research indicate that sites in the area would likely consist of open artefact scatters near a source of water, or as rock shelters on rocky outcrops and would be rare on the plains. As the survey areas consisted of level ground with only minor waterways there is a low probability for the presence of any sites using the above criteria.

While it is likely that there are no archaeological sites or objects in the vicinity of the on-shore project area there are several factors that may have influenced the visibility of any archaeological material.

- Ground visibility during the survey of the on-shore pipeline ranged from 15 – 70%. In areas where visibility was 15% it is highly likely that less dense artefacts scatters and isolated object would not be visible. In areas with 70% visibility artefacts scatters would most likely be visible but isolated objects may be missed.
- Sandy soils in sections of the on-shore pipeline would cover any archaeological material.
- Artefacts close to waterways in the Moyle Land System are prone to flooding and would be visible only in eroded areas.

6.2. Sites of heritage significance

6.2.1. Register of National Estate.

There are no historic or archaeological sites recorded on the Register of the National Estate located on or near the Blacktip Gas Plant and on-shore pipeline.

6.2.2. Sites recorded on Commonwealth and/or NT Heritage Registers

There are no historic or archaeological sites recorded on the National Heritage List and there are no declared or prescribed places or objects as described by the *Northern Territory of Australia Heritage Conservation Act 1991* that are in the vicinity of the proposed Blacktip Gas Plant or the on-shore pipeline.

6.2.3. Macassan sites and Aboriginal and ATSI archaeological and heritage places and objects

The archaeological survey over the area located only one site, a shell midden that will be disturbed by the development. This site is a prescribed site under the *NT Heritage Conservation Act 1991* and is therefore a protected site.

6.2.4. European historic sites

No European historic sites were located during the survey of the proposed gas plant and on-shore pipeline.

6.3. Blacktip Gas Plant survey

The proposed gas plant is located on level ground of red soils covered in tall eucalypts. While three quarters of the area had been recently burnt the leaf litter on the ground lowered the average ground visibility to 70%. The unburnt area had an average ground visibility of less than 10%.

No archaeological or historic material was located in the area of the proposed gas plant.

6.4. On-shore pipeline survey

The pipeline alignment from the gas plant site to the coast is over level ground covered in tall eucalypts. As the proposed pipeline nears the coast the soil becomes more sandy and the vegetation changes to scrubby woodlands. A large shell midden was located during pedestrian transects along the dunes above the beach. No archaeological material was identified inland from the beach / sand dune area. Details of the pedestrian transects are found in Table 6.

Table 6 Details of pedestrian transects made between the gas plant site and the coast.

Transect	Ground Visibility %	Distance (m)
1	70	200
2	15	500
3	40	1200



Blacktip Project

DRIMS-#1572636

ARCHAEOLOGICAL AND HISTORIC HERITAGE SITES IN PROJECT AREA

Figure 1

Site 8 - Shell Midden 1.

Location:
Between 52 544509E 8425508N and 52 544186E 8424816N
1:100,000 Mapsheet Pierce, 4769 Datum: WGS84

Geomorphological context: Sand dunes

Land System: Littoral.

Dimensions. N-S 600m, E-W 40m.

Ground visibility: Minimum - 90%. Maximum - 100%. Average- 95%

The site is located over the length of the sand dunes, which run in a north to south direction parallel to the beach (Plates 1 and 2). Sections of the dunes are covered in grasses and vines and there are large areas that have been wind eroded. The back of the sand dunes drop quickly to a low ironstone area covered in a closed forest with patches of pandanus and a larger area of monsoon forest in the south. There are stands of mangroves to the south of the beach. A track runs along the length of the dunes and approximately 20 metres north of the most northerly eroded area is a 30 x 20 x 3 metre section where the sand had been removed by mechanical means (Plate 5). Traditional owners stated that this occurred during the 1960s. The location of this disturbed area is 52 544495E 8425488N.

The highest density of archaeological material (60 shells per square metre) appears in the eroded areas along the western side of the highest part of the most easterly sand dune. The deepest section of the eroded areas is estimated to be half a metre. A lower density of archaeological material (10 shells per square metre) is eroding from patches of smaller eroded areas closer to the beach on a more level section of the sand dunes (Plate 6).

The highly fragmented shell consists of 90% *Terebralia sp.*, 5% *Telescopium sp.*, 2% *Saccostrea sp.* (oyster) with smaller numbers of *Volema sp.*, *Nerita sp.*, *Turbo sp.*, and *Anadara sp.* The stone artefacts noted during the survey consisted of ten hammerstones, one ground edge axe and one ground axe (Plate 3) (both also used as hammerstones), one sandstone rock with drill marks (Plate 4) and possible cooking stones carried from a type of ironstone that is found outcropping from the promontories at both ends of the beach. There were also small sandstone manuports eroding from the sand. Macropod, fish and possibly dugong bone were located over the southern section of the sand dunes.

6.4.1. Relationship to proposed development

The proposed onshore pipeline will cross over the shell midden site in a west to east direction.

6.5. Assessment of heritage significance

While there has been detailed archaeological research into past Aboriginal settlement patterns or use of coastal resources in other areas of the Northern Territory (Bourke 2000, Crassweller 2002, Sim 2002, Mowat 1995, Hiscock 1997, Woodroffe *et al* 1988) there has been no research work and few surveys carried out along the coast between Darwin region and the Victoria River. Therefore it is difficult to assess whether the presence, and the archaeological attributes of Shell Midden 1, are a rare occurrence in the region or not. However when compared to shell midden sites in other areas of coastal Northern Territory its size, the surface archaeological material and site integrity would suggest that this site has a high potential for further research and therefore the site has a rating of high archaeological significance.

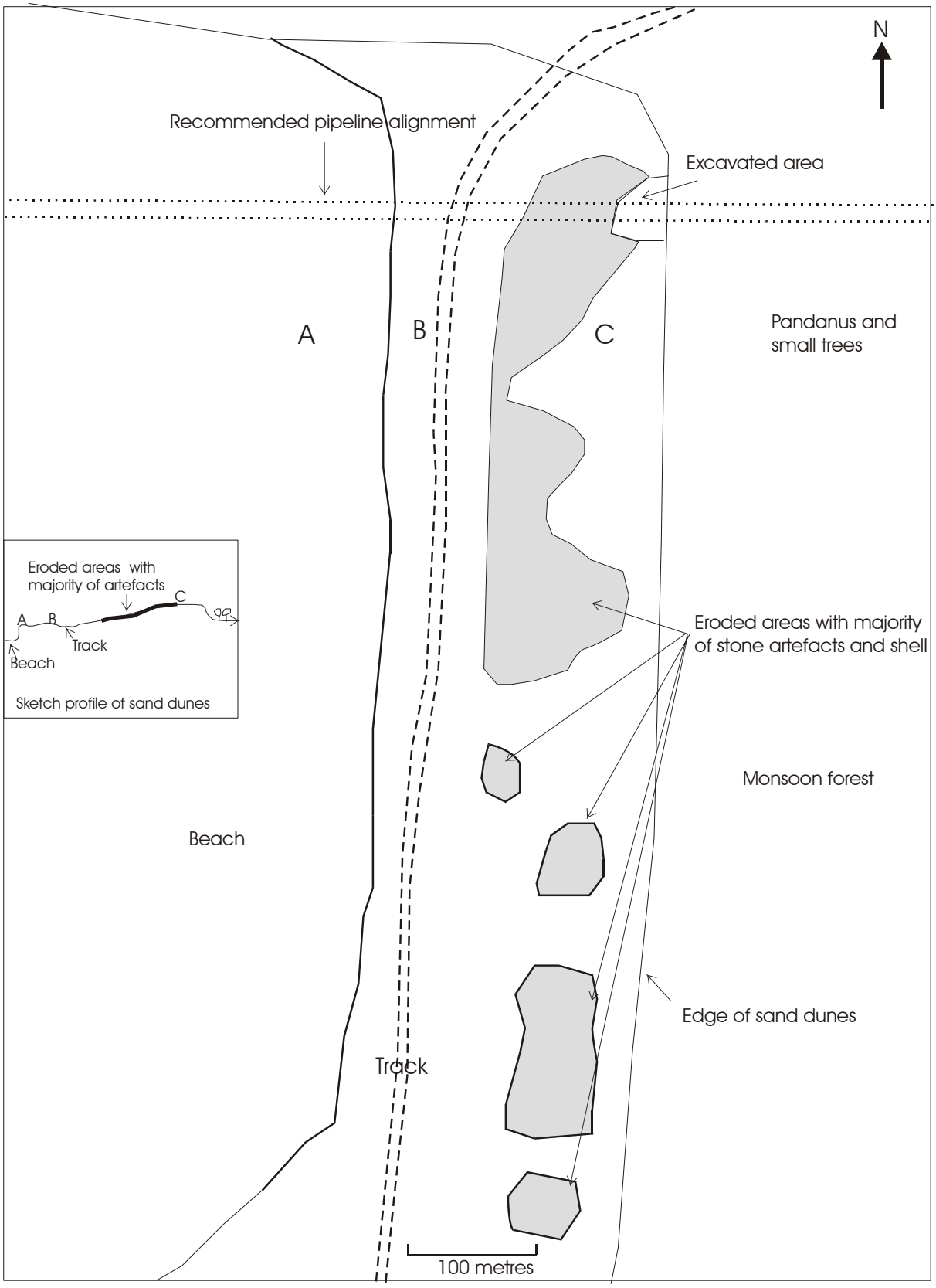


Figure 2 Sketch map of Shell Midden 1.

7. POTENTIAL PROJECT IMPACTS

While the lack of previous archaeological research in the area of the on-shore pipeline makes it difficult to assess the frequency and distribution of sites that are likely to be encountered during the development there is enough data from neighbouring regions and ethnographic research to predict that any areas within 200 metres of a source of freshwater are archaeologically sensitive.

The preliminary survey failed to locate any sites within the areas of the proposed gas plant and the on–shore pipeline after it leaves the sand dunes at the back of the beach. However as ground visibility was low in some areas during the survey of the pipeline alignment, all which were not surveyed, it is possible there are sites in the area that will only be located after the exact route has been examined.

7.1. Design phase

There were no archaeological objects or sites identified on the proposed gas plant. However there was one archaeological site, Shell Midden 1, identified during the preliminary survey of the proposed on-shore pipeline alignment. The shell midden is located on sand dunes behind the beach where the pipeline leaves the seabed. As this site covers the full length of the sand dunes, it is impossible for the pipeline to detour around the site. Damage to the archaeological site can be mitigated if the pipeline leaves the seabed further north than the original proposal so that it crosses the sand dunes at 8425488N where a section of the sand dunes had been previously destroyed.

The sections of the pipeline that have not been surveyed should have an archaeological inspection when the surveyors are pegging the pipeline route. Any areas selected for the construction of associated roads, access routes, construction camps quarries, borrow pits and laydown areas should also be surveyed for archaeological material. There are no archaeological concerns for the area on which the gas plant will be constructed.

7.2. Construction phase

The construction of the pipeline through the sand dunes will destroy and disturb a section of the archaeological site, Shell Midden 1. Therefore processes should be set up to limit the area to be destroyed.

During the initial clearing of the pipeline alignment and during the construction phase there is a possibility that there will be disturbances to sub-surface archaeological materials such as human skeletal remains, stone artefacts, shell middens and the remains of hearths.

7.3. Operational phase

At this stage the main concern for the archaeological site, Shell Midden 1, is the stabilisation of the area so that there is no erosion of the sand dunes in the area where the sand has been removed and / or disturbed.

8. RECOMMENDATIONS

An archaeological site, referred to as Shell Midden 1, is located over the full length of sand dunes that run parallel to the beach where the pipeline emerges from the seabed. A number of recommendations for actions to protect this site, that include a full archaeological survey of the construction corridor during the pegging of the final pipeline alignment, are made in this section. There was no archaeological material identified on the area on which the proposed gas plant is to be constructed and therefore there are no specific controls that need to be implemented for this site. When areas are to be selected for the construction of access roads or other areas that need to be cleared during construction, then the predictive model developed in Section 4.5 of this report should be used to avoid areas that have a high probability for the presence of archaeological sites, such as areas near a source of fresh water. Specific recommendations are provided below.

8.1. Design phase

It is recommended that during the design phase of the project:

1. The pipeline route takes advantage of the previously disturbed section of the sand dunes and leaves the seabed further north than the original proposal so that it crosses the sand dunes at 8425488N.

2. A full archaeological survey of the onshore pipeline corridor should be conducted at the time of pegging of the final alignment. The archaeologist can make decisions in the field as to the correct procedures for protection of sub-surface material.

3. All access tracks, borrow pits, laydown areas etc. are chosen in accordance with the predictive model developed in this report, and final locations are subject to an archaeological survey.

8.2. Construction phase

It is recommended that prior to construction:

4. The proponent obtain permission from the Heritage Conservation Services, Department of Infrastructure, Planning and Environment, as directed by the *NT Heritage Conservation Act 1991*, to disturb the Shell Midden 1 site only after a thorough recording and collection is made of the archaeological materials located within the site.

5. The area to be disturbed is minimised and the boundaries of the pipeline construction area over the shell midden is appropriately fenced. The area outside the fence line should be delineated as a “no go” area with no pedestrian or vehicular movement, heavy machinery, drilling or grading occurring outside this fenced area.

It is recommended that during construction:

6. A response mechanism is set up to ensure that subsurface material is not disturbed and is protected. This response should include informing contractors of the importance of site protection and a mechanism for the cessation of work around discovered archaeological material until advice from the Heritage Conservation Services is obtained to ensure that the conditions of the *NT Heritage Conservation Act 1991* are not contravened.

8.3. Operational phase

It is recommended that during the operation phase of the project:

7. The sides of the sand dune on either side of the pipeline alignment are stabilised so that further damage does not occur through erosion.

8. All appropriate Woodside Energy personnel and contractors are notified of the site location and operate strictly to avoid disturbing the site.

9. REFERENCES\BIBLIOGRAPHY

Aldrich, J.M., Howe, D.E., and Robinson, C.S. 1977. *Land systems of the Port Keats area, 1972.* Land Conservation Section, Department of the Northern Territory, Darwin.

Bourke, P. 2000. Late Holocene indigenous economies of the tropical Australian coast: an archaeological study of the Darwin region. Ph. D. thesis, Department of Anthropology, Northern Territory University, Darwin.

Brockwell, C.J. 1995. Prehistoric settlement patterns and mobility strategies on the lower Adelaide River, Northern Australia. Unpublished report to Heritage Conservation, Department Land Planning and Environment, Darwin.

Clegg, J. 1983. Recording prehistoric art. In G. Connah (ed.) *Australian Field Archaeology: A Guide to Techniques.* Australian Institute of Aboriginal Studies, Canberra.

Crassweller, C. 2002. The excavation of two shell middens at Wickham Point, Darwin Harbour, NT. An unpublished report to URS Darwin

Crassweller, C. 2001. An archaeological survey at the Old Mission Outstation, via Port Keats, NT. An unpublished report for EcOz Environmental Services, Darwin.

Flood, J. 1970. A point assemblage from the Northern Territory. *Archaeology and Physical Anthropology in Oceania*. 5:27-52.

Forrest, P.1985. *The Spirit of the Daly.* Daly River Community Development Association, Daly River Northern Territory.

Gleeson, J. & Richards, M. 1985. *The Mataranka and the Daly. Two Studies in the History of Settlement in the Northern Territory*. Australian National University North Australian Research Unit Monograph, Darwin.

Gregory, R.L. 1998. *Aboriginal Settlement Patterns in the Ord-Victoria River Region.* Ph. D. thesis, Department of Anthropology, Northern Territory University, Darwin.Vol.1 & 2.

Guse, D. 2001. The Northern Territory Archaeological Survey Stage 11. The Daly River Basin Bioregion . Heritage Conservation Branch, Department of Lands, Planning and the Environment.

Heritage Surveys, 1997. Darwin LNG Plant Draft Environmental Impact Statement. A report for Phillips Oil Company Australia.

Hiscock, P. 1984. A preliminary report on the stone artefacts from Colless Creek Cave, Northwest Queensland. *Queensland Archaeological Research*, 1:120-151.

Hiscock, P. 1996. Archaeological evidence for environmental change in Darwin Harbour. In JR Hanley and GM Caswell's (eds.) *The Marine Flora and Fauna of Darwin Harbour, Northern Territory*. Museum and Art Galleries of the Northern Territory. pp. 445-9.

Hiscock, P. and Mitchell, S, 1993. *Stone Artefact Quarries and Reduction Sites in Australia: Towards a Type Profile.* Technical Publications Series Number 4. Australian Heritage Commission, Canberra.

Hiscock P. and Mitchell, S. 1992. Stage 11 Archaeological survey of the proposed Telecom Darwin-Katherine Optical Fibre Route. A report to Telecom.

Heritage Surveys, 1997. Baseline Archaeological Survey of the proposed North Australian Training Area. A Report to Connel Wagner.

Hughes, P.J. & Sullivan, M.E. 1984. Environmental approaches to assessing archaeological significance. In M.E. Sullivan and S. Bowdler (eds.) *Site Surveys and Significance Assessment in Australian Archaeology*. Dept. of Prehistory, Research School of Pacific Studies, ANU, Canberra. pp. 34 –37.

Hughes, P.J. and Baker, R. 1983. RAAF Tindal environmental studies, archaeological survey and impact assessment. An unpublished report to Kinhill Stears for the Department of Housing and Construction.

Maquis-Kyle, P. and M. Walker, 1992. *The Illustrated Burra Charter: Making good decisions about the care of important places*. Australian Heritage Commission, Canberra.

McCarthy, FD 1976. *Australian Aboriginal Stone Implements*. The Australian Museum Trust, Canberra.

Morgan, C.M. 1972. *Port Keats, N.T. 1:250,000 Geological Series.* Bureau of Mineral Resources, Geology and Geophysics. Australian Government Publishing Service, Canberra.

Mowat, F.M. 1995 Variability in western Arnhem Land shell midden deposits. Unpublished (MA) thesis, Department of Anthropology, Northern Territory University, Darwin

Pye, J. n.d. T*he Port Keats Story*. Coleman's Printer, Darwin.

Sim, R. 2002 Preliminary results from the Sir Edward Pellew Islands Archaeological Project, Gulf of Carpentaria 2000-2001. A report for the Australian Institute of Aboriginal and Torres Strait Islander Studies.

Stanley, O. 1985. *The Mission and Peppimenarti: an economic study of 2 Daly River Communities.* Australian National University North Australian Research Unit, Darwin

Stanner, W.E.H. 1933a. The Daly River Tribes: a report of fieldwork in North Australia, Part 1. O*ceania,* 3: 377-405.

Stanner, W.E.H. 1933b. The Daly River Tribes: a report of fieldwork in North Australia, Part 2. O*ceania,* 4: 10-29.

Sullivan, M.E. and S. Bowdler 1984. *Site Surveys and Significance Assessment in Australian Archaeology*. Dept of Prehistory, Research School of Pacific Studies, ANU, Canberra.

Thorley, P. 2002. An archaeological assessment of the Katherine-Daly Basin. An unpublished report for the Department of Infrastructure, Planning and Environment, Darwin.

Wilson, B.A., Brocklehurt, P.S., Clarke, M.J. and Dickenson, K.J.M. 1990. *Vegetation Survey of the Northern Territory, Australia*. Technical Report 49. Land Conservation Unit, Conservation Commission of the Northern Territory, Darwin.

Woodroffe, C.D. Chappell, JMA and Thom, BG. 1988. Shell middens in the context of estuarine development, South Alligator River, Northern Territory. *Archaeology in Oceania* 23:95-103.

Appendix 1 Plates referred to in text.



Plate 1 Shell Midden 1 on sand dunes -facing south.



Plate 2 Shell midden 1 facing north



Plate 3. Edge ground axe and broken axe used as hammer stones



Plate 4. Stone with drill hole



Plate 5. Area of sand dune that has been mined for sand.



Plate 6. Shell scatter on fore dunes, near the beach.

Appendix J

Blacktip Produced Formation Water Assessment prepared by International Risk Consultants Environment






This page has been left intentionally blank



Blacktip Produced Formation Water Assessment

DATE: 5 AUGUST, 2004

PROJECT: J03-187

DOC NO.: ENV-REP-03-187-001 REV 0.DOC

IRC Environment

26 Colin Street West Perth
Western Australia 6005
PO Box 418 West Perth
Western Australia 6872
Telephone 61 8 9481 0100
Facsimile 61 8 9481 0111
Email environment@intrisk.com
www.intrisk.com

© 2004 IRC Environment

DOCUMENT REVISION STATUS					
REV	**DESCRIPTION**	**AUTHOR**	**REVIEW**	**APPROVAL**	**DATE**
A	Internal Review	Rob Phillips	Peter Jernakoff		30 July 2004
0	Issued to client	Rob Phillips	Peter Jernakoff	Kian Feng	5 August 2004

Title: Blacktip Produced Formation Water Assessment	**Job Number:** J03-187	
	Report Number: ENV-REP-03-187-001 Rev 0.doc	
Client: Woodside Energy	**Author:** Rob Phillips	**IRC Office:** Perth
Industry Sector: Offshore Oil and Gas		
Key words: Woodside Energy Ltd., Blacktip, PFW, Modelling, toxicity, Initial dilution, Joseph Bonaparte Gulf		
Abstract: Woodside Energy Ltd (WEL) is planning to develop the Blacktip Gas Field in the Joseph Bonaparte Gulf. This report provides an assessment of the environmental risk associated with disposing of produced formation water (PFW) from the development. The preferred disposal option is onshore treatment followed by discharge to the ocean through a long sea outfall.		
Country: Northern Territory, Australia		
Reference: N/a		

Contents

ABBREVIATIONS **5**

EXECUTIVE SUMMARY **8**

1 INTRODUCTION **9**
1.1 Background 9
1.2 Objective 9
1.3 Scope of Work 9
1.4 IRC 9

2 PRODUCED FORMATION WATER CHARACTERSITICS **12**
2.1 Introduction 12
2.2 Chemical Composition of PFW 13
2.3 Fate of PFW in the Marine Environment 22
2.4 Environmental Fate of Individual PFW components 27
2.5 Assessing Environmental Effects and Risks 32
2.6 Observations of Exposure and Effect 37
2.7 Regulatory Framework and International Best Practice for PFW Discharges 38
2.8 International Best Practice 40
2.9 Treatment Technology 40
2.10 Summary 41

3 JOSEPH BONAPARTE GULF RECEIVING ENVIRONMENT **43**
3.1 General 43
3.2 Bathymetry 43
3.3 Climate 44
3.4 Winds 44
3.5 Oceanography 48
3.6 Biological Environment 53

4 DISPERSION MODELLING **56**
4.1 General 56
4.2 Near field Dispersion 56
4.3 Far Field Dispersion Modelling 59
4.4 Dissolved Oxygen 80

5 CONCLUSIONS AND RECOMMENDATIONS **88**
5.1 Conclusions 88
5.2 Recommendations 89

6 REFERENCES **90**

ABBREVIATIONS

ADCIRC	Advanced Circulation Model
AGSO	Australian Geological Survey Office
ANZECC	Australian and New Zealand Environment and Conservation Council
ASTM	American Society for Testing Materials
BAF	Bioaccumulation Factor
BCF	Bio-concentration Factor
BF	Biomagnification Factor
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethyl benzene and Xylene
CHARM	Chemical Hazard Assessment and Risk Management
CORJET	Cornell Buoyant Jet Integral Model
CORMIX	Cornell Mixing Zone Expert System
CP	Cossack Pioneer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DO	Dissolved Oxygen
DREAM	Dose related Risk and Effect Assessment Model
EC50	The Median Effect Concentration
EIF	Environmental Impact Factor
EPBC	Environment Protection and Biodiversity Conservation
FE	Finite Element
FEED	Front End Engineering Design
FID	Flame Ionisation Detection
GC-MS	Gas Chromatography – Mass Spectrometry
GWA	Goodwyn ‘A’
HAT	Highest Astronomical Tide
Hs	Significant Wave Height
HQ	Hazard Quotient
IC50	Median Inhibition Concentration
IR	Infra-Red
IRCE	IRC Environment

IUCN	International Union for the Conservation of Nature and Natural Resources
K_{oc}	Organic carbon/water partition coefficient
K_{ow}	Octanol/water partition coefficient
K	Diffusion coefficient
LAT	Lowest Astronomic Tide
LC50	Median Lethal Concentration
LTS	Low Temperature Separator
MAH	Monocyclic Aromatic Hydrocarbon
MFO	Mixed Function Oxygenase
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MHWS	Mean High Water Springs
MHWN	Mean High Water Neaps
MSL	Mean Sea Level
ND	Not Detected
NE	Northern Endeavour
NOAA	National Oceanic and Atmospheric Administration
NOEC	No Observed-Effect Concentration
NORM	Naturally Occurring Radioactive Material
NNE	North Northeast
NV	No Value
NPD	Naphthalene, Phenanthrene and Dibenzothiophene
NRA	North Rankin ‘A’
OGP	International Association of Oil and Gas Producers
OL	Ocean Legend
OSPAR	Oslo and Paris Commission
PAH	Polycyclic Aromatic Hydrocarbons
PSU	Practical Salinity Unit
PEC	Predicted Environmental Concentration
PFW	Produced Formation Water
PID	Photoionisation detection

PNEC	Predicted No Effect Concentration
P(SL)A	Petroleum (Submerged Land) Act
P(SL)(ME)R	Petroleum (Submerged Land)(Management of the Environment) Regulations
PWCNT	Parks and Wildlife Commission of the Northern Territory
SDH	Sorbital Dehydrogenase
SE	Southeast
Tm	Mean Spectral Period
TOC	Total Organic Carbon
UKOOA	United Kingdom Offshore Operators Association
USEPA	United States Environmental Pollution Authority
WA	Western Australia
WEL	Woodside Energy Ltd.
WET	Whole Effluent Toxicity
^{o}C	Degree Celsius

EXECUTIVE SUMMARY

This report assesses the environmental risk associated with disposing of produced formation water (PFW) from Woodside Energy Limited's (WEL's) Blacktip Gas development. The preferred disposal option is onshore treatment followed by discharge to the marine environment of the Joseph Bonaparte Gulf through a long sea outfall.

PFW discharge rates are projected to increase from 200 bbl/day at start-up to a maximum of 7,000 bbl/day five years into production. The actual toxicity of the PFW is presently unknown, however, WEL's previous ecotoxiciology studies on PFW from all its other offshore assets indicate that the lowest threshold concentration for potential environmental impact is 0.1% concentration of PFW. Blacktip PFW will be treated onshore to a higher standard than the offshore facilities and the toxic threshold is expected to be higher, ie, the PFW is likely to be less toxic.

The favoured offshore release point is in the vicinity of the Swamp Mooring, which lies three kilometres offshore in a water depth of 15m. Tidal currents in the Joseph Bonaparte Gulf are large and the assimilative capacity of the receiving waters high. Initial dilution from the discharge can be further enhanced through use of an end-of-pipe diffuser.

Pipeline hydraulics were reviewed and, based on preliminary information, a four port diffuser configuration was proposed. Dispersion modelling for this configuration predicted that at least 700 initial dilutions would be achieved for the maximum future discharge rate, reducing the PFW concentrations to 0.14%.

Far field modelling showed that the receiving waters are well flushed due to the large tidal currents. Maximum PFW concentrations occurred at slack waters with values building up to just over the 0.1% PFW threshold within 400m from the near field mixing zone. As the modelling was undertaken for worst case conditions of maximum discharge rate combined with a neap tide and low wind speed, 400m is likely to be the maximum extent of the impact. At all other stages of tide, this zone of impact would reduce substantially.

PFW also has an oxygen demand. This can be controlled by treatment prior to discharge. It was predicted that to maintain oxygen levels to within 90% of saturation levels, the biochemical oxygen demand of the effluent should be kept below 2,500mgL^{-1} for the maximum discharge rate.

The overall conclusion is that the proposed discharge should have minimal impact on the marine environment. This is based on the Blacktip PFW being no more toxic than those from other WEL assets. It is recommended that ecotoxiciology studies be undertaken once PFW becomes available to verify this assumption. As well as reducing the concentration of dispersed oil, treatment should focus on removing polycyclic aromatic hydrocarbons and reducing the toxicity of process chemicals, the compounds of most concern in PFW.

1 INTRODUCTION

1.1 Background

Blacktip is an offshore gas development located 300km South West of Darwin, Australia. The development comprises of an unmanned wellhead platform in 50m of water and a 16 inch, 120km long pipeline through which well fluids will be transported to an onshore gas treatment station (Figure 1.1 and Figure 1.2). The wet gas will be conditioned at the treatment station and then exported to Gove through the trans-territory pipeline. The favoured option for disposal of the Produced Formation Water (PFW) is treatment prior to offshore discharge to the Joseph Bonaparte Gulf through a long sea outfall.

As part of the Front End Engineering Design (FEED) for the project, IRC Environment (IRCE) was commissioned by Woodside Energy Limited (WEL) to devise an effective ocean disposal scheme and to assess the environmental risks associated with discharging PFW to the ocean.

1.2 Objective

The objective of the study is to devise an effective PFW disposal scheme for the Blacktip development and to gain a full understanding of the environmental impact associated with it.

1.3 Scope of Work

The scope of work included:

- describing the typical composition of PFW, its fate and toxicity in the marine environment;
- describing the meteorological and oceanographic conditions for the Joseph Bonaparte Gulf;
- developing a discharge model and using it to derive an effective PFW disposal scheme for the Blacktip PFW; and
- predicting the fate and effect of the PFW once it has been discharged.

1.4 IRC

IRC is an independent consultancy providing a variety of services to the mining, oil and gas exploration, production and financial industries. IRC's methods and tools have been developed to enable rapid, confident decision making, and to recognise the key decision criteria necessary to minimise risk and maximise value. IRC has an overall objective of assisting our clients improve their performance and increase the value of their assets. This is achieved by improving:

- safety performance through reducing the risk/cost associated with injury/fatality;
- environmental performance through reducing environmental damage and clean up costs;
- production performance through optimising production uptime and availability;
- health performance through implementation of organisation cultural assessment and change programs, including the Peak Performance Program; and
- information system performance through development, integration, implementation and support of stable and secure business systems.

Figure 1.1 Location of the Blacktip Gas Field and associated infrastructure (from WEL)

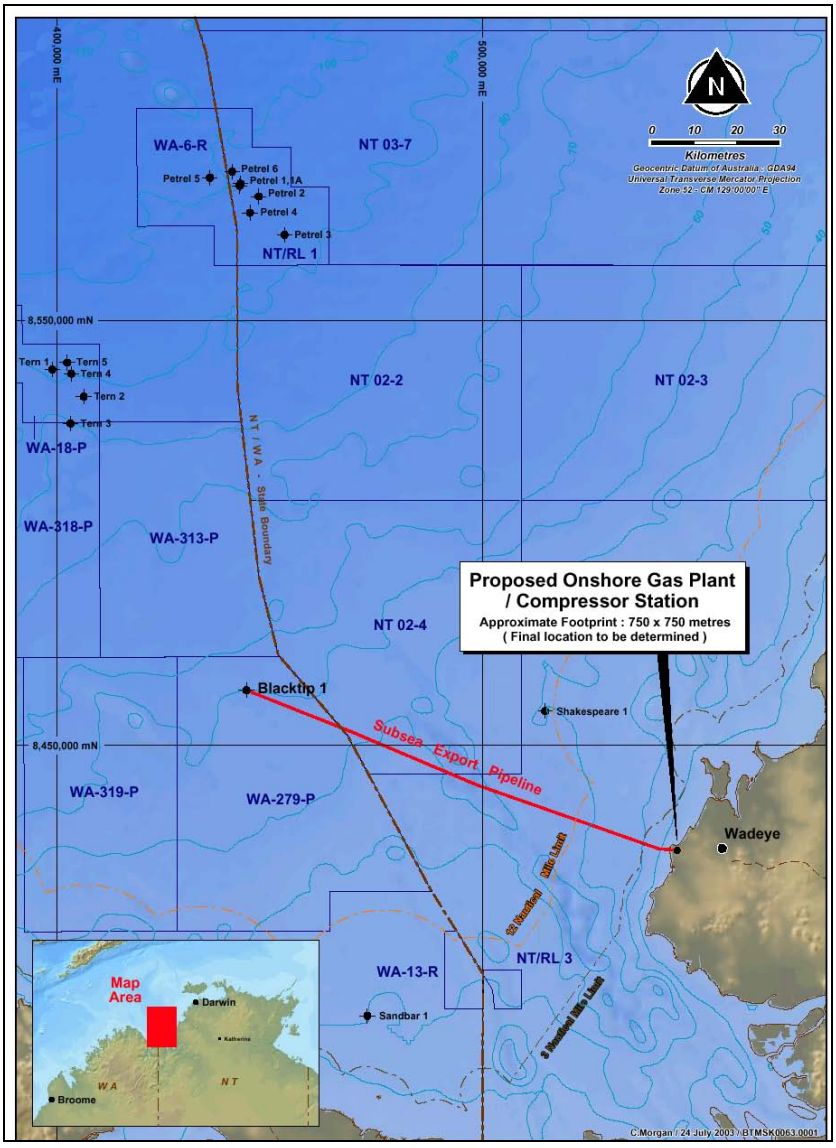
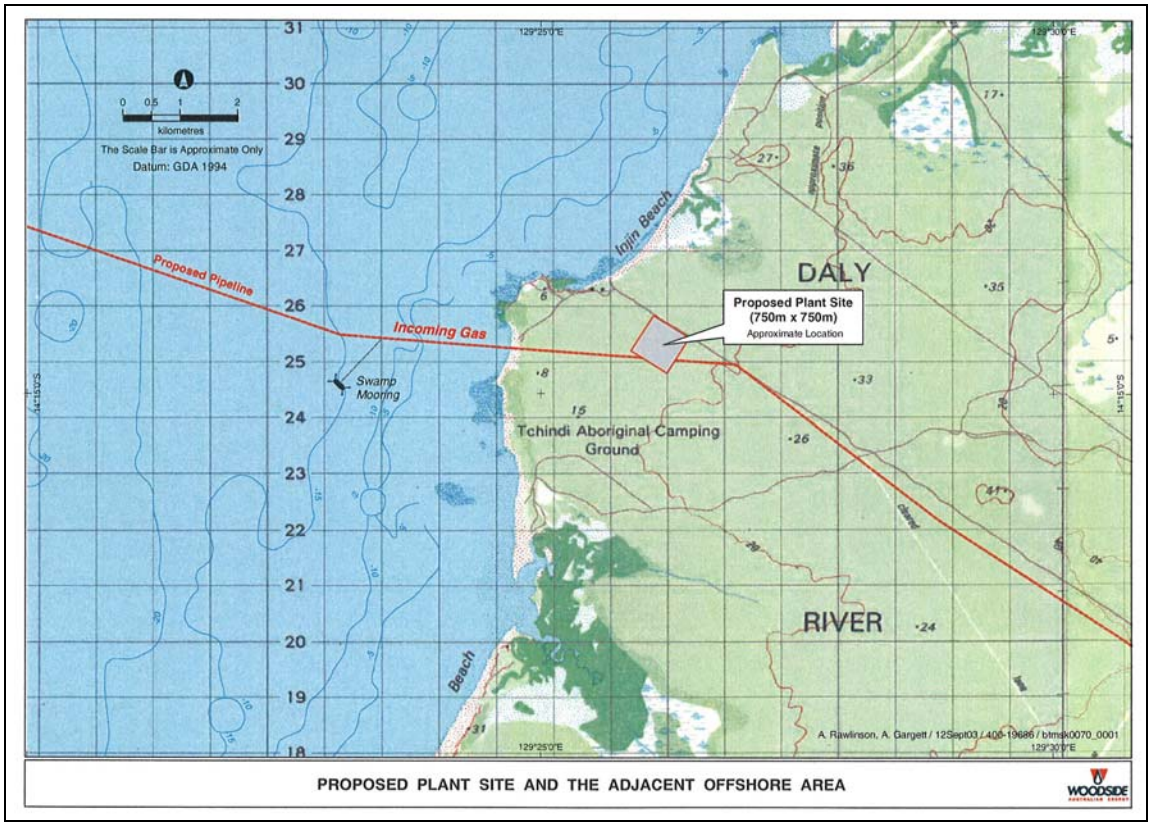


Figure 1.2 Shoreline crossing and proposed plant site (from WEL)



2 PRODUCED FORMATION WATER CHARACTERSITICS

2.1 Introduction

2.1.1 Overview

PFW (also referred to as produced water or formation water) is the waste water that is separated from the production stream during oil and gas production operations. For oil production fields the largest constituent is typically fossil water, the water found with the oil and gas inside the geological reservoir. However in gas and condensate wells, it is generally associated with saturation water that condenses due to the pressure drop between the reservoir and surface. As the reservoir matures, fossil water may be introduced and volumes of PFW tend to increase.

It is common practice throughout the offshore industry to physically separate the water from the well fluids and then dispose of the water directly to the ocean. This separation is not 100% effective and the PFW often contains small amounts of naturally occurring contaminants including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons, organic acids and phenols), inorganic compounds and residual process chemicals. Although only small concentrations of these compounds are released, the continuous discharge of large PFW volumes gives rise to environmental concern. Accordingly, most of the world's national or regional regulatory authorities set limits on the concentration of petroleum hydrocarbons (or total oil and grease) that can remain in PFW for ocean disposal. Many regulators also require that environmental impact assessments be undertaken to fully evaluate the risk.

The chemical composition of PFW varies over a wide range and depends mainly on attributes of the reservoir geology. The composition of PFW may also change slightly through the production lifetime of the reservoir. Compared to oil production fields, PFW from gas/condensate fields generally have higher hydrocarbon contents due to technical difficulties in separating condensate and water and also due to the higher aromatic content of condensate. However, the total volume of water produced from gas fields is much smaller than from oil production fields. Many gas fields discharge less than $10m^3$ of PFW per day whilst most oil fields discharge hundreds or even thousands of cubic metres per day.

2.1.2 Previous Studies

In 2002 WEL undertook a comprehensive study of PFW discharges from their assets on the North West Shelf and Timor Sea (IRCE, 2003a-e). These assets included:

- North Rankin 'A' (NRA);
- Goodwyn 'A' (GWA);
- Cossack Pioneer (CP);

- Ocean Legend (OL); and
- Northern Endeavour (NE).

The study consisted of:

- characterising the chemical composition of the PFW;
- ecotoxicology; and
- dispersion and risk assessment modelling.

The results from these studies will be applied here. There are numerous other studies in the scientific literature and excellent reviews of these are given in Swan *et al*. (1994) and, more recently, in Neff (2002).

2.2 Chemical Composition of PFW

2.2.1 Introduction

The chemical composition of PFW has been described extensively by several authors (see for example Neff, 2002; OGP, 2002; DK, 2001; Roe Utvik, 1999 and Flynn *et al.,* 1996) and operators in the North Sea report regularly on the composition and volumes of their discharges (see UKOOA, 2002; OGP, 2002 and DK, 2001).

Prior to production, it is difficult to predict the exact composition or toxicity of Blacktip PW, however, based on knowledge of other PW in the region and also worldwide, it is likely to contain trace concentrations of:

- petroleum hydrocarbons;
- phenols;
- organic acids;
- metals;
- radioisotopes; and
- residual process chemicals.

This Section introduces the chemical characteristics of each of these constituents and presents typical concentrations from oil and gas production facilities around the world.

2.2.2 Petroleum hydrocarbons

Petroleum hydrocarbons are the organic components of greatest environmental concern in PFW. These compounds contain only carbon and hydrogen atoms, with the carbon atoms linked by single or double covalent bonds to form linear branched and cyclic hydrocarbons. In aliphatic hydrocarbons all carbon-carbon bonds are single. Aromatic hydrocarbons are composed of six carbon rings in which six carbon atoms equally share nine covalent bonds.

The aqueous solubility of petroleum hydrocarbons decreases as their molecular weight increases. As oil/water separator equipment is efficient in removing oil droplets from the PFW but not dissolved oil, most of the petroleum hydrocarbons remaining after treatment are low molecular weight aromatic and aliphatic hydrocarbons that are dissolved in the PFW.

Aliphatic hydrocarbons

Aliphatic hydrocarbons are carbon structures without any aromatic nucleus. They are further divided into alkanes, alkenes and alkynes. The alkanes are the major group in crude oil. Alkanes have the general formula C_nH_{2n+2}. In crude oil they cover a broad range from methane (CH_4) which is a gas at normal conditions to heavy components like n-tetracontane ($C_{40}H_{82}$) or even heavier, which are solid compounds at normal conditions. The essential characteristic of alkane hydrocarbon molecules is that only single covalent bonds are present. In these compounds, the bonds are said to be saturated thus the alkanes are also known as the saturated hydrocarbons.

Low molecular weight alkanes are volatile whilst those with more than 16 carbons have an extremely low aqueous solubility. The most abundant alkanes found in PFW are therefore in the C13 to C16 range. It is likely that the higher molecular weight alkanes are in colloidal form or associated with dispersed oil droplets not removed by the oil/water separator.

Due to technical difficulties with separating condensate from water, aliphatic hydrocarbon concentrations in PFW are generally higher from gas/condensate fields than they are from oil fields. The average concentration from North Sea gas installations was 242mgL^{-1} in 2001 (UKOOA, 2002). This compared with 52mgL^{-1} from oil installations. However, most gas installations have concentrations of less than 40mgL^{-1} and the average value is enhanced by a few installations reporting very high concentrations (up to 700mgL^{-1}).

Aromatic hydrocarbons

Aromatic hydrocarbons are carbon structures with double bonding in all positions and the carbon skeleton arranged in planar six-rings. The most typical example is benzene (C_6H_6). The structure can include more than one six-ring-structure, e.g. naphthalene which has two rings ($C_{10}H_8$), and phenanthrene, which has three rings ($C_{14}H_{10}$). In environmental investigations structures with up to six rings are included, but structures with more rings exist. The rings are often alkylated with methyl groups and in some crude oils the content of the alkylated aromatic is an order of magnitude higher than the content of the pure aromatic hydrocarbon.

The aromatic hydrocarbons are grouped into:

- monoaromatic hydrocarbons (MAHs); and
- polyaromatic hydrocarbons, (PAHs).

PAHs contain three or more aromatic rings. The two ring hydrocarbons are not included in either of these groups, however, in practice they are grouped with the PAHs.

Monocyclic aromatic hydrocarbons

MAHs have one aromatic ring that may be alkylated. The most common compounds and those of most concern in the environment are:

- benzene (C_6H_6), without any substitutes;
- toluene, (C_6H_5-CH_3) with one methyl substitute;
- ethyl benzene, (C_6H_5-C_2H_5), with one ethyl substitute; and
- xylene (C_6H_4-$(CH_3)_2$), with two methyl substitutes, which can be placed in three different positions and therefore there are three isomers.

These hydrocarbons are often named by the combined abbreviation BTEX. There are higher alkylated MAHs, with three and four carbons alkylated, but normally they are not specified or determined individually. The BTEX compounds are more soluble in water than other hydrocarbons and are generally the most abundant in PFW.

Ranges of BTEX concentrations in PFW from oil and gas facilities in the North Sea are given in Table 2.1. Concentrations may range from 0.042mgL^{-1} to as high as 2,244mgL^{-1}. PFW from gas wells usually contain higher concentrations of BTEX than oil wells due to the higher aromatic content of the condensate and gas produced. Benzene is often the most abundant BTEX compound in effectively treated PFW, followed by toluene. Ethyl benzene and the three xylene isomers are usually present at only a small fraction of the concentrations of benzene and toluene. A large number of C3- and C4- benzene isomers may also be present, usually at low concentrations.

Table 2.1 Concentration ranges of BTEX compounds in PFW from oil and gas fields in the North Sea (1999 – 2001) (from OGP, 2002)

	Oil (mgL^{-1})	Gas (mgL^{-1})
Norway	0.7 – 24.1	1.9 – 36
UK	<0.5 - 34	0.5 – 2,244
Holland	0.042 – 4.8	0.01 – 1,164
Denmark	8.7 - 14	N/A

N/A – Not available

Table 2.2 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea. Values range from 29.4mgL^{-1} at NRA to 3.3mgL^{-1} at GWA.

Table 2.2 BTEX concentrations measured in PFW from Woodside's Assets in 2002 (from IRCE, 2003a–e)

Compound	Concentration (mgL^{-1})				
	NRA	GWA	CP	OL	NE
Benzene	7.3	1.2	1.3	2.3	0.7
Toluene	13.0	1.3	1.9	3.6	1.3
Ethyl Benzene	0.8	0.1	0.2	<0.2	0.3
Xylenes	8.3	0.7	1.1	3.3	1.5
Sum BTEX	**29.4**	**3.3**	**4.5**	**9.2**	**3.8**

Notes: Measured by PID/FID (USEPA 5030B, 8020A and 8260)

Polycyclic aromatic hydrocarbons

PAHs cover a broad range of compounds, which may be formed by a variety of mechanisms (Neff, 1979), such as:

- very rapid, high temperature (700°C) incomplete combustion or pyrolisis of organic materials (pyrogenic PAHs);
- very slow (millions of years) rearrangement and transformation of biogenic organic materials at moderate temperatures of 100-300°C to form fossil fuels (petrogenic PAHs);
- relatively rapid (days to years) transformation of certain classes of organic compounds in soils and sediments (diagenic PAHs); and
- direct biosynthesis by organisms (biogenic PAHs).

In environmental investigations it is common to measure the 16 PAH defined by the list of Priority Pollutants from the United States Environmental Pollution Authority (USEPA) (see Table 2.3). These 16 compounds are all full aromatic hydrocarbons without any substitutes. In crude oil, alkyl homologues usually are more abundant than the parent PAHs, however, this often is not so in PFW because of the decreasing aqueous solubility with increasing PAH alkylation, favouring retention in the oil phase.

Concentrations of total PAHs in PFW typically range from about $0.04mgL^{-1}$ to $3.0mgL^{-1}$ (Neff, 2002). Naphthalene and occasionally phenanthrene (three fused aromatic rings) and their alkyl homologues are the only PAHs that are present at higher than trace concentrations. These low molecular weight PAHs usually represent 95% of the total PAHs in PFW.

Four to six ring PAHs, some of which are phototoxic, mutagenic and carcinogenic, are rarely detected in PFWs that meet effluent standards for oil and grease. For example, the carcinogenic benzo(a)pyrene is rarely present in PFW at concentrations greater than about $0.1\mu gL^{-1}$. The aqueous solubility of benzo(a)pyrene is so low and its affinity for the oil phase

so high that it would not be expected to be present in PFW in dissolved form. Despite the low level measurements of PAHs in PFW, there is ongoing concern about the environmental effects of such components in the marine environment.

Table 2.3 The 16 USEPA priority PAHs

Compound	No. of rings
Naphthalene	2
Phenanthrene	3
Acenaphthylene	3
Acenaphthene	3
Fluorene	3
Anthracene	3
Fluoranthene	4
Pyrene	4
Benz(a)anthracene	4
Chrysene	5
Benzo(b)fluoranthene	5
Benzo(k)fluoranthene	5
Benzo(a)pyrene	5
Indeno(1,2,3-c,d)pyrene	5
Dibenz(a,h)anthracene	5
Benzo(g,h,i)anthracene	6

The concentration ranges of naphthalene, phenanthrene and dibenzothiophene (NPD) and other PAH compounds in PFW from oil and gas facilities in the North Sea are given in Table 2.4. Concentrations of NPD range from 0.001mgL^{-1} to10.4 mgL^{-1}. Concentrations of other PAHs range from 0. 0004mgL^{-1} to 4.125mgL^{-1}.

Table 2.4 Concentration range of NPD and other PAH compounds in PFW from oil and gas fields in the North Sea (1999 – 2001) (from OGP, 2002)

	NPD[1]		PAH[2]	
	Oil (mgL^{-1})	Gas (mgL^{-1})	Oil (mgL^{-1})	Gas (mgL^{-1})
Norway	0.8 – 10.4	0.24 – 0.8	0.001 – 0.13	0.003 – 0.05
UK	0.007 – 0.74	0.001 – 0.74	0.002 – 0.12	0.0004 – 0.23
Holland	N/A	N/A	0.0026 – 0.1545	0.002 – 4.125
Denmark	0.22 – 0.436	N/A	0.12 – 0.285	N/A

[1] including C1 – C3 alkyl homologues; [2] 16 USEPA PAH other than naphthalene and phenanthrene; N/A – not available

Studies of one specific field over a period of one week show that there is little variation in composition of aromatic hydrocarbons over that time span (OGP, 2002). Results from the Norwegian database also show that composition of PFW is relatively constant from one year to another at individual fields (OGP, 2002).

Table 2.5 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. Values of NPD range from 0.67mgL^{-1} at NRA to 0.15mgL^{-1} at GWA. Of the other PAHs, only fluorene was detected in OL and NE PFW at 0.021mgL^{-1} and 0.018mgL^{-1}, respectively.

Table 2.5 PAH concentrations measured in PFW from Woodside's Assets in 2002 (from IRCE, 2003a–e)

Compound	Concentration (mgL^{-1})				
	NRA	GWA	CP	OL	NE
NPD[1]	0.670	0.150	0.304	0.568	0.537
Other PAHs[2]	ND	ND	ND	0.021[3]	0.018[3]

Notes: Measured by GC-MS in SIM mode (USEPA 3550B, 8270); [1] including C1 – C3 alkyl homologues; [2] 16 USEPA PAH other than naphthalene and phenanthrene; [3] fluorene; ND – Not Detected;

2.2.3 Phenols

Phenol is a hydroxy derivative of benzene with the formula C_6H_5OH. The five aromatic carbons not bonded to the hydroxyl group readily react with methyl carbons to form methyl phenol (alkyl phenols) and with halogens to form a wide variety of halogenated phenols. Phenol, alkyl phenols and to a lesser extent halogenated phenols are natural components of the environment. Many different phenols are synthesized by a wide variety of bacteria and fungi, plants and animals. Phenols can be formed from the oxidation of benzene. The most abundant phenols in many crude oils are the C2 through C9 alkyl phenols. However, phenol solubility decreases with increasing alkylation so PFW rarely contains detectable concentrations of the more highly alkylated phenols.

The most complete analysis to date of phenols in PFW are those from three production facilities in Indonesia (Neff and Foster, 1997) and five in the Norwegian sector of the North Sea (Roe Utvik, 1999). Phenols with up to five alkyl carbons were detected and total phenols ranged from 0.36mgL^{-1} to 16.83mgL^{-1} (Table 2.6).

Table 2.7 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. Phenols with up to three alkyl carbons were detected. Both NRA and GWA had relatively high total concentrations at 15.4mgL^{-1} and 17.3mgL^{-1}, respectively. Concentrations at CP, OL and NE were much lower at less than 2.1mgL^{-1}.

Table 2.6 Concentration of phenol and different alkylphenol groups in PFW from three production facilites in Indonesia and five production facilities in the Norwegian Sector of the North Sea (from Neff, 2002)

Chemical	Indonesian PFW (mgL^{-1})	North Sea PFW (mgL^{-1})
Phenol	0.67 – 2.49	0.007 – 7.0
C_1-Phenols	0.77 – 1.69	0.011 – 6.78
C_2-Phenols	0.58 – 1.10	0.19 – 2.51
C_3-Phenols	0.30 – 0.59	0.064 – 0.60
C_4-Phenols	0.13 – 0.37	0.077 – 0.43
C_5-Phenols	0.04 – 0.09	0.007 – 0.02
C_6-Phenols	ND	ND
C_7-Phenols	ND	ND
C_8-Phenols	ND	ND
C_9-Phenols	ND	ND
Total Phenols	2.49 – 6.33	0.36 – 16.83

ND – Not Detected

Table 2.7 Concentration of phenol and different alkylphenol groups measured in PFW from Woodside's assets in 2002 (from IRCE, 2003a–e)

Chemical	NRA	GWA	CP	OL	NE
Phenol	4.00	2.90	0.73	0.03	0.25
C_1-Phenols	7.70	6.60	0.94	0.17	0.21
C_2-Phenols	3.33	6.34	0.36	0.17	0.06
C_3-Phenols	0.37	1.49	0.03	ND	ND
C_4-Phenols	ND	ND	ND	ND	ND
C_5-Phenols	ND	ND	ND	ND	ND
C_6-Phenols	ND	ND	ND	ND	ND
C_7-Phenols	ND	ND	ND	ND	ND
C_8-Phenols	ND	ND	ND	ND	ND
C_9-Phenols	ND	ND	ND	ND	ND
Total Phenols	**15.40**	**17.33**	**2.06**	**0.36**	**0.51**

Notes: Measured by GC-MS (USEPA 8270 modified); ND – Not Detected

2.2.4 Organic acids

Much of the total organic carbon (TOC) in PFW consists of organic acids. These are thought to have been produced by hydrous pyrolysis of kerogen and hydrocarbons in the source rocks and hydrocarbon-bearing formation (Neff, 2002). Most of the organic acids are short chain aliphatic monocarboxylic acids, such as acetic (C_2), propionic (C_3), butyric (C_4) and valeric (C_5) acids. Concentrations tend to decrease with molecular weight with the most abundant acid usually being acetic acid.

2.2.5 Metals

PFW may contain several metals in solution. The metals present and their concentrations are extremely variable, depending on the age and geology of the formation from which the oil and gas are produced. There is usually a poor correlation between concentrations of metals in crude oil and the water produced with it (Neff, 2002).

Metals are classified as alkali and alkaline earth metals (sodium, potassium, magnesium, calcium, strontium and barium) and heavy metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver and zinc). The alkali and, to a lesser degree, the alkaline earth metals are very reactive. Hence they never occur in elemental form and are found combined with halide, sulphate, carbonate or silicate ions. In this form they are not considered toxic and water quality guideline values for these metals do not exist. The heavy metals are considered toxic and, with the exception of iron and silver, USEPA marine quality criteria and Australian and New Zealand Environment and Conservation Council (ANZECC) guideline trigger values exist.

Generally, heavy metal concentrations in PFW are very low (typically $<0.5 mgL^{-1}$ – $1.0 mgL^{-1}$ (UKOOA, 2002). The metals most frequently present in PFW at elevated concentrations include: barium, chromium, copper, iron, lead, nickel and zinc. Usually only a few of these metals are present at elevated concentrations in a particular PFW sample. Table 2.8 shows the concentration ranges of heavy metals from North Sea samples taken between 1999 and 2001 (UKOOA, 2002). These are average ranges and higher concentrations at individual facilities were detected.

Table 2.9 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. In general heavy metal concentrations were low and not considered to be an environmental hazard.

Table 2.8 Concentration range of heavy metals in PFW from oil and gas fields in the North Sea (1999 – 2001) (from UKOOA, 2002)

	Heavy metal Concentrations	
	Oil (mgL^{-1})	Gas (mgL^{-1})[1]
Arsenic	0.679 – 1.300	0.030 – 0.414
Cadmium	0.145 – 0.313	0.033 – 0.097
Chromium	15.4 – 20.1	0.005 – 0.140
Copper	0.072 – 2.620	0.020 – 0.164
Lead	1.959 – 3.524	0.890 – 3.865
Mercury	0.045 – 0.157	0.008 – 2.630
Nickel	21.0 – 24.6	0.016 – 0.120
Zinc	16.0 – 26.0	11.002 – 14.640

[1] annual average concentrations from 35, 27 and 21 North Sea gas platforms in 1999, 2000 and 2001, respectively.

Table 2.9 Concentration range of heavy metals in PFW from WEL's Assets (IRCE, 2003a-e)

	Heavy metal Concentrations (mgL^{-1})				
	NRA	GWA	CP	OL	NE
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	0.0080	0.0200	0.0260	0.0270	0.0200
Copper	<0.005	<0.005	0.0060	0.0100	<0.005
Lead	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury	<0.0001	0.0001	<0.0001	<0.0001	0.0002
Nickel	<0.005	0.0110	<0.005	<0.005	<0.005
Zinc	0.0230	0.0100	0.0110	0.0320	0.0270

Notes: Measured by Atomic Absorption Spectrometry.

2.2.6 Radioisotopes

Several naturally occurring radioactive materials (NORMs) occur in PFW. The most abundant, because of their relatively long half lives, are radium-226 and radium-228 (^{226}Ra and ^{228}Ra). Radium is derived from the radioactive decay of uranium and thorium associated with certain rocks and clays in the hydrocarbon reservoir. The half-lives for ^{226}Ra and ^{228}Ra are 1,620 and 5.76 years, respectively. They decay through several intermediates to stable ^{207}Pb and ^{208}Pb, respectively. Typical total radium concentrations in PFW range from $0BqL^{-1}$ to $190BqL^{-1}$ (Neff, 2002).

2.2.7 Process Chemicals

Large numbers of speciality additives are available for use in the production system of a well to aid in recovery and pumping of hydrocarbons, protect the production system from corrosion and facilitate separation of oil, gas and water. The number of additives used in a particular production system is usually low and depends on the particular production problems encountered in the well. They could include:

- biocides;
- corrosion inhibitors;
- scale inhibitors;
- oxygen scavengers;
- demulsifiers;
- emulsifiers;
- coagulent/deoiler;
- flocculant;
- antifoam agent;
- dispersants;
- thinners;
- viscosifiers;
- surfactants/detergents; and
- hydrate inhibitors.

Three process chemicals will be added to the Blacktip system. These are:

- Corrosion Inhibitor;
- Methanol/Mono Ethylene Glycol; and
- Demulsifier/coagulant.

2.3 Fate of PFW in the Marine Environment

2.3.1 General

An understanding of the processes involved in changing the nature and behaviour of the individual compounds in PW is essential to predict their fate and impact. This section describes some of the processes that PFW undergoes when discharged to the ocean and introduces the mechanisms by which marine organisms bioaccumulate contaminants.

2.3.2 Degradation processes

Upon discharge contaminants in the PFW undergo a number of degradation or weathering processes, including:

- dilution;
- evaporation of volatile components;
- adsorption to particles and sedimentation;
- biodegradation; and
- photodegradation.

Collectively, these processes tend to decrease the concentration of chemicals in the PFW plume and thereby decrease its toxicity to marine organisms. However, weathering is a complex process and difficult to predict with accuracy. It may produce new chemicals or

result in speciation of chemicals in the mixture to forms that are more bioavailable and toxic than the original chemicals. Therefore, it is possible that PFW may not lose toxicity and could even increase in toxicity during the weathering process (Neff, 2002). Furuholt (1996) suggests that these transformation processes are more likely to cancel each other out for mixtures with more than five toxicants.

Plume behaviour is unique to each platform, however, Burns, *et al*. (1999) provide an estimated mass balance (within 900m) for petroleum hydrocarbons discharged daily from Harriet 'A', a shallow water platform in 22m of water on the North West Shelf of Australia. They estimate that 37% of hydrocarbons are dissolved and 36% become attached to suspended particles (11% of which settle and 25% remain suspended). Dispersion, photodegradation and biodegradation accounts for 24% and evaporation just 3%.

For Blacktip, dilution is likely to be the most effective process for reducing the inorganic and organic contaminants. Evaporation will also be important for removing volatile components. In experiments, Flynn *et al*. (1996) demonstrated that sparging had little effects on volatile fatty acids, however, it removed some of the phenols (<50%) and over 90% of BTEX and PAH compounds. Toxicity did not reduce significantly, suggesting, for that particular sample, volatile compounds were not necessarily the most important in determining the overall toxicity of the PFW. Adsorption of dispersed oil and heavier chemical components onto particles is not likely to be an issue for Blacktip as the PFW should contain mainly low molecular weight compounds. Sedimentation of hydrocarbon compounds from PFW is not generally thought to be a problem as suspended particles would be spread over a wide area meaning that concentration build up in the sediments is likely to be extremely low and probably of no significance (Furuholt, 1996). Biodegradation will occur over longer time scales (greater than one day) and is important for reducing possible chronic toxicity effects. As dilution and biodegradation are the most important processes for Blacktip they are described in more detail in the following two subsections.

2.3.3 Dilution

Dilution is divided into two phases: the jet phase which is the initial, rapid dilution; and, the ambient phase which is the slower, far-field dilution (North Sea PFW and Effect Task Force 1994). PFW discharges are generally less dense than seawater. Unless there is adequate dilution at the point of discharge, a surface slick will form providing visual evidence of the discharge. Slicks may also be discoloured and give rise to odour problems. The presence of petroleum hydrocarbons in the effluent can enhance slick formation. Once a dense slick has formed, mixing is inhibited and advection can transport the poorly diluted effluent to environmentally sensitive areas where it can exert an undesirable effect.

Slick prevention requires adequate dilution for the discharge and initial dilution standards apply to marine outfalls. Initial dilution is defined as the number of dilutions received by an effluent from the time it leaves the diffuser port to the time it makes impact with either a submerged or surface field. Two forces are responsible for the enhanced dilution in the near field:

- the momentum of the discharge; and
- the buoyancy resulting from the density difference between the effluent and the receiving waters.

Studies have shown that slick formation can be prevented with an initial dilution of 100:1. Saline PFWs dilute rapidly upon discharge to well-mixed marine waters. Smith (1993), Terrens and Tait (1993), Stromgren *et al*. (1995) and Brandsma and Smith (1996) all predict a rapid initial dilution of discharges by 30- to 100-fold within the first few tens of metres of the outfall, followed by a slower rate of dilution at greater distances. Mixing is less rapid for positively buoyant or for high volume discharges (see for example Smith *et al*., 1996).

In most marine environments, current speeds and directions are not constant as they are driven by a variety of forces such as tide, wind and regional circulations. Under these conditions, the distribution and concentration of a PFW plume is observed to be highly variable over time and space (see Smith *et al*., 1996; Terrens and Tait, 1996; King and McAllister, 1998).

2.3.4 Biodegradation

A wide range of marine micro-organisms are able to utilise organic matter as an energy source in the natural environment. Low molecular weight, soluble hydrocarbons and organic acids are utilised particularly rapidly, as these classes of compounds occur ubiquitously in the environment and micro-organisms have evolved to degrade them efficiently. The importance of biodegradation in the destruction of organic chemicals in PFW plumes depends primarily on the persistence of elevated concentrations of the organic chemicals in the plume and the pre-adaptation of the local microbial community for resistance to and biodegradation of PFW chemicals (Neff, 2002). As a general rule, linear hydrocarbons are more easily biodegraded than aromatic hydrocarbons (Neff, 2002).

Biodegradation experiments performed by Stromgren *et al*. (1995) and Roe Utvik (1996) with PFW from the North Sea have provided valuable information about the marine environmental fate of some organic components of PFW. They showed that whilst low molecular weight aliphatic and aromatic hydrocarbons tend to evaporate rapidly from the PFW mixtures, many of the medium molecular weight aromatic hydrocarbons and phenols are biodegraded by indigenous microbiota in seawater. Higher molecular weight organic components, as well as heterocyclic compounds may be resistant to biodegradation and persistent in the plume. In the field, these compounds are lost primarily by dilution and adsorption on to suspended particles, particularly living and dead organic matter (Neff, 2002). Due to the differential rate

of biodegradation the relative concentrations of the different hydrocarbons remaining in seawater after discharge will vary over time.

Experiments by Flynn *et al*.(1996) showed that after eight days, over 99% of phenols and PAHs were degraded, and BTEX was reduced to below detection limits. Toxicity, as measured by Microtox®, was also reduced from 8.6% PFW to 100% PFW, suggesting that the components responsible for the initial toxicity are readily biodegradable. Biodegradation rates for individual components in PFW are given in Johnsen *et al*. (2000) (see Table 2.10).

Table 2.10 Biodegradation rates for PFW compound groups (from Johnsen *et al*., 2000)

Group	Main Group	Biodegradation rate 1/2 life (days)
1	BTEX	0.5
2	Naphthalenes	1.5
3	PAH 2-3 ring	17
4	PAH 4-ring +	350
5	Alkyl phenols C0 – C3	1.2
6	Alkyl phenols C4+	10
7	Aliphatic hydrocarbons	60
8	Metals	None
10	Organic acids	Not included
11-n	Process Chemicals	Specific data

2.3.5 Biochemical Oxygen Demand

Biological oxygen demand (BOD) is a measure of the rate at which oxygen is consumed by bacterial activity in the water and thus is an indirect measure of the organic content of wastewater. BOD concentrations in PFW can be high. However, in the ocean where dissolved oxygen is abundant, demand is met quickly. It is estimated that in any area where BOD levels deviate by <1.5mgL^{-1} from background levels, the resulting impact on dissolved oxygen levels will be <0.5mgL^{-1} (CSTT, 1993). A change of 0.5mgL^{-1} can be assumed to cause no adverse effect. The Australian guidelines (ANZECC, 2000) are slightly less conservative stating that that dissolved oxygen (DO) should not normally be permitted to fall below 90% saturation, this being determined over at least one diurnal cycle. For the current project a BOD value below 1.5mgL^{-1} is taken as the threshold below which there should be no adverse impact on oxygen concentrations.

2.3.6 Bioaccumulation mechanisms

Bioavailability

A contaminant can have no effect on an organism unless it is bioavailable, ie, in a form that can move through or bind to a surface coating (e.g. skin, gill epithelium, gut lining, cell membrane) to prevent it from functioning properly. As a general rule, hydrocarbons in solution are most bioavailable followed by those in tissues of marine organisms or associated with liquid oil droplets (Neff, 2002). The bioavailability of hydrocarbons decreases sharply with increasing carbon chain length and molecular weight.

Bioaccumulation

Aquatic biota do not only degrade pollutant chemicals, they may also accumulate them. Bioaccumulation is the uptake and retention of bioavailable chemicals from any one of, or all possible external sources (water, food, substrate, air). For bioaccumulation to occur, the rate of uptake from all sources must be greater than the rate of loss of the chemical from the tissues of the organism. The bioaccumulation factor (BAF) is the ratio of the concentration of the chemical in the tissues of the organism to its concentration in all ambient environmental compartments in equilibrium with the organism.

Bio-concentration

Bio-concentration is a special case of bioaccumulation as it is defined as uptake and retention of a chemical from water alone as opposed to all possible external sources. It is measured by the bio-concentration factor (BCF), which is the ratio at equilibrium of the concentration of a chemical in the tissues of the organism (C_t) to the concentration of the chemical in solution in the water (C_w) to which the organism was exposed. The BCF can also be measured as the ratio of the uptake rate constant or uptake clearance (k_1) to the release rate constant (k_2).

$$BCF = C_t/C_w = k_1/k_2$$

Non-polar (un-ionisable) organic compounds such as aromatic hydrocarbons generally have a low aqueous solubility and a high lipid solubility. According to equilibrium partitioning theory, when an animal is exposed to a non-polar organic chemical dissolved in ambient water, the chemical partitions into tissue lipids until an equilibrium, approximated by the octanol/water partition coefficient (K_{ow}), for the chemical is reached. It is possible to predict the equilibrium BCF for a particular non-polar organic compound from its log K_{ow}, (if underlying assumptions are met) as follows:

$$\text{Log BCF} = a \log K_{ow} + b$$

EPA (1991) recommends using a = 0.79 and b = -0.4, from the experiments of Veith and Kosian (1983). This provides a conservative estimate of the potential for bio-concentration of non-polar organic chemicals. The BCF for polar (ionisable) compounds, such as phenols, is generally higher if ionised, however, their behaviour will be similar to un-ionisable organic chemicals if they remain un-ionised at the pH and salinity of seawater.

Bioaccumulation of metals by marine organisms is more complex than for organic chemicals. Concentrations of heavy metals in Blacktip PFW should be low and therefore bioaccumulation of this class of chemical is not considered to be an issue.

Trophic Transfer

Marine animals are able to bioaccumulate most bioavailable forms of metals and organic contaminants from their food. Bioaccumulation of chemicals from food is called trophic transfer. Biomagnifcation is the process whereby a chemical, as it is passed through a food chain or food web by trophic transfer, reaches increasingly higher concentrations in the tissues of animals at each higher trophic level. The biomagnification factor (BF) can be defined as the ratio of the concentration of a contaminant in the tissues of the consumer to its concentration in the food.

2.4 Environmental Fate of Individual PFW components

2.4.1 General

This section described how the individual components described previously behave when discharged to the marine environment.

2.4.2 Oil compounds

Dissolved Oil

Dissolved oil in PFW (predominantly aliphatics, BTEX, low molecular weight PAHs and phenols) will dilute readily into the receiving water and be dispersed by the ambient currents. These compounds are bioavailable to marine organisms and will biodegrade rapidly. While they may bioaccumulate at lower trophic levels, vertebrates including fish have detoxification mechanisms that break hydrocarbon compounds down. They are also volatile and will evaporate if they reach the sea water surface and come into contact with the atmosphere. They do not adsorb strongly to suspended particles so are unlikely to be transported to the sea bed.

Dispersed Oil

Oil compounds associated with oil droplets will either follow the plume or be retained at certain depths in the water column depending upon their buoyancy and turbulence. Vertical turbulence generated by wind shear and wave action will mix oil droplets with diameters less than about 100µm into the water column. These smaller droplets tend to float back to the surface only very slowly where they are repeatedly forced back into the water column. In this case, they are considered to be permanently dispersed. Larger oil droplets remain at the sea surface where they will spread to form a thin micro-layer (sheen) that in calm water is typically less than 1µm thick. The micro layer is then splintered and dissipated through evaporation and surface turbulence. Surface turbulence breaks the micro-layer into smaller sized droplets which causes dispersal through the water column. Once hydrocarbons have

been dispersed into the water column as fine droplets they may be removed through adsorption to particles followed by sedimentation and biodegradation, as described above.

Polycyclic Aromatic Hydrocarbons

Overview

PAHs are the petroleum hydrocarbon of greatest environmental concern in PFW because of their toxicity and persistence in the marine environment (Neff, 1987). The wide range of solubilities and partition coefficients exhibited by the different PAHs means that they exhibit a wide spectrum of behaviour (Neff, 2002). The most common PAHs (naphthalene, alkylnaphthalenes, fluorene and phenanthrene) are soluble and have relatively high Henry's law constants and tend to evaporate where possible from the water. Higher molecular weight PAHs are less soluble and are expected to be associated with particulates and the oil droplets in the PFW. These will partition primarily between the aqueous and solid (particulate) or colloidal phases according to their organic carbon/water partition coefficients (K_{oc}s), which are proportional to K_{ow}s. Biodegradation half lives range from readily to poorly biodegradable and vary from 1.5 days for naphthalene, 17 days for two to three ring PAHs and 350 days for more than four ring PAHs (Johnsen, *et al*., 2000).

Bioaccumulation

The PAHs in PFW may bioaccumulate and cause adverse biological effects in marine organisms near offshore oil and gas production platforms (Neff, 2002). Ordinarily, the concentrations of PAHs in receiving waters in deep offshore areas are low enough due to the rapidly diluting PFW plume to prevent bioaccumulation. In contrast, discharges to shallow, poorly mixed coastal waters may not dilute rapidly enough and marine organisms may bioaccumulate PAHs to potentially harmful concentrations.

Burns and Codi (1999) measured PAH concentrations in the water column around a platform in 22m of water on the North West Shelf of Australia. Concentrations were highly variable reflecting the variability of PAH concentrations in the PFW and the complex nature of the current regime in the area.

Typical water concentrations of naphthalenes and PAHs at 10m depth and at different distances from an oil production platform are shown in Table 2.11 (from OGP, 2002). These were calculated from mussel residue and converted to water concentrations as described in Roe Utvik *et al*. (1999). The results confirm the high dilution rates, however, they are point measurements and do not provide a complete description of fate and behaviour. Comparisons of these results with predictions from the DREAM (Dose related Risk and Effect Assessment Model) model are generally favourable, supporting and justifying the application of models for regional evaluation of PFW (OGP, 2002). The DREAM model is a random walk, particle tracking model based on the same principle as that used in the present study and described in Section 4.3.3.

Table 2.11 Water column concentrations of naphthalenes and PAHs at different distances from an oil production platform in the Norwegian Sector of the North Sea

	Concentrations (μgL^{-1})			
	In PFW	**At 500 m**	**At 2,000 m**	**At 10,000 m**
Naphthalene	1200	0.04	0.013	0.007
PAHs	33	0.004	0.001	0.0004

2.4.3 Organic acids

Organic acids biodegrade rapidly in the ambient sea water and so are unlikely to be important contributors to toxicity of PFW in the ambient environment (Neff, 2002). However, many studies attribute the acute toxicity of PFW to organic acid concentrations (eg. DK, 2001). These studies use ecotoxicology results from freshwater species which have high toxicity values. These high values are likely to be due to a pH effect rather than the actual toxic effect of the compound. Natural seawater is a buffer solution and acidity will be quickly neutralised. Organic acids are therefore not considered to be toxic in the marine environment.

2.4.4 Heavy metals

The heavy metals associated with PFW are usually present as dissolved mineral salts. Reservoir water is anoxic and the metal ions are typically in low oxidation states. However, when brought to the surface and exposed to the atmosphere they oxidise. The metal oxides then combine with anions such as sulphides, carbonates and chlorides and form insoluble precipitates. Heavy metal concentrations are generally low in PFW. Dilution in the receiving environment reduces them to background levels and well below chronic toxic thresholds. When they form precipitates, there is the potential for build up in the sediments, however, the quantity will be so low and the spread across the sea bed so wide that the environmental impact will be insignificant.

2.4.5 Radioisotopes

Upon discharge of PFW to the ocean, radium is rapidly co-precipitated with barium sulphate. Radium concentrations in ambient water near PFW discharges are rarely higher than background levels. Toxic concentrations are well above the saturation concentrations of radium in sulphate-rich seawater. Marine animals are highly tolerant to low-level radiation as might occur in the traces of radium isotopes in the vicinity of PFW discharges. Radium, because of its low concentrations in solution in seawater, has a low bioavailability to marine organisms. There is also no evidence that radium accumulates in sediments or marine animals (molluscs, crabs and fish) living in the vicinity of offshore PFW discharges (Neff, 2002).

The Brookhaven National Laboratory performed a human health risk assessment for radium in PFW discharged to the northwestern Gulf of Mexico. It concluded that radium in PFW

represents a minimal risk to even the most sensitive workers (platform crew and recreational fishermen) who consume fish from the vicinity of PFW discharges (Brookhaven National Laboratory (1992) in Neff (2002)).

2.4.6 Process Chemicals

General

The impact of process chemicals depends on the concentration at which they are discharged and the breakdown characteristics of the chemical. The initial dosage concentration range is specified by the chemical supplier and then fine-tuned by the operator to achieve optimum performance of the chemical in combination with other chemicals and the oil.

Many of these chemicals are more soluble in the oil than in PFW and remain in the oil phase. Others are water soluble and concentrate in the PFW and are disposed with it. The point in the production stream where the chemical is added influences the amount that may be discharged in the PFW. The fraction of chemical released into the water phase (f) can be estimated from the octanol/water partition coefficient (K_{ow}) as follows:

$$f = \frac{1}{\left(1 + K_{ow}\right)\left(P_o / P_{PFW}\right)}$$

where, P_o is the total oil production and P_{PFW} is the total PFW production. The concentration of the process chemical in the PFW (C_w) can then be expressed as:

$$C_w = \left(C_d f\right) - \left(C_d r\right)$$

where, C_d is the dosage concentration and r is the fraction that reacts during the production process.

Due to the variability in the characteristics of the oil and the production process, the Oslo and Paris Commission (OSPAR) use a conservative formula for determining the concentration of a chemical discharged with the PFW. Reaction during the production process is ignored and a safety factor of 10% is applied so that the concentration in the discharge is now given by:

$$C_w = \left(C_d f\right) + \left(0.1 C_d\right)$$

For process chemicals not on the Pollution control Authority A list, OSPAR require ecotoxicity data on the whole product. Testing should be undertaken on marine organisms, including an alga and a crustacean.

As stated in Section 2.2.7, the process chemicals that will be added to Blacktip are:

- Corrosion Inhibitor;
- Methanol/Mono Ethylene Glycol; and
- Demulsifier/coagulant.

Corrosion Inhibitor

Corosion inhibitor will be added to the produced fluids in order to protect the production system from corrosion. Table 2.12 provides a list of corrosion inhibitors recommended from a detailed study aimed at selecting environmentally acceptable chemicals for Blacktip (de Reus, 2004).

Table 2.12 also includes their dose rate and hazard quotient (HQ) for each chemical. The hazard quotient, calculated using the CHARM model, provides an indication of the likelihood of adverse effects occurring due to the use and discharge of the chemical under a realistic worst-case scenario. An environmental effect can be expected if the HQ is greater than one. As can be seen from Table 2.12 the HQ ranges from 0.045 to 0.977. All four chemicals are therefore environmentally acceptable.

Table 2.12 Recommended Corrosion Inhibitor chemicals

Supplier	Inhibitor	Dose rate (L/day)	HQ (hazard quotient)
Baker Petrolite	CRW-85155	50	0.977
Champion-Servo	CK-981	25	0.239
Champion-Servo	CK-988	100	0.045
Nalco	EC-1440A	50	0.130

Methanol/Mono Ethylene Glycol;

Methanol will be injected upstream of the chokes on the offshore platform to prevent hydrate formation on cold start-ups. The injection rate will be around 20-40 Lhr^{-1} for a short duration (hours).

Methanol (or possibly Mono Ethylene Glycol) may also be injected at the onshore plant in the gas processing facility for hydrate control. This would likely be injected only occasionally upstream of the Low Temperature Separator (LTS) and so some will remain in the liquid leaving the LTS and end up in the condensate processing train, and therefore the water treatment process.

Methanol is miscible in water, non-carcinogenic and poses little long term risk to the environment. It is, however, a strong reducing agent and, in the short term, has the potential for depleting oxygen in the receiving waters. This will contribute to the BOD discussed in Section 2.3.5.

Demulsifie/coagulant.

Demulsifier/coagulant will be injected in the water treatment facility to aid in the operation of the gas flotation unit. Most, if not all, of this will be removed as skimmings from the unit and will therefore not enter the PFW.

Both the corrosion inhibitor and the methanol are water soluble so the majority of these additives will end up in the PFW discharge. On discharge to the marine environment, dilution will be the main factor reducing concentrations.

2.5 Assessing Environmental Effects and Risks

2.5.1 General

An effect on an organism is a measurable biological response which reduces its survival or reproductive capacity. A sustained widespread effect may alter the ability of a population or a community to persist. The ecological significance of an effect may be considered in terms of the magnitude and nature of the change induced at individual, population, community or higher trophic levels. The social and economic significance of effect can be considered in terms of impact on recreational or commercial fishing, tourism, conservation values and the benefit to the community of the petroleum industry (Cobby, 2002).

2.5.2 Toxicity

Toxicity depends on the chemical compounds present, the exposure duration (acute or chronic), the organisms impacted and the environmental compartment. Most hydrocarbons are considered non-specific narcotic toxins and their toxicity depends on attainment of a critical volume or concentration in the tissues of aquatic organisms (Neff, 2002). The toxicity of hydrocarbons in mixtures is additive, so the toxicities of a complex mixture depends on the total concentration of bioavailable hydrocarbons and degradation products in the water to which aquatic organisms are exposed.

Acutely toxic responses have a sudden onset after or during relatively high exposure, usually for short durations: within four days for fish and macroinvertebrates and shorter times (two days) for organisms with shorter life spans. The response may be lethal or sub-lethal. Examples of sublethal effects include: impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease and other histopathological disorders. Early development stages can be especially vulnerable to hydrocarbon exposure, and recruitment failure in chronically contaminated habitats may be related to direct toxic effects of hydrocarbon contaminated sediment.

In contrast, chronic responses involve endpoints that are realised over a relatively long period of time, often one-tenth of the life span of an organism or more. A chronic toxic response is usually characterised by slow toxic progress and long continuance and may be

measured in terms of reduced growth, reproduction or fertilisation at different life stages, in addition to lethality.

Toxic concentrations are standardised as median lethal concentration (LC50s) for lethal responses or median effect concentration (EC50s) and median inhibition concentration (IC50s) for non-lethal response. Definitions for these terms are as follows:

LC50 The toxicant concentration killing 50% of exposed organisms at a specific time of observation.

EC50 The toxicant concentration estimated to cause a specified effect in 50% of exposed organisms at a specific time of observation.

IC50 The toxicant concentration estimated to cause a specified inhibition (eg. growth) in 50% of exposed organisms at a specific time of observation.

PFW from oil and gas wells vary widely in composition and toxicity to freshwater and marine organisms, confounding the development of generalisations about the causes of toxicity (Neff, 2002). This uniqueness makes it necessary to undertake site specific studies. In estimating the risk of PFW to marine organisms and ecosystems in the receiving water environment there are two different approaches:

- whole effluent toxicity (WET) testing; and
- individual component toxicity testing.

Whole Effluent Toxicity Testing

General

As its name suggests, WET testing involves undertaking ecotoxicological tests on the whole PFW sample. This method represents a toxicity value for the PFW prior to discharge to the ocean. It has the advantage that it is directly relevant to the effluent that is being discharged and it takes into consideration all chemicals in the PFW and any synergy or antagonism between them. The disadvantage is that degradation rates in the environment are unknown and are difficult to determine.

Worldwide toxicity data

Stephenson *et al*. (1994) have summarised marine and toxicity data for a large number of marine and freshwater organisms and PFW from throughout the world, particularly the North Sea (Table 2.13). Due to the extreme variability in chemical composition and toxicities of the PFW from different sources, no consistent trends between taxa and sensitivity to PFW emerge.

Table 2.13. Summary of the acute, sublethal and chronic toxicity of PFW from throughout the world to different taxa of marine and freshwater organisms (from Neff, 2002)

Taxon	Species	Test Endpoint	Test Duration (days)	EC50/LC50 (%PFW)
Algae	*Phaeodactylum tricornutum*	Growth	4	0.09 – 3.6
	Skeletonema costatum	Growth	2	4.5 – 67.6
			3	1.0 – 42.5
Coelenterates	*Campanularia flexuosa*	Growth	10	5.0
Bivalve Molluscs	*Crassostrea gigas* larvae	Mortality	2	5.0
	Mytilus californianus larvae	Shell formation	2	2.1
	Donax faba adults	Mortality	4	0.02 – 15.3
Polychaetes	*Neannthes arenaceodentata*	Mortality	4	18.1 – 28.6
Copepods	*Tisbe holothuriae*	Mortality	4	35.7 – 66.7
	Calanus finmarchicus	Mortality	1	10.0
	Arcatia tonsa	Mortality	2	2.0 – 18.0
		Reproduction	20	0.3 – 5.0
		Immobility	4	2.0
Amphipods	*Allorchestes compressa*	Mortality	4	29.4 - >100
	Chaetogammarus marinus	Mortality	4	0.2 – 3.2
Shrimp	*Penaeus aztecus* larvae	Mortality	2	0.8 – 1.2
	Penaeus aztecus juveniles	Mortality	4	6.0 – 18.3
	Penaeus aztecus adults	Mortality	4	7.8 – 17.8
	Penaeus setiferus adults	Mortality	4	7.0
	Crangon crangon adults	Mortality	1	2.0
Mysids	*Americamysis bahia*	Mortality	4	4.9 – 11.8
		Mortality	7	4.4 – 9.0
		Fecundity	7	0.7 – 7.0
Brine Shrimp	*Artemia salina*	Mortality	1	16.0 – 18.0
Barnacles	*Balanus tintinabulem*	Mortality	4	8.3
Echinoderms	*Strongylocentrotus Purpuratus gametes*	Fertilisation	1 hour	0.74 – 1.7
Fish	*Menidia beryllina* larvae	Mortality	4	>1.1 – 5.5
	Hypleurochilus germinatus	Mortality	4	15.8 – 40.8
	Cyprinodon variegaus	Mortality	4	7.2 – 60.0
		Mortality	7	3.7 - >28.0
	Poecilia reticulata	Mortality	4	0.75 – 42.3
	Oncorhynchus mykiss	Mortality	2	10.0

Acute and sublethal effect concentrations (as EC50 and LC50) of whole PFW ranges from 0.02% to more than 100%. Overall the most sensitive taxa appear to be marine algae, bivalve mollusc larvae, and various species of crustaceans, particularly larval forms. Among the crustaceans, mysids appear to be as or more sensitive than other crustacean species. Generally, fish are more tolerant to PFW than marine invertebrates.

North West Shelf and Timor Sea

Figure 2.1 summarises the ecotoxicology test results for NRA, GWA, CP, OL and NE (see IRCE, 2003a–e). Individual tests target toxicity of different components in the PFW, hence results, both between tests and facilities, are quite variable. For example, PFWs from NRA and CP are most toxic to the sea urchin fertilisation test whilst not so toxic to the acute prawn and chronic algae tests. In contrast, NE PFW is most toxic towards the prawn test and only moderately toxic to the sea urchin tests. GWA and OL show the most consistency across the suite of tests. In general, NRA PFW is consistently the most toxic. This is followed, in order of toxicity, by CP, OL, GWA and NE.

Both unfiltered and filtered samples from NRA and GWA were tested. The results showed little variation in toxicity. The filtered GWA sample was slightly less toxic for the sea urchin fertilisation, rock oyster larval development and algae growth inhibition tests, more toxic for the tiger prawn acute test and about the same for the sea urchin fertilisation test. These results are within experimental variability and it may be concluded that the dissolved component contributes most to the toxicity and that there would be only minor benefit in filtering the PFW prior to discharge.

Figure 2.2 summarises the Microtox® results. These tests exhibit significant sensitivity to the PFW and results correlate with the general trend shown by the more sophisticated tests, ie, NRA is the most toxic and Northern Endeavour being the least. Microtox® could therefore provide a useful and cost effective screening tool to monitor toxicity over time.

2.5.3 Risk Assessment

The ratio of the Predicted Environmental Concentration (PEC) to the Predicted No Effect Concentration (PNEC) (PEC/PNEC ratio) is an established technique to screen chemicals in offshore discharges (EC, 1996). It forms the basis of the OSPAR Harmonised Notification Scheme (OSPAR, 2000) and is used in the EIF tool (Johnsen *et al*., 2000). The PNEC is derived from ecotoxicity data and is the concentration below which it is believed there will be no detrimental effect on the environment. It relies upon the assumption that a single value captures the concentration at which no toxic response (acute or chronic) is expected in the target population of marine biota. Dispersion models, such as that used in the present study (see Section 4.3.3), provide spatially and temporally varying PECs for either the whole effluent or individual compounds. A PFW plume with a PEC/PNEC ratio of one will generally correspond to a probability of 5% that biota will be affected. In the EIF method, the combined risk of simultaneous exposure to a mixture of chemicals like PFW, is estimated by statistical summation of the risks for individual chemicals.

Figure 2.1 Ecotoxicology results for WEL's North West Shelf and Timor Sea Assets (from IRCE, 2003a-e)

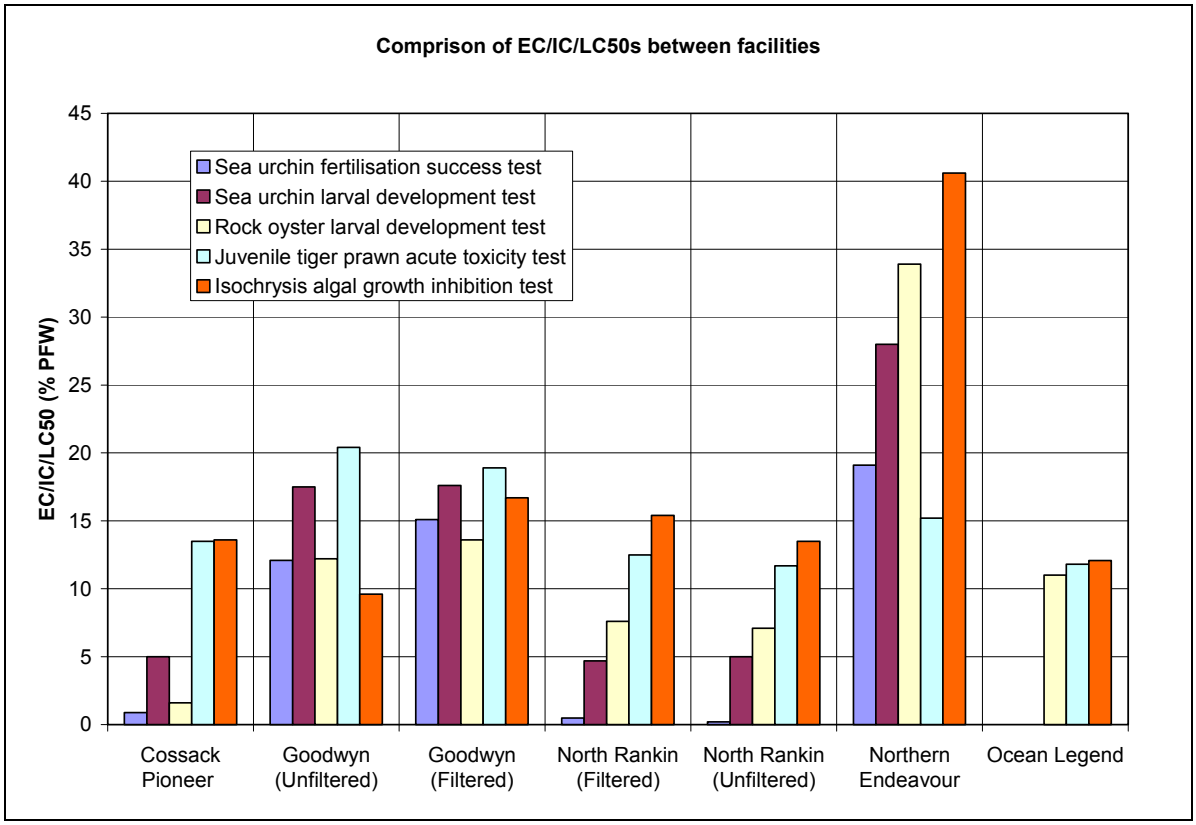
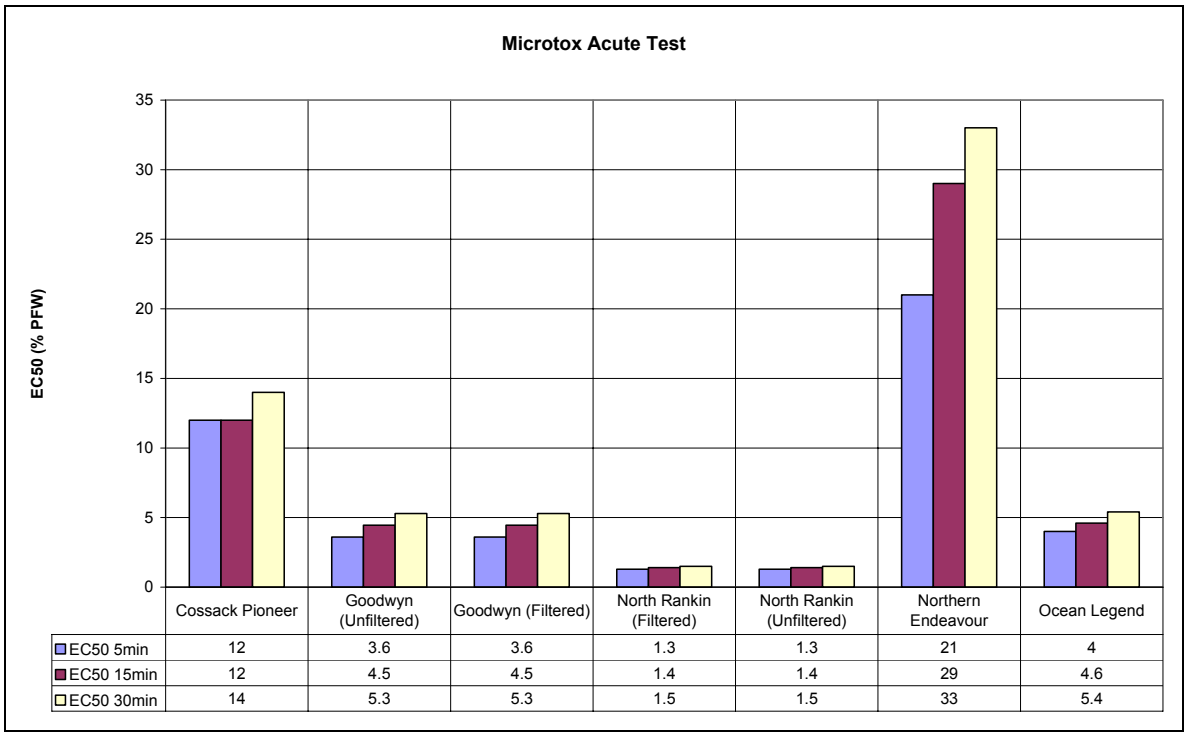


Figure 2.2 Comparison of Microtox® test results between facilities (from IRCE, 2003a-e)



If spatial scale of the effect is limited to the immediate area around an offshore facility and the significance of the effect is considered to be low, then the risk is likely to be acceptable (Terrens and Tait, 1996). Conversely, if the spatial scale of the effect is widespread and the survival or reproductive capacity of marine organisms is significantly reduced then the risk is likely to be considered unacceptable. Where there are unacceptable risks, management actions to reduce risk to acceptable levels would be required.

2.6 Observations of Exposure and Effect

Bioaccumulation studies

Any assessment of PFW effects and risks should consider acute and chronic effects as a production facility may have an operating life of up to 25 years or more. Chronic effects are notoriously difficult to measure in the natural environment. The Offshore Operators Committee (1997) reported that there have been no field observations of bioaccumulation in marine organisms living naturally in the vicinity of offshore oil and gas facilities in the Gulf of Mexico. This lead to conclusions that exposure times to PFW concentrations above chronic toxicity levels is short.

In contrast, monitoring programmes in the Norwegian sector of the North Sea using caged mussels deliberately moored in the path of a PFW plume reveal elevated (compared to background) concentrations of PAHs in mussel tissue (Johnsen *et al*., 1998 and Roe Utvik *et al*., 1999). Burns and Codi (1999) also present results from caged oyster studies that show bioaccumulation. It is therefore possible for marine organisms to bioaccumulate particular chemical from PFW, however, it is uncommon in freely living organisms due to the intermittent nature of their exposure (see Section 4.3.8 for a further discussion).

Biochemical Marker Studies

An alternative to measuring bioaccumulation in marine organisms is to measure the biological response induced by contaminants using biochemical markers (biomarkers) (Cobby, 2002). As suggested in Section 2.3.6, an organism may be exposed to a contaminant but it will not necessarily be adversely affected. Table 2.14 provides a summary of biomarker tools, contaminant triggers, indicator type, mechanism and ecological relevance (see Cobby (2002) for further information). These biological responses or biomarkers are direct indicators of exposure or effect and provide environmental managers with an early warning system for identifying exposure and any adverse environmental effects.

Table 2.14 Summary of biomarker tools, contaminant triggers, indicator type, mechanism and ecological relevance (from Cobby, 2002)

Biomarkers	Triggers	Indicators	Mechanism	Ecological relevance
Mixed Function Oxygenase (MFO)	Petroleum hydrocarbons	Indicator of exposure	Initial step of detoxification process to eliminate contaminant out of the body.	Correlation with reduced reproductive success. Production of PAH metabolites is related to onset of cancer in fish.
Bile metabolites	Hydrocarbons (naphthalene, pyrene)	Indicator of exposure	Final steps of the elimination of hydrocarbons. After metabolites are made water soluble they are directed to the bile for elimination.	Production of PAH metabolites is related to onset of cancer in fish. PAH metabolites may be more biologically active than parent compounds and cause genetic damage.
DNA damage	Any biological active contaminant	Indicator of effect	Contaminant integrates itself into DNA molecule causing damage to the integrity of the DNA molecule. This causes incorrect synthesis of proteins, enzymes etc.	Damaged DNA can result in no viable eggs, malformed larvae, reduced reproductive success, biochemical imbalances in living organisms, cancers etc.
Sorbital dehydrogenase (SDH)	Hydrocarbons, Solvents, Hepatotoxic agents	Indicator of effect	SDH is normally present in the liver only. Its presence in the blood of an organism indicates liver damage.	Liver damage will affect vital functions including digestion, synthesis and regulation of production hormones, production of eggs by females, detoxification by MFO's.
Stress proteins	Any sustained or chronic mechanical or chemical stress	Indicator of effect	Stress causes higher levels of transcription errors during the synthesis of biomolecules. The role of stress protein is to repair transcription errors.	Any sustained stress (heat shock, acoustic disturbance, moulting, long term handling, exposure to chemicals) can induce stress proteins.

2.7 Regulatory Framework and International Best Practice for PFW Discharges

2.7.1 Australia

In Australia, the Petroleum (Submerged Land) Act (P(SL)A) Schedule of Specific Requirements for Offshore Petroleum Exploration and Production 1995 requires that PFW shall not be discharged into the sea unless approved by the Designated Authority (Clause 602 C and 616 (4)). Where approval is granted, the concentration of petroleum in any PFW:

- shall not exceed 50mgL^{-1} at any one time; and
- average less than 30mgL^{-1} during each 24 hour period.

The Schedule applies to both Commonwealth and State/Territory jurisdictions.

In addition, Regulation 13(3) of the Commonwealth Petroleum (Submerged Land)(Management of the Environment) Regulations 1999 (P(SL)(ME)R) states that operators are required to assess the environmental effects and risks associated with PFW discharge, as part of a petroleum activity.

As in most countries, the definition of "petroleum" is open to interpretation but is thought to refer to dispersed aliphatic hydrocarbons. Removal of polar compounds by filtering through Florisil (silica material) and nitrogen sparging is accepted practice. Measuring techniques vary but mostly in-line analysers are used (Sigrist, Horiba, Hach and Turner). Results are reported daily.

In Australia, guidelines for water quality are provided by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). These guidelines provide trigger values for various chemicals.

2.7.2 USA

The USEPA requires oil and grease concentrations in produced water to be monitored by EPA Method 413.1 or 1664A. Both methods are gravimetric. Non-polar and slightly polar organic matter in produced water is extracted with Freon (Method 413.1) or n-hexane (Method 1664A). In method 1664A, the analyst has the option to treat the hexane extract with silica gel to remove polar interfering compounds. The extract is dried and weighed to derive a concentration of total extractable organic matter (total oil and grease). It should be noted that in revision A of the method N-hexane extractable material is synonymous with "oil and grease", whilst applying silica gel (ie, Florisil) extracts the "non-polar material".

The discharge limits in the US varies depending on law in different States. In U.S. Federal waters and state waters of Upper Cook Inlet, Alaska, the current limit for total oil and grease (defined as dispersed and dissolved oil as measured by gravimetric or infrared analysis) in treated PFW is:

- $42mgL^{-1}$ daily maximum; and
- $29mgL^{-1}$ monthly average.

Discharge of PFW to estuarine and coastal waters is not permitted. Permits for the Gulf of Mexico prohibit discharge of more than $4,000m^3$ per day of PFW from a single platform.

Since it is a generally realised fact that Infrared (IR) Absorption based methods are simpler, faster, cheaper and less labour intensive than gravimetric, the USEPA and American Society for Testing Materials (ASTM) have initiated a study with focus to develop a stand alone infrared absorption method replacing Freon as solvent.

2.7.3 OSPAR Signatory States

The OSPAR Convention is the basis for national laws governing the discharge of offshore wastes in the northeast Atlantic and covers the following countries: Belgium, Denmark, Faeroe Islands, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway,

Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland. Under OSPAR, the regulatory limit for total oil and grease in PFW discharged to the waters of the northeast Atlantic is 40mgL^{-1} averaged over a month (Ray, 1996). The United Kingdom Offshore Operators Association (UKOOA) have adopted a voluntary standard of 30mgL^{-1}.

'Oil and grease' refers to the free (liquid phase) dispersed hydrocarbons. This is indicative of the origin of concerns of oil pollution at sea. This origin is from shipping-derived oil spills where the impact is from oil as a gross, smothering, 'physical' contaminant, responsible for damage to seabirds and other wildlife and contamination of beaches and coastal amenities. In contrast, the oil in PFW is a low concentration 'chemical' pollutant (soluble as a fine stable dispersion), which rarely appears as a visible contaminant. Effects, if any, are likely to be at tissue level and not at gross physical level as in the case of oil spills (Genesis, 2000).

In recognition of this, it is likely that in the future, changes will be made to regulations to account for:

- soluble and dispersed hydrocarbons;
- polycyclic aromatic hydrocarbons (PAHs);
- heavy metals;
- process chemical residues; and
- radioactivity.

2.7.4 Other Areas

The regulatory limit for total oil and grease in PFW discharged to most offshore waters of the Mediterranean, the Arabian Gulf and Asia is 40mgL^{-1}(Ray, 1996).

2.8 International Best Practice

It is common practice throughout the offshore industry to treat the PFW to below the regulatory limit and then to dispose to the ocean. Alternatives for PFW disposal include: piping to shore for onshore disposal; reinjection and down hole separation (Johnsen *et al*., 2000). There is also a move towards achieving zero environmentally harmful discharge. In Norway, for example, the government is requiring the oil industry operating in the Norwegian sector of the North Sea to develop a strategy for reaching this objective for PFW by 2005 (Frost *et al*. 2002). The Russian government also requires minimal discharges for the new Sakhalin Shelf oil and gas fields.

2.9 Treatment Technology

A detailed description of treatment technologies for PFW is beyond the scope of this review. The reader is referred to OGP (2002) for a useful introduction to technologies presently

available. The summary of chemical removal capabilities for each technology is reproduced here in Table 2.15.

All of the technologies are capable of removing the dispersed oil fraction, with the actual performance being dependant on the fluid properties and process conditions. As a result of the removal of the dispersed oil droplets, an associated reduction in PAH concentrations is to be expected. Physical and enhanced separation techniques do not remove dissolved BTEX, NPD or PAHs, however, the new technologies are capable of removing at least some or all of these compounds. The advantages and disadvantages of each technique are given in OGP (2002).

2.10 Summary

PFWs are known to contain a number of chemical components that have potential to cause chronic effects in the marine environment. These include heavy metals, MAHs and PAHs. Although toxic effects have been demonstrated in the laboratory, no effects on species living naturally in the environment have been observed in the field. However, most studies recognise that the measurement of sub-lethal effects in the natural environment is difficult because of the nature of the species at risk and the presence of contaminants from other sources.

Each PFW is unique in its chemical composition confounding the development of generalities about the cause of toxicity. The high dilution received by PFW is believed to reduce PFW concentrations in the receiving environment to levels below toxic thresholds very quickly. PAHs are the petroleum hydrocarbon of greatest environmental concern in PFW because of their toxicity and persistence in the marine environment.

Although only small concentrations of contaminants are released, the continuous discharge of large volumes gives rise to environmental concern. Accordingly, most of the regulatory authorities from international to regional levels set limits on the concentration of petroleum hydrocarbons that can remain in PFW for ocean disposal. Oil is not a single substance but a very wide range of hydrocarbons substances, both in solution and dispersion. The component targeted by the regulation is dictated by the method used to measure the oil-in-water content, which up until recently has been the free (liquid phase) dispersed hydrocarbons. This is not the most toxic component, which is the dissolved phase. The regulations do not tend to consider the loading to the environment either. Operators in Australia are now required to assess the environmental effects and risks of PFW discharged to the ocean as well as to meet standard regulatory limits. There are moves in OSPAR signatory states to change regulation to legislate on the more relevant toxic components of PFW.

Table 2.15 Current PFW treatment technologies

Technology	Removal Capability			
	Dispersed oil	BTEX	NPD	Other PAHs
Physical separation				
Flotation	Yes	No	No	Some
Sparging	Yes	No	No	Some
Coalescence	Yes	No	No	Some
Enhanced separation				
Hydrocyclones	Yes	No	No	Some
Hydrocyclones + coalescence (Pect-F, Mare's Tail)	Yes	No	No	Some
Centrifuges	Yes	No	No	Some
Alternative (new) technology				
Absorption (polymers, MPPE, clays)	Yes	Yes	Yes	Yes
Adsorption (carbon, natural fibres)	Yes	Yes	?	?
Hydrocyclones + solvent extraction (C-Tour)	Yes	No	Yes	Yes
Membranes	Yes	Yes	Yes	Yes
Steam stripping	No	Yes	No	No
Biological (aerobic degradation)	Yes	Yes	?	?
Produced Water Reinjection	Yes	Yes	Yes	Yes

3 JOSEPH BONAPARTE GULF RECEIVING ENVIRONMENT

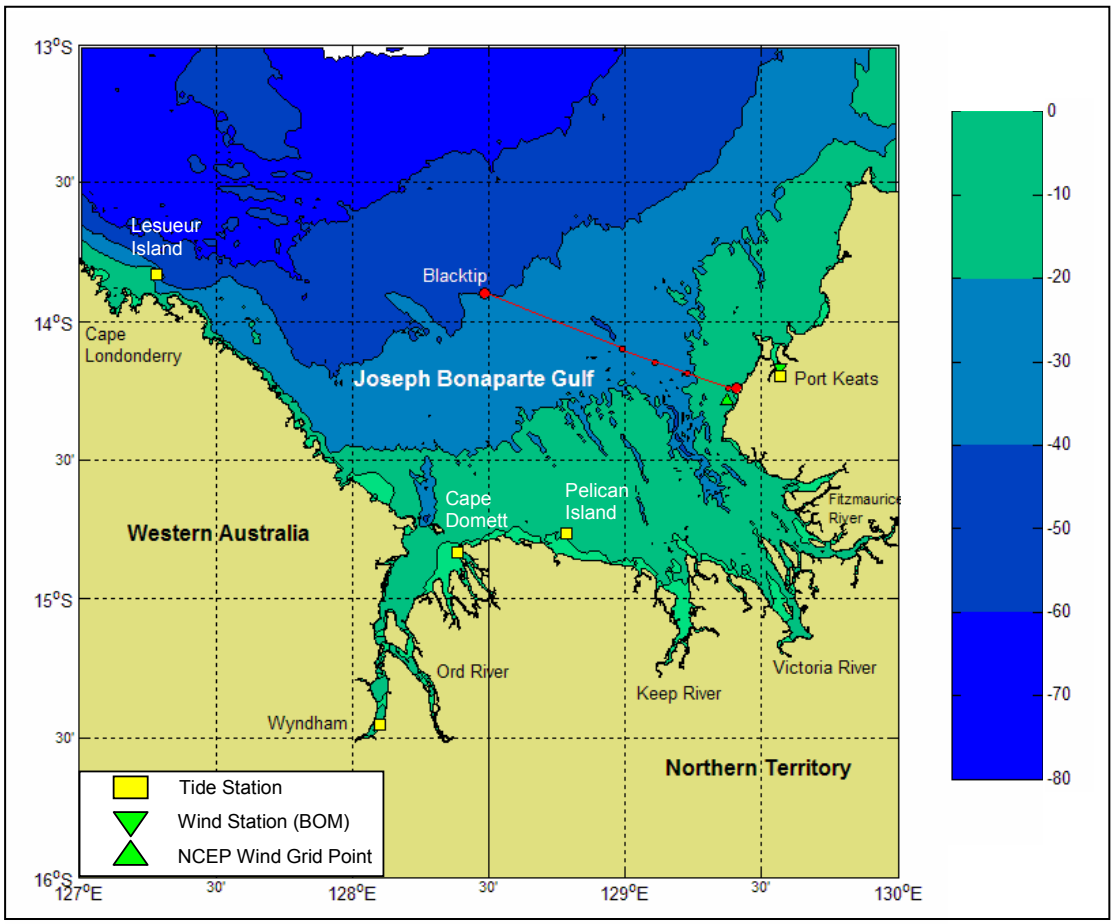
3.1 General

Joseph Bonaparte Gulf is a large embayment on the northwestern continental margin of Australia (Figure 3.1). It is approximately 300km east-west and 120km north-south with a broad continental shelf to seaward. Maximum width from the southernmost shore of Joseph Bonaparte Gulf to the edge of the continental shelf is 560km. Several large rivers enter the gulf along its shoreline.

3.2 Bathymetry

The offshore facility is located on the Sahul Shelf in 50m of water (Figure 3.1). Depths along the pipeline route generally decrease shoreward. There are no reefs or emergent banks along the pipeline route although it does pass through a dune field in the nearshore region.

Figure 3.1 The Joseph Bonaparte Gulf



3.3 Climate

The climate of the Timor Sea is monsoonal with a wet “summer” and a dry “winter”. The wet season commences between September and November as the southeast (SE) Trade winds weaken over Northern Australia and land temperatures rise. This results in two or more semi-permanent heat lows forming over central Australia, one over the Kimberley - Great Sandy Desert, and often another just south of the Gulf of Carpentaria.

The early part of the season is marked by frequent thunderstorms. As the season progresses moist ocean air from the north and northwest streams into the lows and several days of heavy rain may occur. Occasionally one of the lows may strengthen and move southeast over the interior. When this happens widespread rains follow and under exceptional circumstances the cloud may effect as far south as New South Wales. The general atmospheric circulation for the wet season is illustrated in Figure 3.2(a).

As winter approaches large highs centre over the southern part of the continent, the trade winds become re-established over Northern Australia and the monsoon retreats. The SE Trades are dry winds that bring no moisture. Figure 3.2(b) illustrates the typical atmospheric circulation for the dry season.

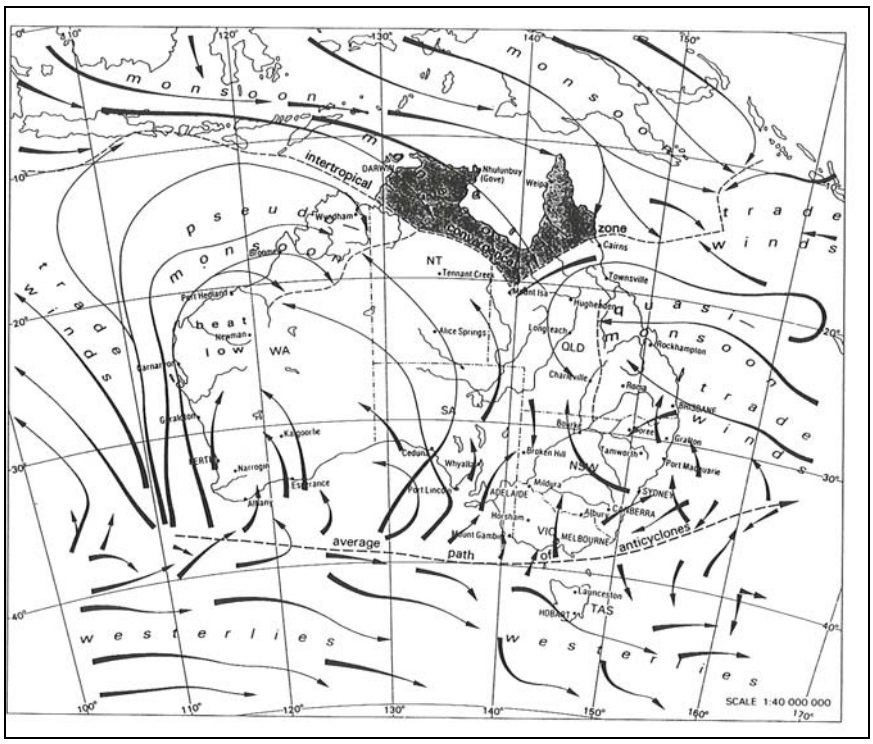
Mean daily maximum temperatures for Port Keats range from about 30 to 34°C, and minima from 14.5°C to 25°C. Annual rainfall is 750 to 900mm. Almost all rainfall occurs between November and April, the greatest falls being in January and February. The frequency and severity of the thunderstorms produce a large variation in the monthly rainfall. Rainfall during the dry months is sporadic and light.

3.4 Winds

Monthly wind roses for Port Keats are shown in Figure 3.3. Winds are predominantly from the northwest between September and February and from the southeast between April and July. During the transition periods between the two seasons in March and August, winds are more variable. Tropical cylones can develop between November and April resulting in short lived, severe storm events often with strong but variable winds.

Figure 3.2 Generalised atmospheric circulation over Australia in Winter (July) and Summer (January) (from Swan *et al*., 1994)

(a) Summer



(b) Winter

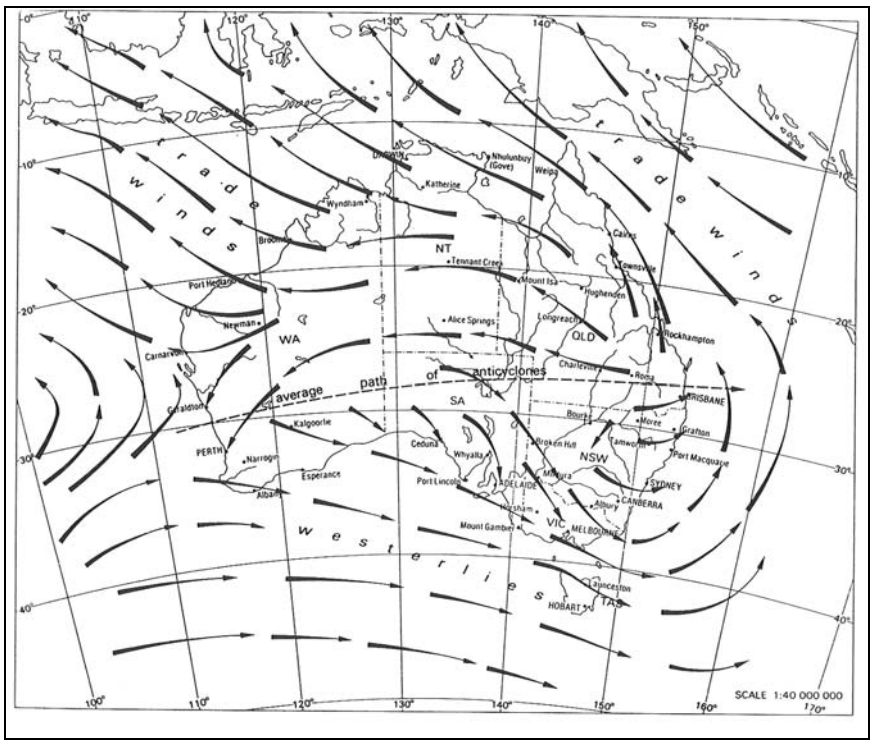


Figure 3.3 Monthly wind roses for Port Keats (2000 -2003)

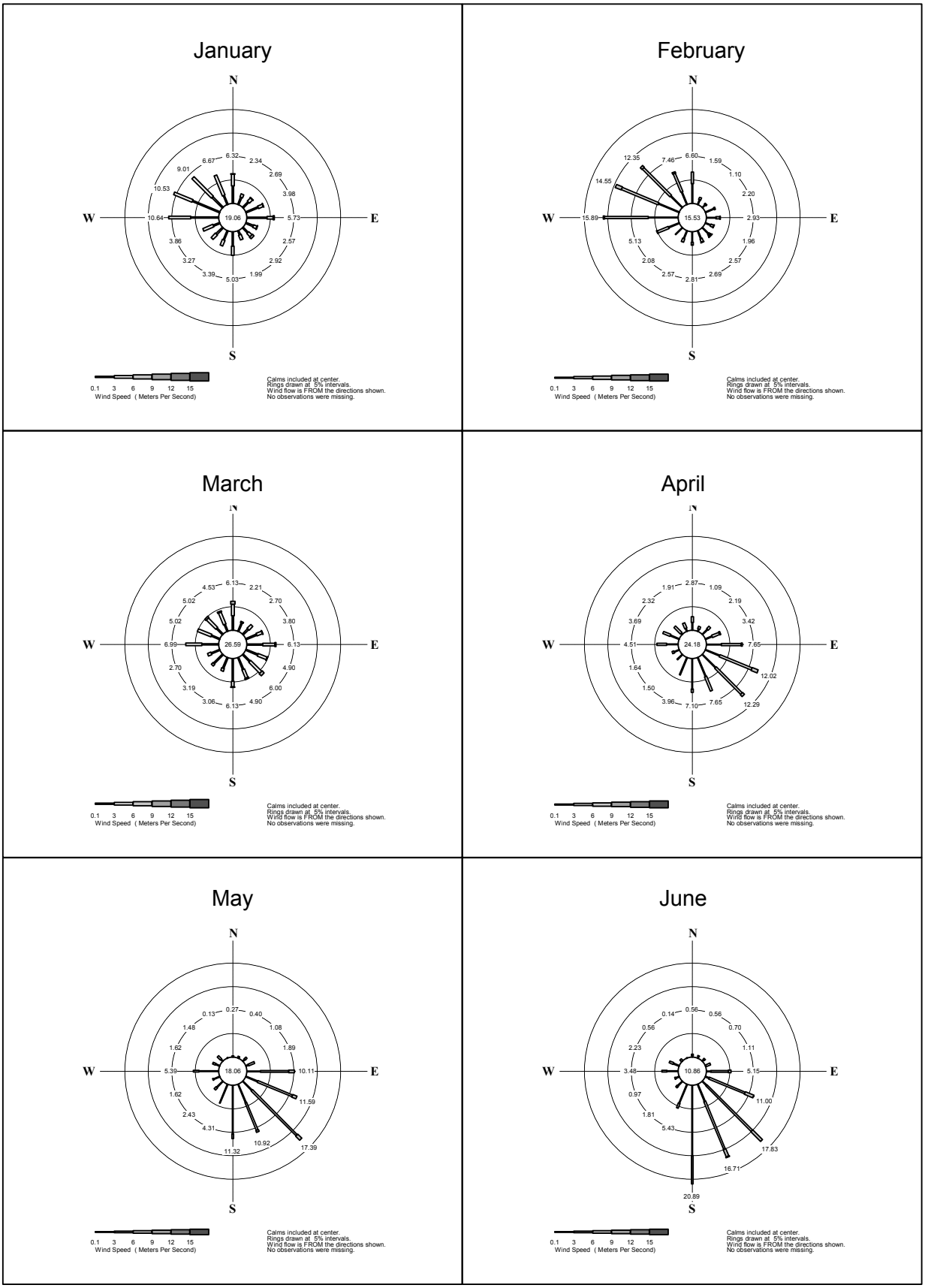
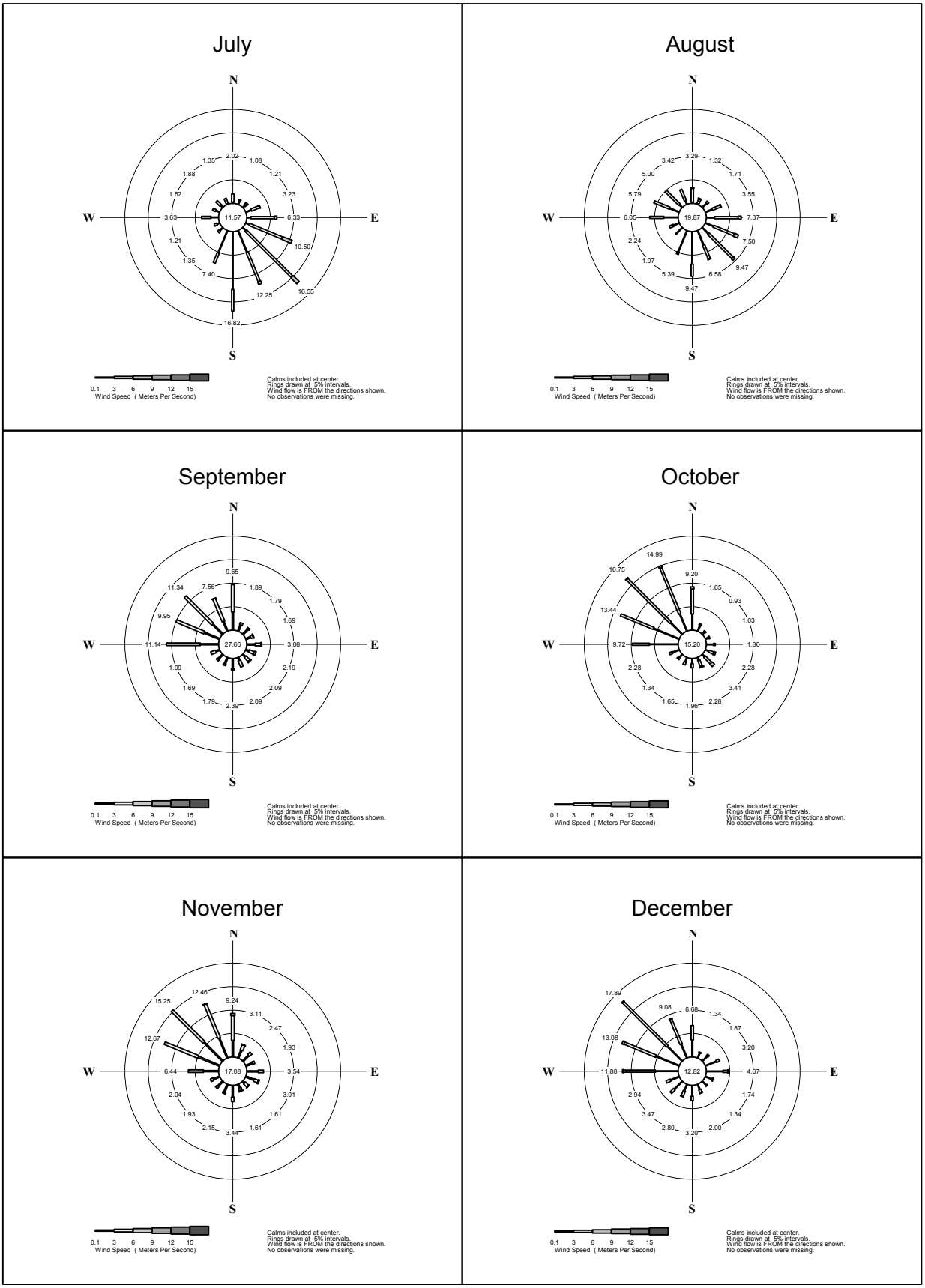


Figure 4.3 (cont.)



3.5 Oceanography

3.5.1 Water Levels

Astronomical tides

The tides in the Joseph Bonaparte Gulf propagate in from the Timor Sea and circulate around an Amphidromic Point located offshore from Cape Londonderry in the northwest. Tidal ranges increase shorewards with maximum tidal ranges exceeding 8m along the shoreline between Wyndham and Darwin.

The closest tidal station to the Blacktip shore crossing is Port Keats. This is a secondary port located between the two standard ports of Darwin and Cape Domett. Figure 3.4 shows a typical tidal record from Darwin. The tides are semidiurnal (two highs and lows each day) with a slight diurnal inequality (difference in heights between successive highs and low). There is a well defined spring-neap lunar cycle, with spring tides occurring two days after the new and full moon. Table 3.1 provides the standard levels for Port Keats. Highest Astronomical Tide (HAT) exceeds 8m and the mean ranges for spring and neap tides are 5.6m and 1.9m, respectively. Tidal ranges will reduce offshore towards the Blacktip facility.

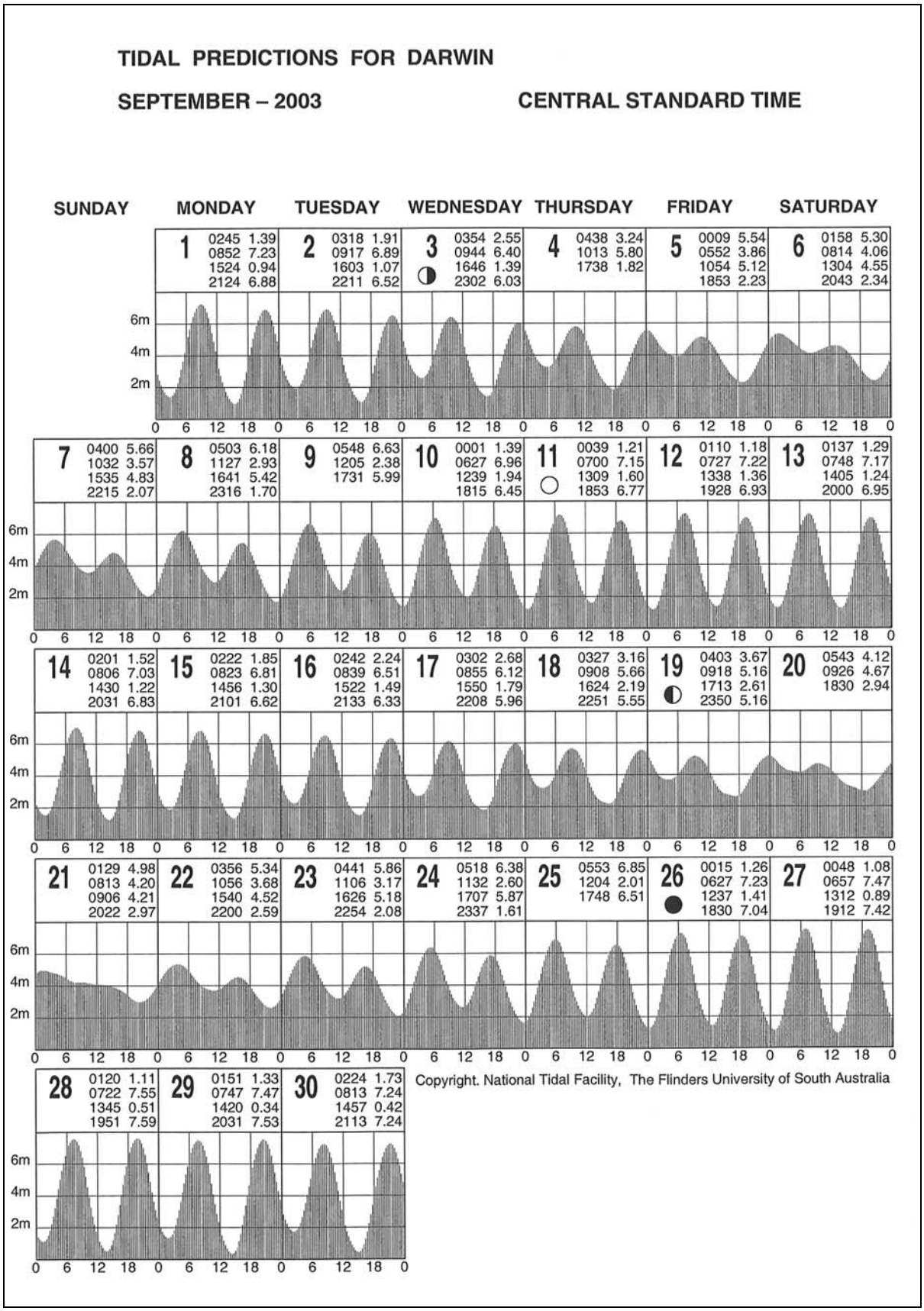
Table 3.1 Standard tide levels for Port Keats (Australian Hydrographic Services, 2003)

Port Keats	Level (m)
Highest Astronomic Tide (HAT)	8.2
Mean High Water Springs (MHWS)	7.2
Mean High Water Neaps (MHWN)	5.3
Mean Sea Level (MSL)	4.4
Mean Low Water Neaps (MLWN)	3.4
Mean Low Water Springs (MLWS)	1.6

Meteorological tides

Superimposed on the astronomical tide are ‘meteorological’ tides resulting from changes in atmospheric pressure and strong onshore or offshore winds. Storm surges during cyclones, in particular, can appreciably raise sea levels above the predicted astronomical tidal height and inundate low-lying areas.

Figure 3.4 Darwin tide curve for September 2003



3.5.2 Circulation

Tidal currents

Circulation in the Joseph Bonaparte Gulf is dominated by the large tidal currents. There are no site specific current measurements in the region of the Blacktip development, however, the hydrodynamic model developed for this study predicts current speeds at the offshore facility of up to 0.9ms^{-1} on spring tides and up to 0.2ms^{-1} on neaps. The currents rotate in a clockwise direction with the major flood and ebb directions towards the southeast and northwest, respectively. Further towards the shoreline, current speeds increase with tidal range and become directed more longshore. These large currents are responsible for the generation of dune forms on the seabed as noted in Admiralty Charts for the region. Very nearshore currents are influenced by the coastal topography with an anticlockwise gyre forming in the landfall Bay on the flood tide and a clockwise gyre on the ebb (see Figure 4.6).

Non-tidal currents

Non-tidal current drift might be associated with:

- local winds;
- river inflow along the coastal boundary;
- large scale ocean circulation in the Timor Sea;
- continental shelf waves; and
- meteorological effects.

Local Winds

The typical “rule of thumb” for surface current flow is 2% to 4% of the wind speed. Surface currents are expected to reflect seasonal wind regimes with flows towards the southeast during summer and westerly flows during winter. Local wind-driven surface currents may attain maximum speeds of 0.7ms^{-1} during extreme monsoonal or Trade Wind surges. More typically speeds would be in the range of 0.2ms^{-}1 to 0.4ms^{-1}.

River inflow

Four major rivers flow into the Joseph Bonaparte Gulf:

- Ord River;
- Victoria River;
- Fitzmaurice River; and
- Daly River.

The influence of these rivers on circulation within the Gulf will be greatest during periods of high flow that may occur during the wet season and minimal during the dry.

Large Scale Ocean Circulation

Large scale ocean circulations are forced by synoptic scale winds. The SE Trade Winds drive a mean westerly of up to 0.2ms^{-1} in the Timor Sea. In the wet season, currents reverse to flow towards the east. The influence of these large scale circulations in the Joseph Bonaparte Gulf is unknown.

3.5.3 Waves

Wave data were derived from a two degree global database constructed from a combination of remotely sensed satellite and modelled data (Young, 1999). The monthly mean significant wave heights (Hs), spectral periods (T_m) and directions for the nearest grid point (approximately 100km to the north northeast) are plotted in Figure 3.5. Note that wave heights are likely to be overestimated as the database location will be more exposed to westerly swell than Blacktip and have greater fetches from the south and southeast.

During the winter season, the ambient wave climate at Blacktip will be composed of waves generated from the prevailing south and southeasterly trade winds. Wave generation will be fetch limited and mean monthly significant wave heights are predicted to be fairly constant, ranging between 0.8m and 1.0m with mean period of between eight and nine seconds. Wave height and period will decrease shoreward along the pipeline route. Longer period swell waves from the Indian Ocean are unlikely to diffract around into the Joseph Bonaparte Gulf.

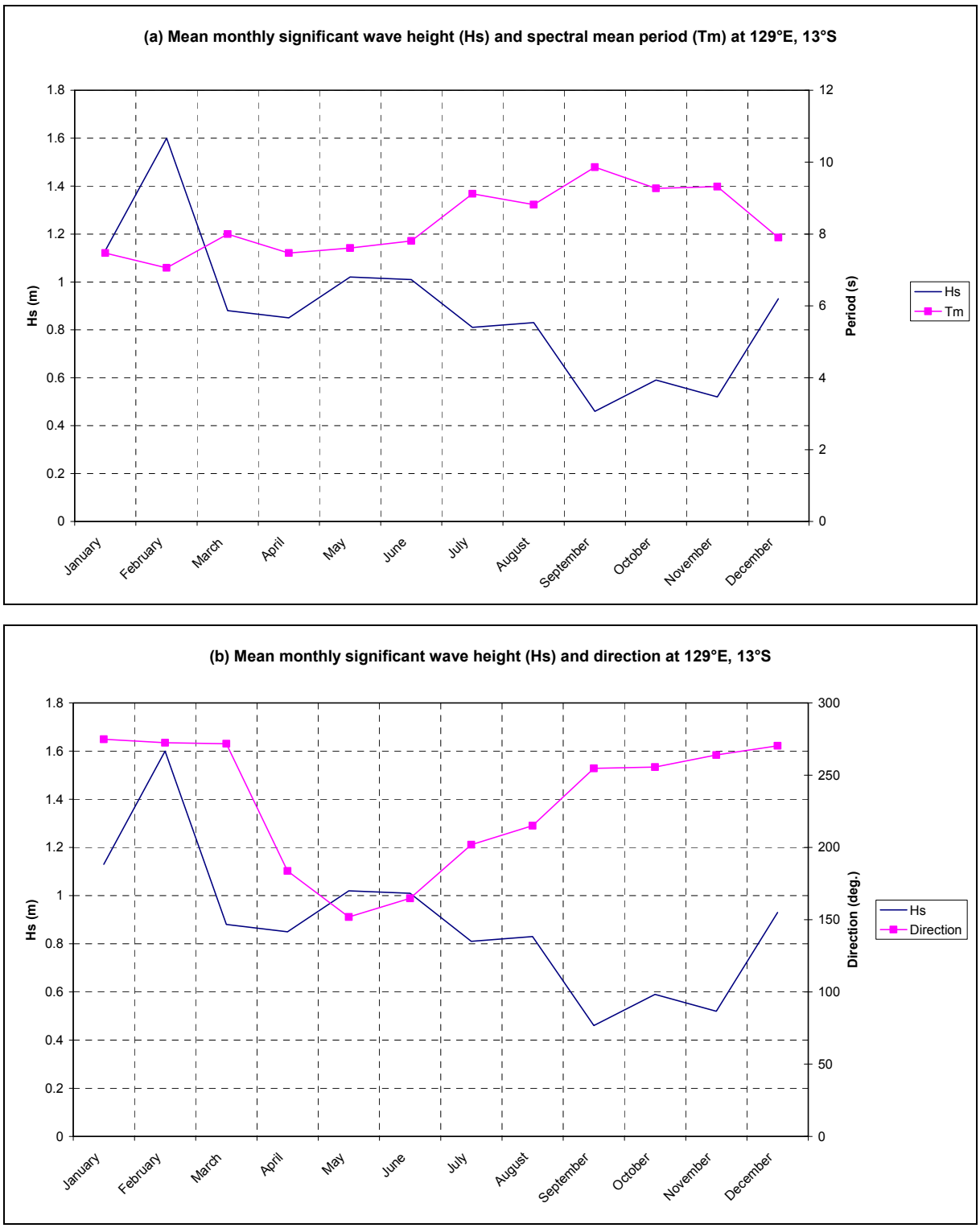
During the summer season, Blacktip is exposed to both sea and swell generated from the prevailing northwesterly monsoon winds blowing across the Timor Sea. As such the predominant swell direction at Blacktip is from the northwest with mean monthly periods of between seven and 10 seconds. Monthly mean significant wave heights range from a minimum of 0.45m in September to a maximum of 1.6m during February. As prevailing winds are onshore, wave heights in the summer will increase shoreward along the pipeline route.

Extreme waves are generated by cyclones during the summer season. The 100 year return period wave will be of the order 5m.

3.5.4 Water temperatures

Mean monthly temperatures in the vicinity of the Blacktip field vary between about 25.8°C in August and 30.5°C in December (AODC, 2004). Due to the large tidal range and high currents, the water column is expected to be well mixed all year around with respect to temperature. During heavy rainfall, there may be some salinity stratification in the south of the Gulf.

Figure 3.5 Monthly mean wave parameters for grid location129°E, 13°S (approximately 100km NNE of Blacktip)



3.6 Biological Environment

3.6.1 Habitats

Coastal habitats in the Gulf include beaches, rocky coastlines and mangroves. The predominant coastline features in the vicinity of the proposed pipeline shore crossing are sand/mud beaches with occasional rocky headlands, small pockets of mangroves and occasional tidal creeks (Figure 1.2). The coasts to the north and south are predominantly sandy beaches with no mangroves. Approximately five kilometres to the south of the shore crossing lies the entrance to a small tidal creek lined with mangroves. Wadeye, approximately 17km to the north of the shore crossing, is the only large tidal inlet system nearby. The nearest significant mangrove conservation areas lie inside the Cambridge Gulf approximately 100km south-west of the project site. Joseph Bonaparte Gulf is not considered to be a significant mangrove area with only 20 known species and densities that are up to 20 times lower than at Gove or Darwin (LDM, 1994).

3.6.2 Flora and Fauna

General

Large terrigenous inputs and re-suspension by large tides are expected to limit the development of corals, seagrasses and other epibenthic organisms. A survey carried out by the WA Museum did not record any intertidal seagrasses in the Joseph Bonaparte Gulf, and no evidence of drift material was found at any of the sites surveyed (Walker *et al*., 1996), though LDM (1994) reported that discussions with local Aboriginal people indicated that seagrass and dugongs may occur along the coastline between Cape Hay to the north and Point Pearce to the south. The nearest large reefs or shoals that might support corals, Howland Shoals and the Emu Reefs, are located approximately 20 to 30km north of the proposed landfall.

Mammals

Whales and dugongs are not expected to be common inhabitants of the Joseph Bonaparte Gulf. The dugong (*Dugong dugon*) is a migratory species listed as vulnerable under the International Union for the Conservation of Nature and Natural Resources, Red Data Book of Threatened Species (IUCN). Dugongs are patchily distributed throughout tropical and subtropical waters of the Indian and Pacific Oceans. with major concentrations of dugongs coinciding with sizeable seagrass beds, on which they feed. The lack of seagrass in Joseph Bonaparte Gulf is expected to limit the distribution of dugong's, though anecdotal evidence reported by local Aboriginals suggests that dugongs can occur between Cape Hay and Point Pearce (LDM 1994).

The two whale species recorded in the Northern Territory are unlikely to be found in the shallow waters of the project area as they are usually restricted to deep waters (sperm whale) or are very rare (blue whale). The northern migration of the humpback whale

terminates in Campden Sound over 400km to the west of the proposed Blacktip Development and they are not expected to occur in the Joseph Bonaparte Gulf. A number of dolphins have wide distributions and are expected to occur within the Joseph Bonaparte Gulf including the Irrawaddy dolphin inhabits tropical, the spotted bottlenose dolphin, Risso's dolphin, Indo-Pacific humpback dolphin and pantropical spotted dolphin (Convention of Migratory Species 2004).

Reptiles

Reptiles in the Joseph Bonaparte Gulf include:

- turtles;
- saltwater crocodiles,
- the mangrove snake; and
- the mangrove monitor.

Turtles

Six species of marine turtle known to occur in Northern Australian waters, however data colected on turtle abundance and distribution in the Joseph Bonaparte Gulf is scarce and numbers are unknown. Examination of the turtle habitat database developed and supplied by Ray Chatto of the Parks and Wildlife Commission of the Northern Territory (PWCNT) indicates that suitable coastal saline flats habitat for sea turtles exist in the southeast of the Joseph Bonaparte Gulf at Turtle point at the mouth of the Victoria River and the Whale Flat area near the mouth of the Fitzmaurice River and to the north of the project area around Anson Bay.

Significant Flatback turtle breeding and nesting sites are documented on the north side of Cape Domett in the inner, western Joseph Bonaparte Gulf (Woodside, 2003) and anecdotal evidence suggests that they may historically have nest on sandy beaches to the north of the pipeline landfall. However, discussions with Wadeye Elders indicate that turtles have not nested in any number following a beach recession event about 15 years ago.

Saltwater Crocodiles

The Northern Territory's saltwater crocodile population is the largest in Australia. The species is protected under Section 43 of the Territory Parks and Wildlife Conservation Act 2000, although it is not listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) 1999 Act. Generally high densities of crocodiles occur in tidal portions of mangrove-lined rivers, particularly those associated with extensive freshwater wetlands or floodplains. However, Studies on crocodile populations in the Victoria and Fitzmaurice Rivers suggest that the project area is not significant for crocodile populations. Nesting sites are limited and recruitment rates are generally low.

Crocodiles are however reported to be in the upper reaches of most rivers and creeks around the Wadeye area. The Ord River system has been gazetted as a nature reserve to protect crocodile breeding habitats in the area (LDM, 1994).

Sea Snakes

Sea snakes are very common in subtropical and tropical Australian waters and occupy a wide range of habitats and water depths, extending offshore from the coast to the reefs and banks of the Sahul Shelf. Although there are no records of their specific occurrence in the Joseph Bonaparte Gulf, sea snakes are expected to be very common, with as many as fifteen species known to occur in the Northern Territory (Storr *et al*., 1986).

Fish

A number of fisheries can operate within waters of the Joseph Bonaparte Gulf, however, it appears that fishing effort is limited in all fisheries except for the Northern Prawn Fishery. Prawns are commercially caught in areas of the Joseph Bonaparte Gulf, mainly in the west of the gulf and, to the north, in Fog Bay. The juvenile prawns that migrate offshore to the fishery come from mangrove nursery habitats from the Victoria River in the east of the Gulf, to the Ord River and Cambridge Gulf in the west, forming a very extensive migration throughout the lower region of the Joseph Bonaparte Gulf. Although there is no data on the exact timing of the migration, it is likely to be from February to April and October to December (Neil Loneragan, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Marine Research, pers. comm., Febuary 2004).

4 DISPERSION MODELLING

4.1 General

Modelling of effluent dispersion from a pipeline is generally divided into two distinct zones:

- near field; and
- far field.

In the near field, transport is governed by the momentum of the discharge and the buoyancy resulting from the density difference between the effluent and the receiving waters. The dilution achieved as the wastewater rises to the surface is known as the initial dilution. Thereafter the plume is transported passively by advection and diffusion in the far field. The following sections describe the modelling work undertaken to simulate dispersion in these two zones for the Blacktip discharge.

4.2 Near field Dispersion

4.2.1 Objective

The objectives of the near field modelling are:

- to compute the initial dilution and to demonstrate the effectiveness of the diffuser design; and
- to provide near field dimensions for input to the far field model.

4.2.2 Model Overview

Initial dilution was simulated using Cornell Buoyant Jet Integral Model (CORJET). This model is part of the Cornell Mixing Zone Expert System (CORMIX), a USEPA recommended analysis tool for industrial, municipal, thermal, and other point source discharges to receiving waters. The three-dimensional hydrodynamic equations governing the conservation of mass and momentum along the curved trajectory of a buoyant jet are solved yielding:

- the trajectory position; and
- centreline concentrations of pollutant mass, density deficit, temperature and salinity.

The computation ceases when the plume impinges on a boundary, after which time the physics change and the results are transferred to the far field model. Cross-sectional values are fixed as a Gaussian distribution. Theoretical details and the validation of CORJET are presented in Jirka *et al.* (1996).

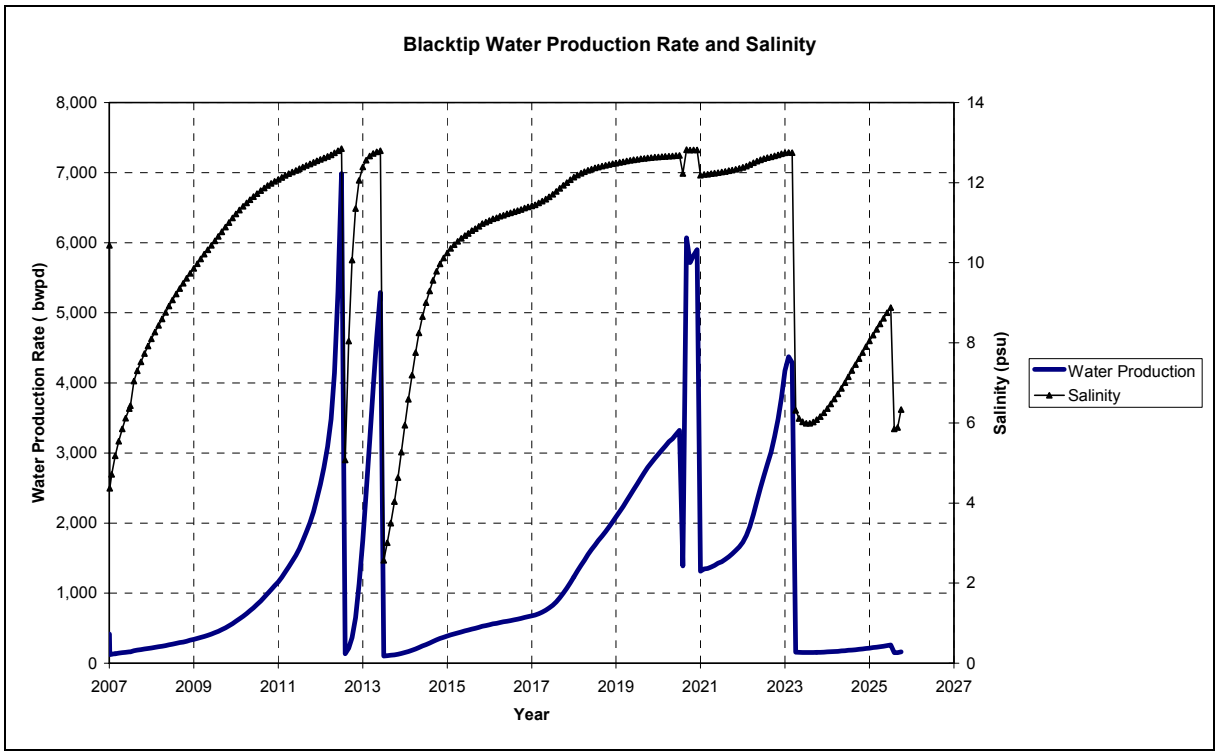
4.2.3 Model Setup

Discharge Flows

Figure 4.1 shows the projected PFW discharge rates over the life of the field. Flows increase from a minimum of 200bbl per day to a maximum of 7,000bbl per day. For the modelling three design flows were used:

- minimum – 200bbl per day;
- base – 2,000bbl per day; and
- maximum future – 7,000bbl per day.

Figure 4.1 Projected PFW flow rate and salinity for the life of the field (from WEL)



Preliminary Diffuser Design

Submarine outfalls consist of the pipe carrying the effluent to the discharge area and the end section or diffuser. For the Blacktip outfall, a six inch pipe has been proposed, however, the design of the diffuser is still yet to be decided. Best practice for diffuser design dictates that:

- the total cross sectional area of the ports must not exceed 65% of cross-sectional area of the pipe, to ensure that flow is distributed evenly through all the ports;
- port diameters should be between 20mm to 150mm to prevent blockage;
- discharge velocities range from $3ms^{-1}$ to $8ms^{-1}$ (higher velocities may require excessive pumping costs);
- the densimetric Froude number should exceed one to prevent saltwater intrusion; and

- port spacing should be in the range one-third to one-sixth of the water depth, so that the plumes from the individual ports just merge on reaching the surface.

Table 4.1 presents a preliminary diffuser configuration that complies with these design criteria

Table 4.1 Preliminary diffuser configuration

Parameter	Value
Diffuser diameter	60mm
No of diffusers	4
Length of diffuser	15m

The parameters used to set-up the model runs are summarised in Table 4.2. Diffuser alignment was set perpendicular to the ambient current direction. Ports were:

- single and unidirectional;
- discharge horizontally and point downstream (ie, co-flowing); and
- located 1m above the seabed.

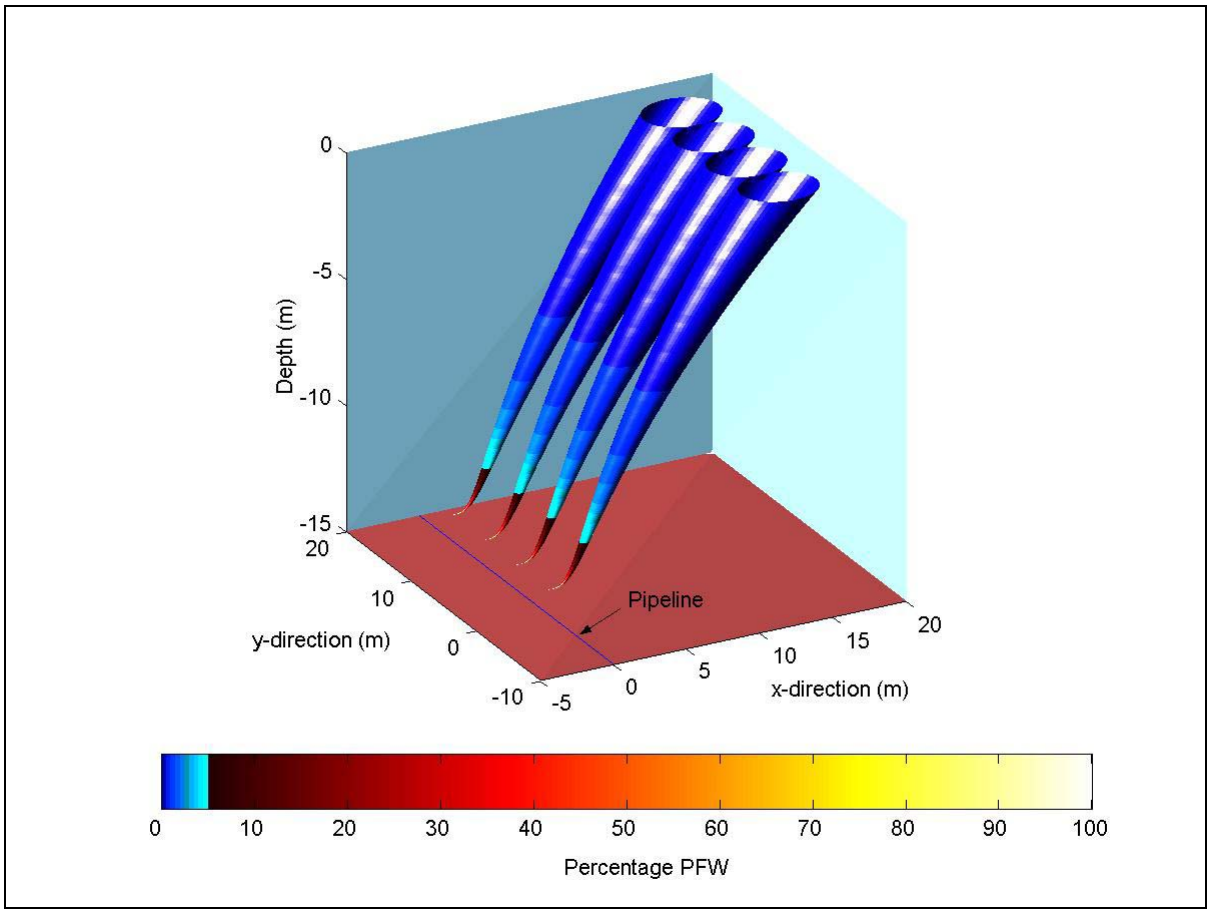
Table 4.2 Model set-up for initial dilution CORJET modelling

Parameter	Value
Ambient conditions	
Average depth	15m
Depth at discharge	15m below LAT
Ambient velocity (CORJET)	$0.05ms^{-1}$
Stratified condition	Unstratified
Ambient temperature	28°C
Ambient salinity	34psu
Discharge parameters	
Discharge orientation	Horizontal (co-flowing)
Port diameter	60mm
Discharge flowrate	7000bbl per day
Temperature	28°C
Salinity	10psu
Concentration	100%
Coefficient of decay	$0s^{-1}$

4.2.4 Model Results

Figure 4.2 shows the predicted horizontal and vertical trajectories of the jet plume in the near field region. The PFW emits from the discharge pipe 14m below the sea surface and rises under the influence of its own buoyancy towards the surface. Due to the relatively low flows, initial dilution is high. Within the first 5m, 100 dilutions are achieved and by the time the plume hits the surface, it has received 700 dilutions. On reaching the surface it spreads horizontally whilst mixing vertically downwards. At this point, dispersion becomes controlled by far field processes (ambient current and passive diffusion).

Figure 4.2 Initial dilution for preliminary diffuser design (worst-case future discharge rate)



4.3 Far Field Dispersion Modelling

4.3.1 Objective

The objectives of the far field modelling were:

- to derive an effective disposal strategy by predicting the fate of PFW discharged from different locations; and
- to predict the environmental risk associated with the discharge.

The far field model is made up of two modules:

- a hydrodynamic module that provides the necessary velocity fields to advect the PFW; and
- a dispersion model that simulates the fate and behaviour of the PFW.

These modules are described in more detail in the following subsections.

4.3.2 Hydrodynamic Model

Overview

The hydrodynamics applied in the present study were computed using the ADvanced CIRCulation model (ADCIRC). This model is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions (Westerink *et al*., 1994). The algorithms that comprise ADCIRC utilise the finite element (FE) method in space and the model can be applied to computational domains encompassing the Deep Ocean, continental shelves, coastal seas and small scale estuarine systems.

Model Details

Figure 4.3 shows the grid for the Joseph Bonaparte Gulf. Elevations and currents were computed at 11,621 points (nodes) in the model domain. Using the significant flexibility provided by the FE method, grid resolution was increased considerably towards the coast and in particular towards the landfall for the Blacktip pipeline (Figure 4.4). The fine nearshore grid spacing was necessary to resolve the complex coastline geometry whilst coarse offshore resolution aids in computational efficiency.

Node resolution varies from approximately 50km offshore to 50m inshore. Model bathymetry is shown in Figure 4.5. This was interpolated from the Australian Geological Survey Office (AGSO) database. The model was forced from the open boundary by tidal elevations calculated from the M2, S2, N2, O1 and K1 tidal constituents. The amplitudes and phases for these were taken from the FES-95.2 global ocean model (Le Provost *et al*., 1998).

The model was validated against tidal stations around the coastline. Examples of vector fields for a spring tide at mid ebb and flood are shown in Figure 4.6 (a) and (b), respectively.

4.3.3 PFW Dispersion Module

Model Overview

The PFW dispersion module is based on the classic random walk particle tracking method (Sherwin, 1992) and assumes that the mass of the discharge can be idealised as a large number of particles that move independently under the action of tide and wind. The particle tracking is integrally linked with the FE model and uses a highly accurate fourth order Runge-Kutta method to interpolate velocities between nodes (Blanton, 1995).

The motion of the particles is the sum of two effects:

- advection by the tidal currents, and
- dispersion due to turbulence and current shear effects.

Advection is calculated by stepping through the variations in the current field in time and space. Dispersion is included by subjecting each particle to a random displacement at each time step. The dispersive displacement (random step) of each particle at each time step (dt) is scaled by the square root of the increment in the variance of the effluent plume which is given by the product:

$$\text{(increment in variance)} = 2Kdt$$

where K is the horizontal (K_{xy}) or vertical (K_z) diffusion coefficient. The actual step length taken by each particle is also determined by a random number selected from a normal distribution with zero mean and unit variance which is scaled by the product (2Kdt). Steps in the x, y and z co-ordinate directions are made independently. Steps in the vertical plane allow for reflection of the particle from the seabed and surface. The current velocity applied to each particle is corrected according to its level in the water column using a Van Veen profile.

Model grid

The model was set up over a 16km x 16km rectilinear grid, with a resolution of 100m. The time step for particle tracking was set at 180 seconds.

Figure 4.3 Hydrodynamic model grid

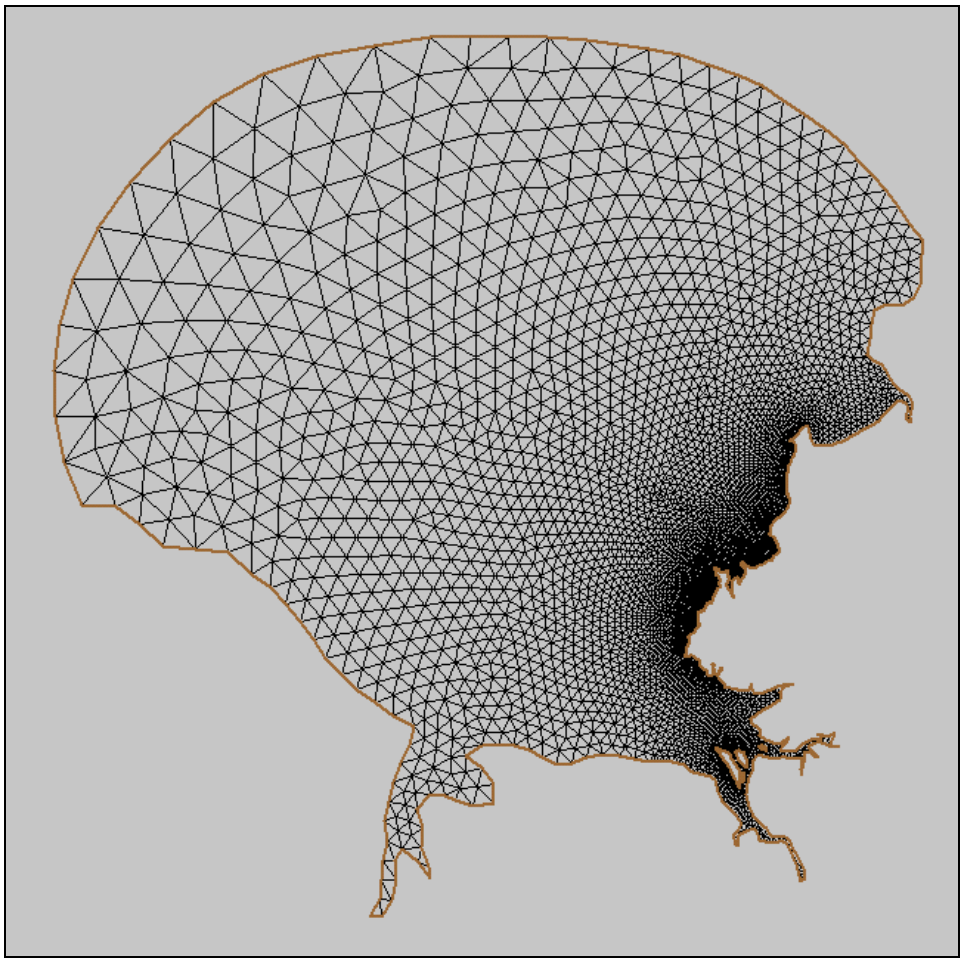


Figure 4.4 Details of model grid in the vicinity of the outfall

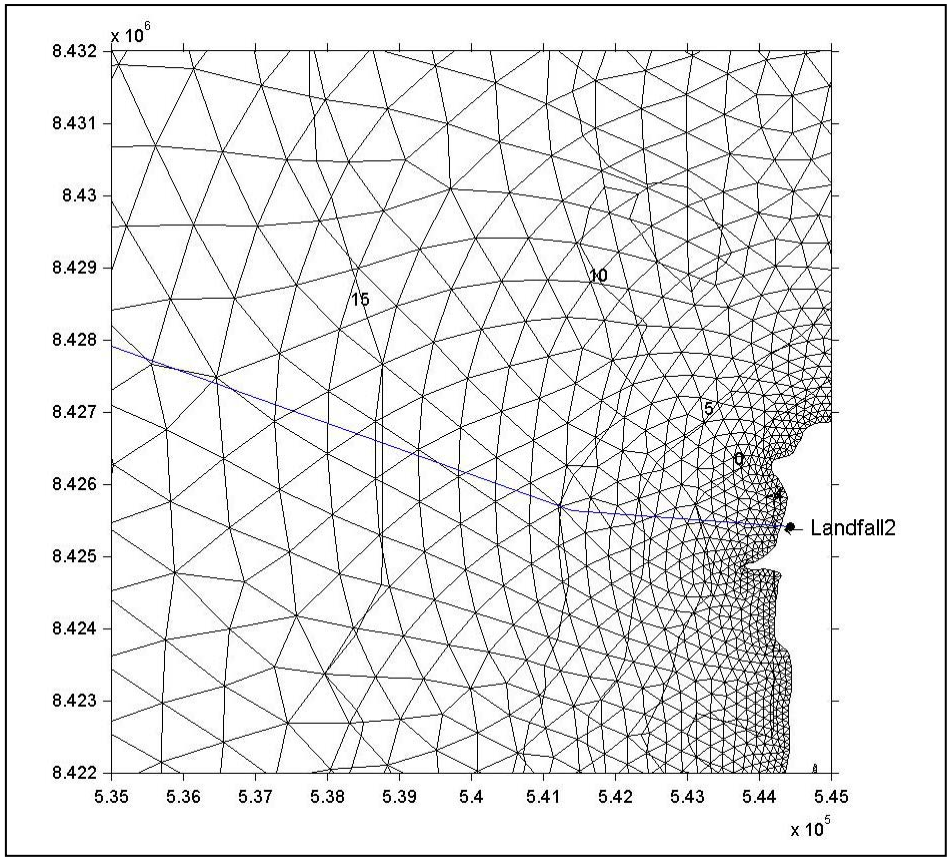


Figure 4.5 Model bathymetry in metres

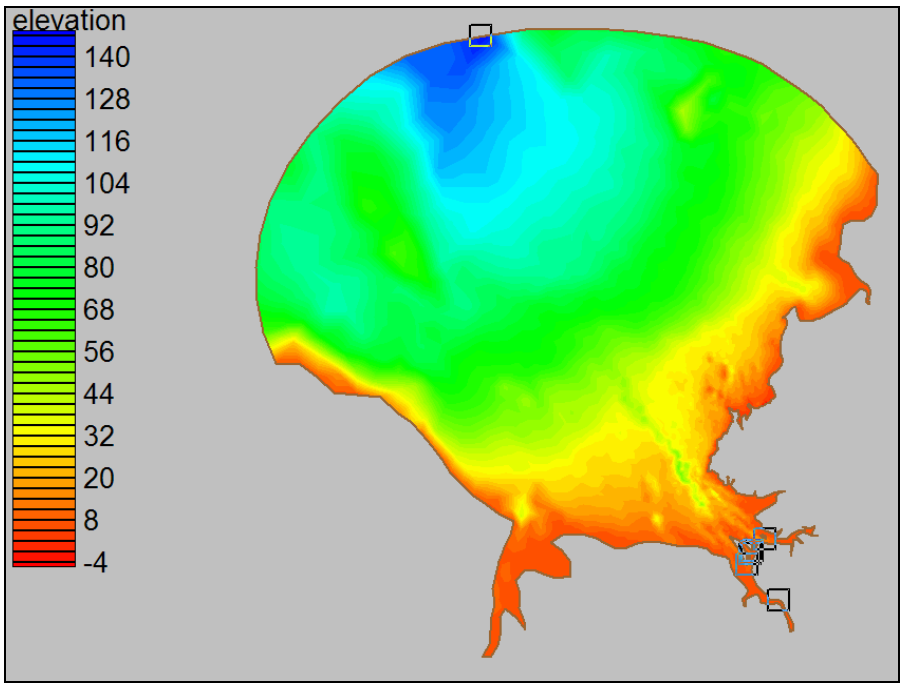
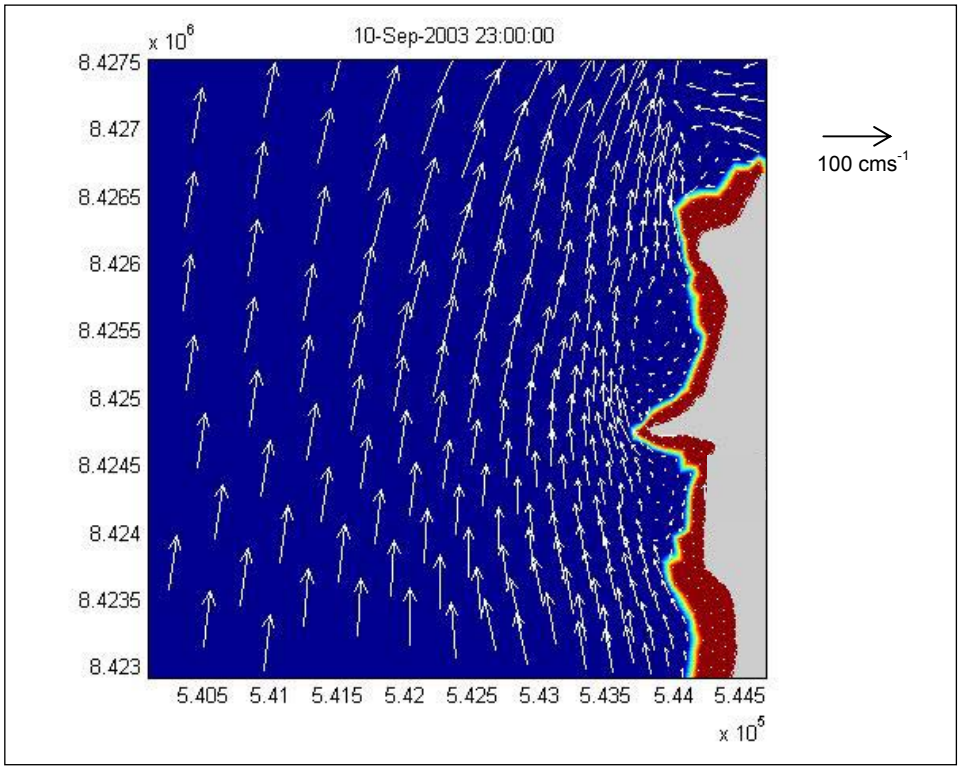
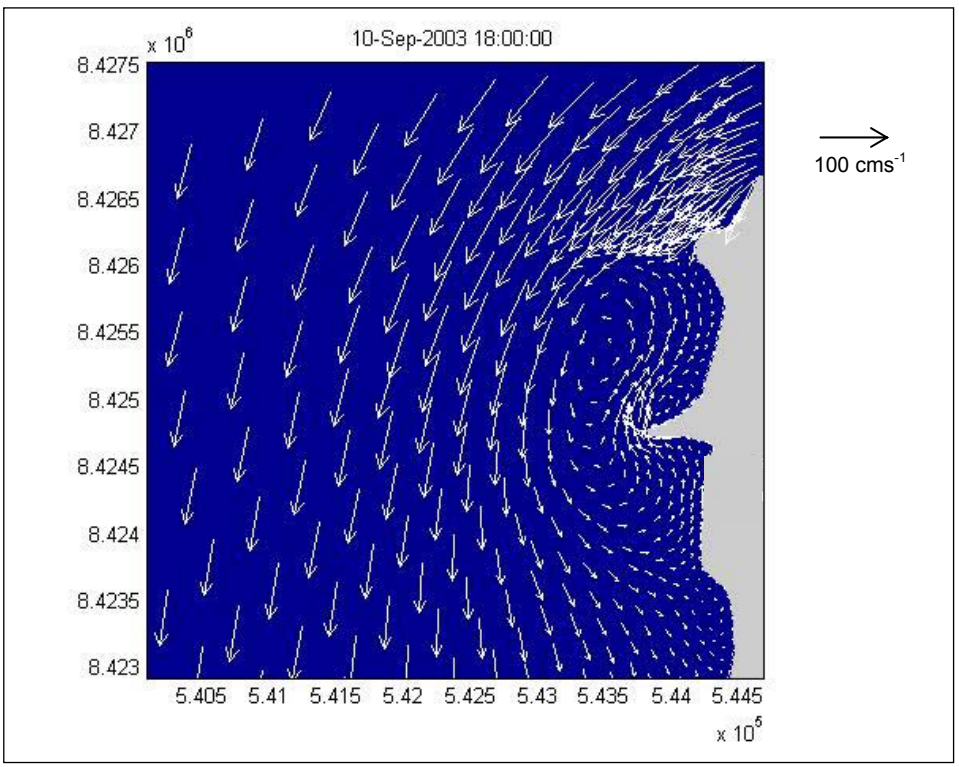


Figure 4.6 Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline

(a) Ebb Tide



(b) Flood Tide



4.3.4 Model scenarios

Table 4.3 summarises the model scenarios undertaken. These used seven different discharge locations, (Figure 4.7), three discharge flows, spring and neap tides and onshore "worst-case" wet season wind conditions.

Worst-case periods were targeted as it is reasonable to assume that if the risk is acceptable under such conditions then it will be acceptable for all other times when conditions are more favourable for dilution and mixing. These simulations do not take into consideration biodegradation as this is unknown for the whole PFW.

Figure 4.7 Positions of discharge locations tested

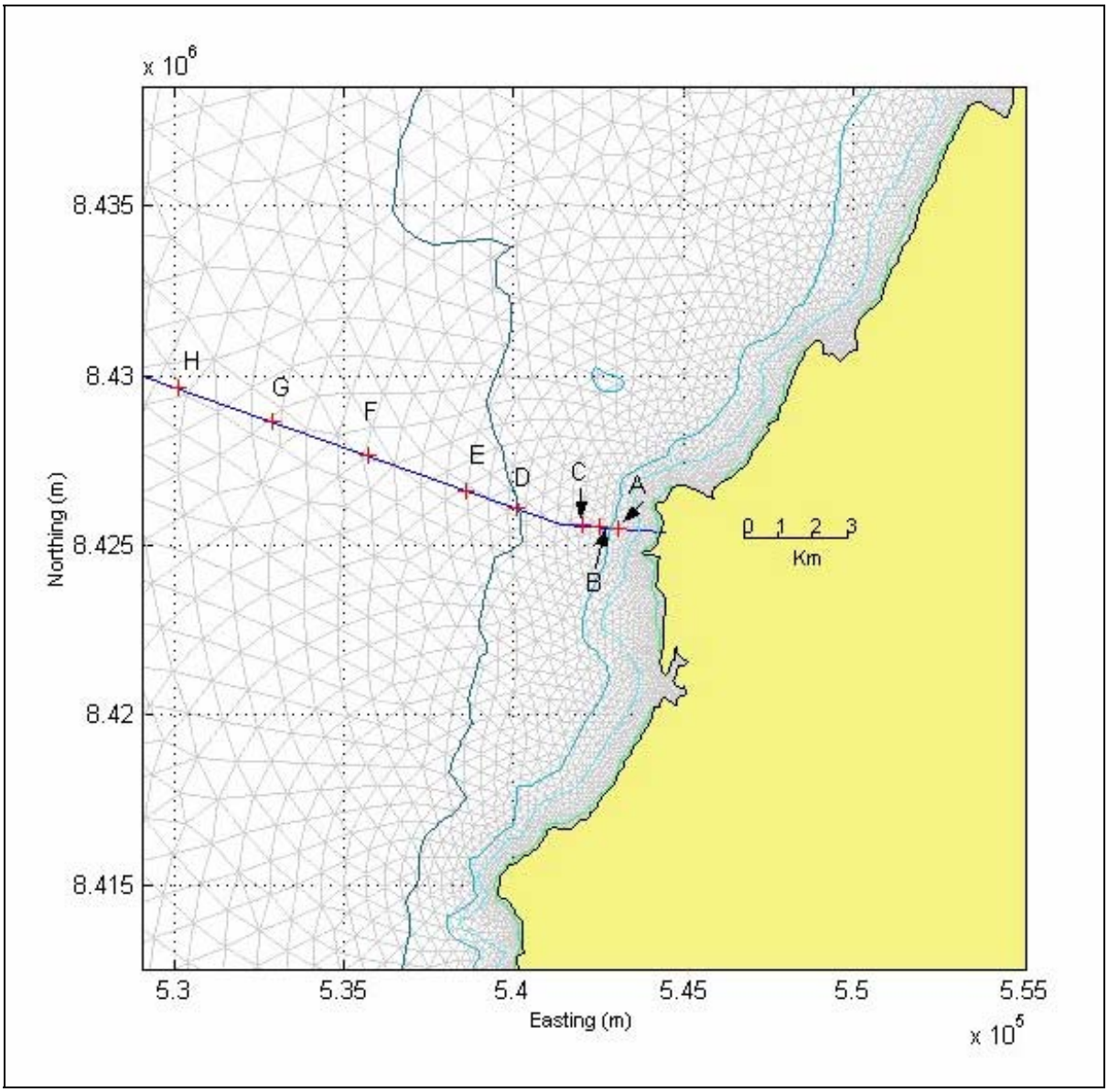


Table 4.3 Summary of model runs

Scenario No.	Discharge Location	Discharge flow (bbl/day)[1]	Tide	Wind
1	A	6,000	Neap	2ms^{-1} NW
2			Spring	
3	B		Neap	
4			Spring	
5	C		Neap	
6			Spring	
7		200	Neap	
8			Spring	
9		15,000	Neap	
10			Spring	
11		6,000	Neap	Typical wind profile for wet season
12			Spring	
13	C	6,000bbl/hr	Neap	
14	D	6,000		
15	E (6km)			
16	F (9km)			
17	G (12km)			
18	H (15km)			

[1] unless otherwise specified

4.3.5 Brief Description of Results

The following presents a brief description of the outcomes from the simulation. This is followed by a more in-depth discussion of the results from the preferred discharge location. Animations and plots for all simulations are presented digitally on CD.

Continuous discharge from locations A to C

Scenarios 1 to 12 examined the impact for continuous discharges from locations A to C (Figure 4.7). These were undertaken for the three design flow rates on spring and neap tides and under typical wind conditions for the “wet season”.

For location A, the plume was entrained into the nearshore gyre and coastline impact occured during the first tidal cycle (Figure 4.8). Due to the high dilution and large tidal currents, levels and duration of impact were low with predicted nearshore peak concentrations of 0.01% PFW (10,000 dilutions) occurring for just one to two hours at any single location per tidal cycle.

Locations B and C were outside the influence of the nearshore gyre and the plume generally remained further offshore. The wind gradually forced the plume shoreward and after about two tidal cycles there was a low concentration coastline impact at about 0.005% PFW (Figure 4.9). Again due to strong tidal currents, this impact was very sporadic with concentration peaks occurring for about one hour per tidal cycle.

Batch discharge

Simulation 13 was undertaken to assess the impact of a batch discharge from Location C. For this 7000 bbls of PFW were released over one hour on the ebb tide (Figure 4.10). As the discharge rate had increased, plume concentrations were higher than the continuous discharge (typically 0.15% PFW (600 dilutions) at 100m from the discharge location). Coastline impact occurred after four tidal cycles at 0.02% PFW (5000 dilutions).

Locations D to H

Simulations 14 to 18 examined the effect of moving the discharge progressively offshore, from 4km (Location D) to 15km (Location H). These were undertaken for maximum future discharge flows, neap tides and typical winds for the "wet season". All locations demonstrated high rates of dilution and minimal coastline impact.

There are a number of logistical advantages with discharging from the Swamp Mooring and this location is the preferred option at the present time. A full set of results and impact assessment are presented in the following section.

Figure 4.8 Predicted PFW concentration from discharge Location A

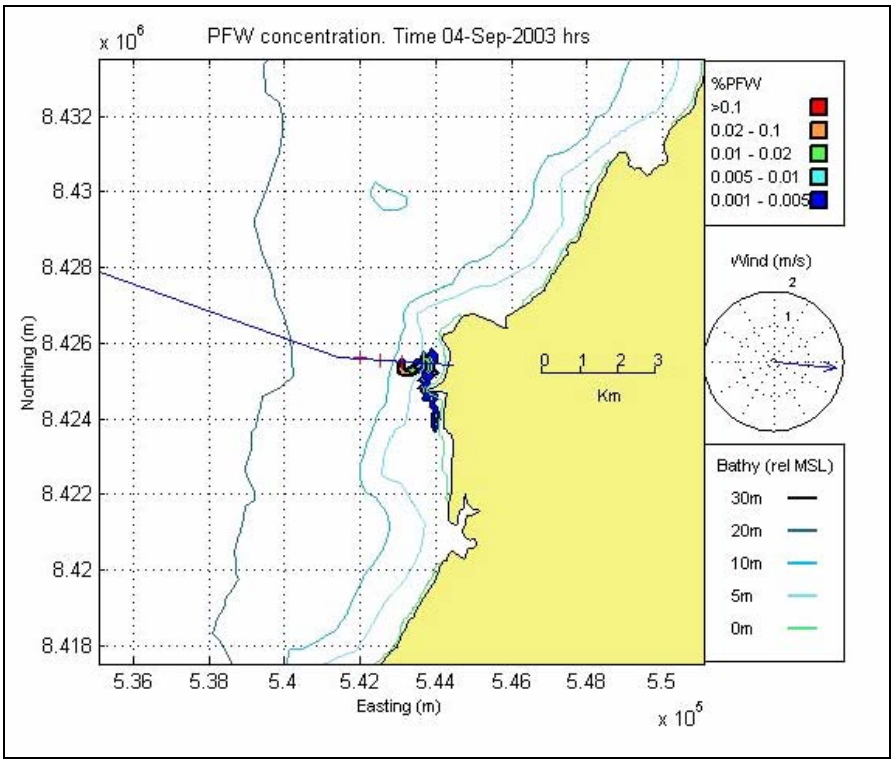


Figure 4.9 Predicted PFW concentration from discharge Location C

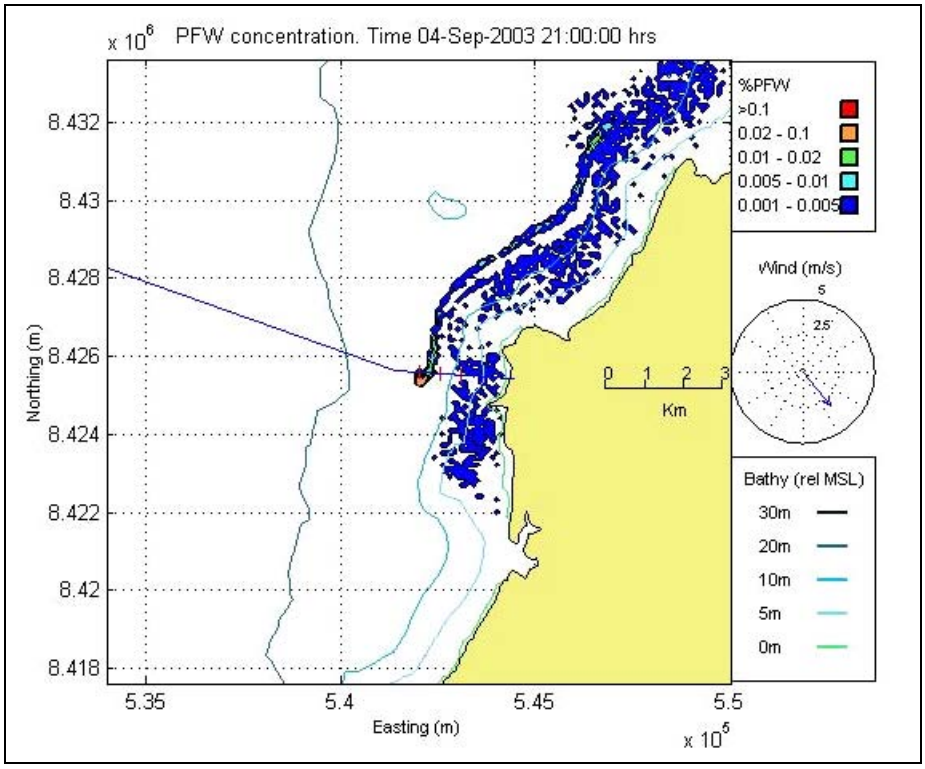
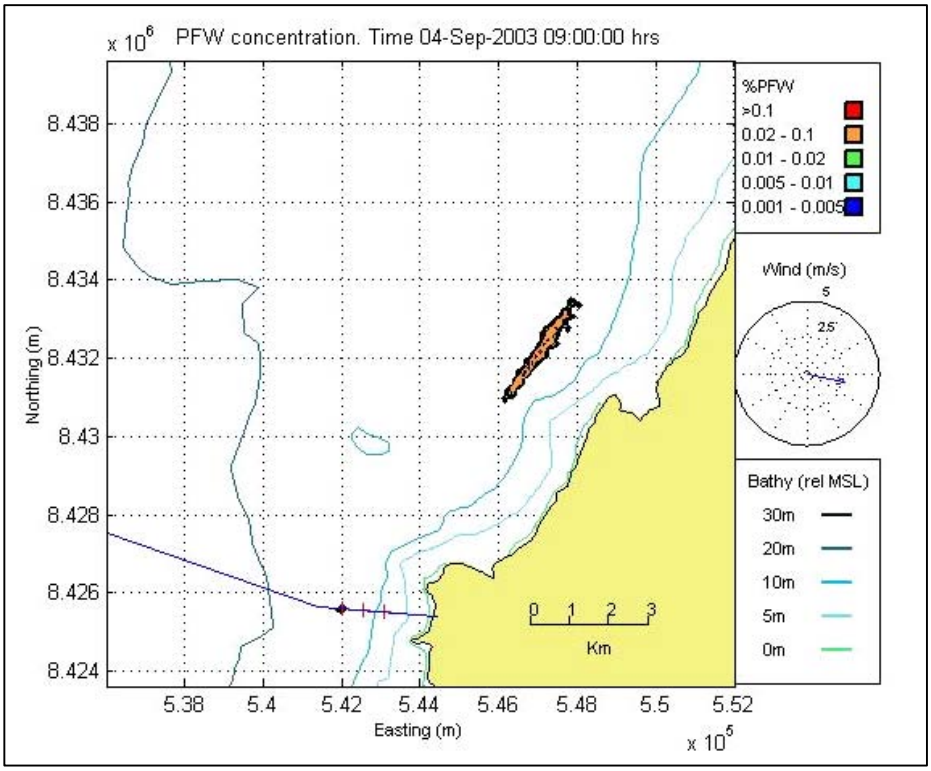


Figure 4.10 Predicted PFW concentration for batch discharge from discharge Location C



4.3.6 Preferred Discharge Location

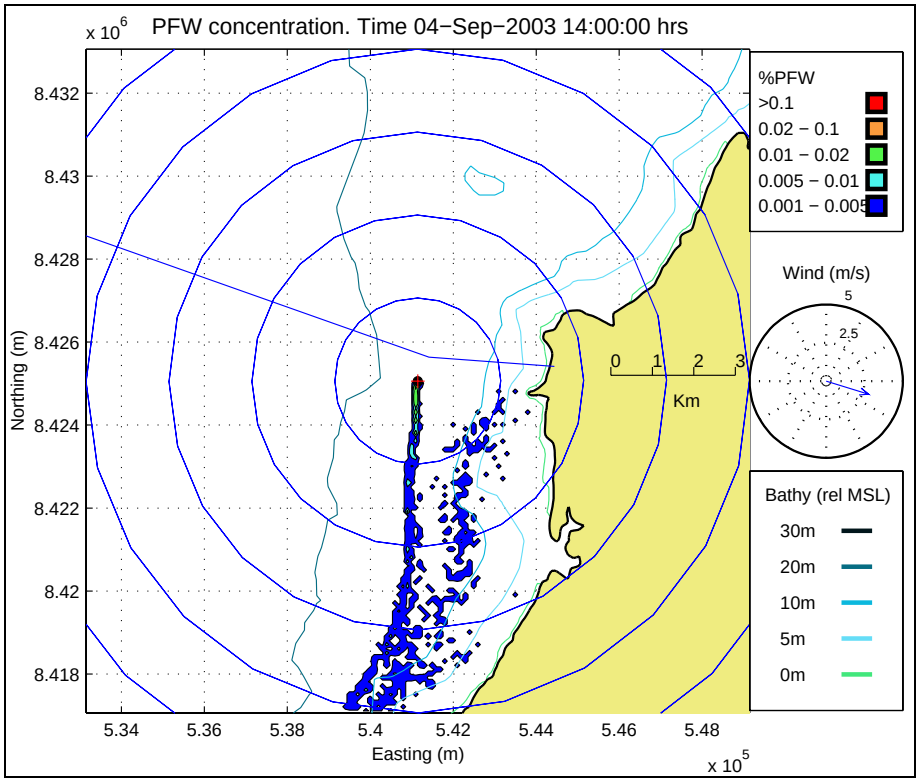
The optimal balance in terms of minimal environmental impact and acceptable cost to the project is to position the discharge in the vicinity of the Swamp Mooring. Figure 4.11 (a) – (i) present a series of plots showing the predicted concentration of PFW at three hour intervals for maximum future flows under "worst-case" ambient conditions (neap tide and typical "wet season" winds).

At high water (Figure 4.11(a)), PFW pools at slack water and concentrations increase to a maximum of 0.05% PFW. On the ebb tide, the plume is advected parallel to the bathymetry for a distance of approximately seven kilometres towards the north. With the increasing ambient flow, there is additional dilution and concentrations reduce to 0.01% PFW. At low water the discharge pools and once again concentrations build up to a maximum of 0.05%. The flood tide advects the plume about six kilometres towards the south.

Approximately six hours after discharge, the plume starts to break up and fragment. This fragmented plume continues to move up and down the coastline with the tide. Superimposed on the ebb and flood of the tide is a persistent onshore surface drift driven by wind and waves. After three tidal cycles the plume impacts the coastline with a very low concentration of between 0.001% and 0.005% PFW (100,000 to 20,000 dilutions).

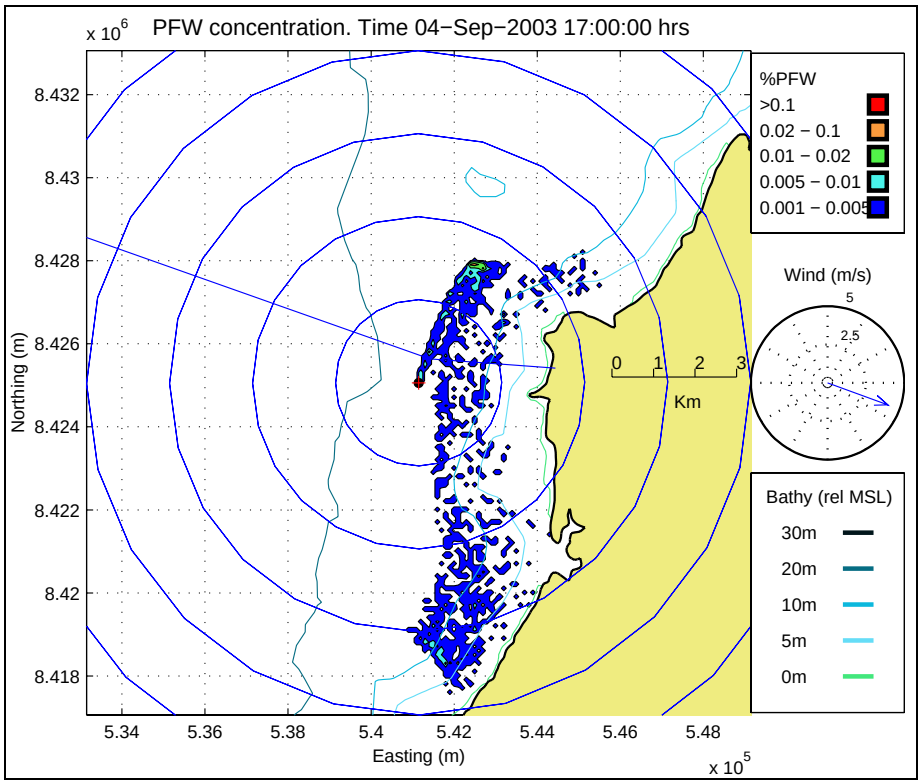
Figure 4.11. Predicted PFW concentration on a neap tide

(a) High Water

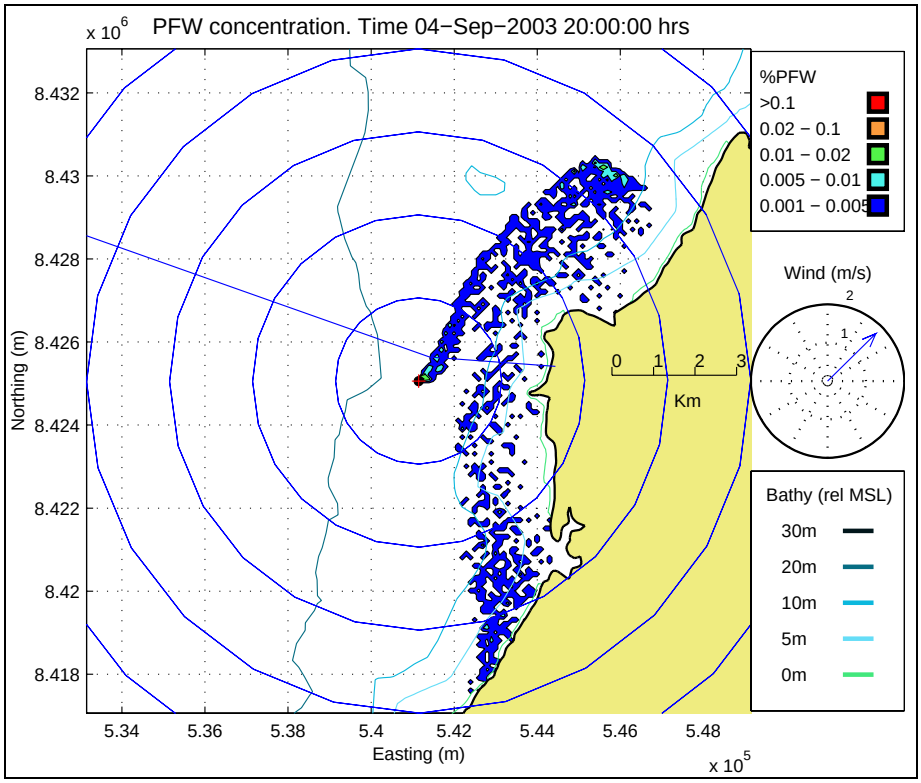


Note: Range rings are drawn at 2km intervals centred on the discharge point

(b) Mid ebb

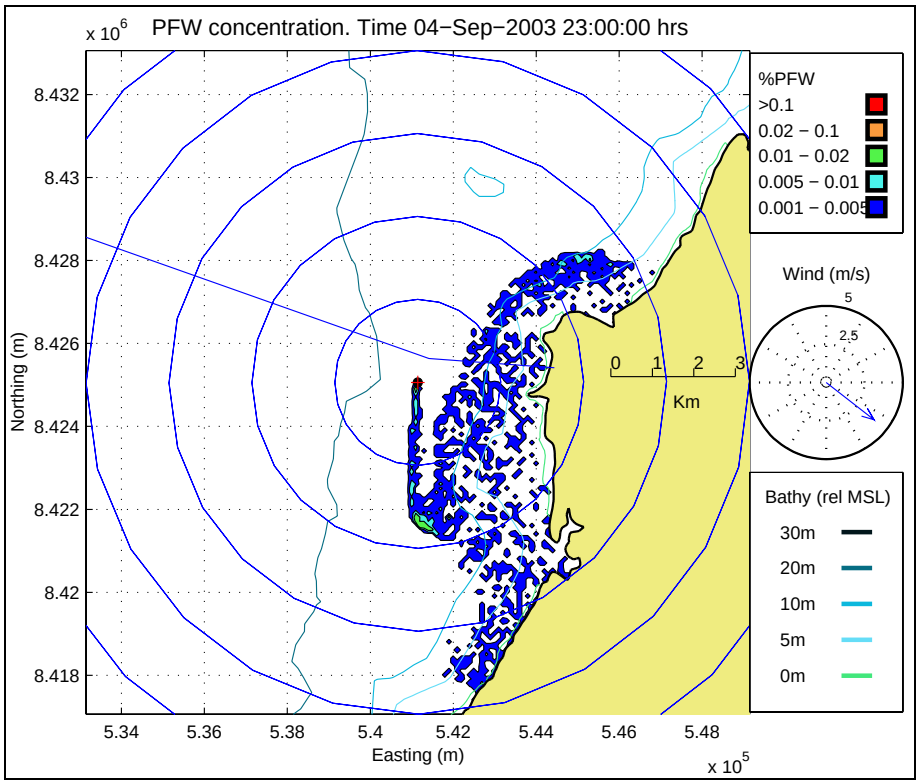


(c) Low water

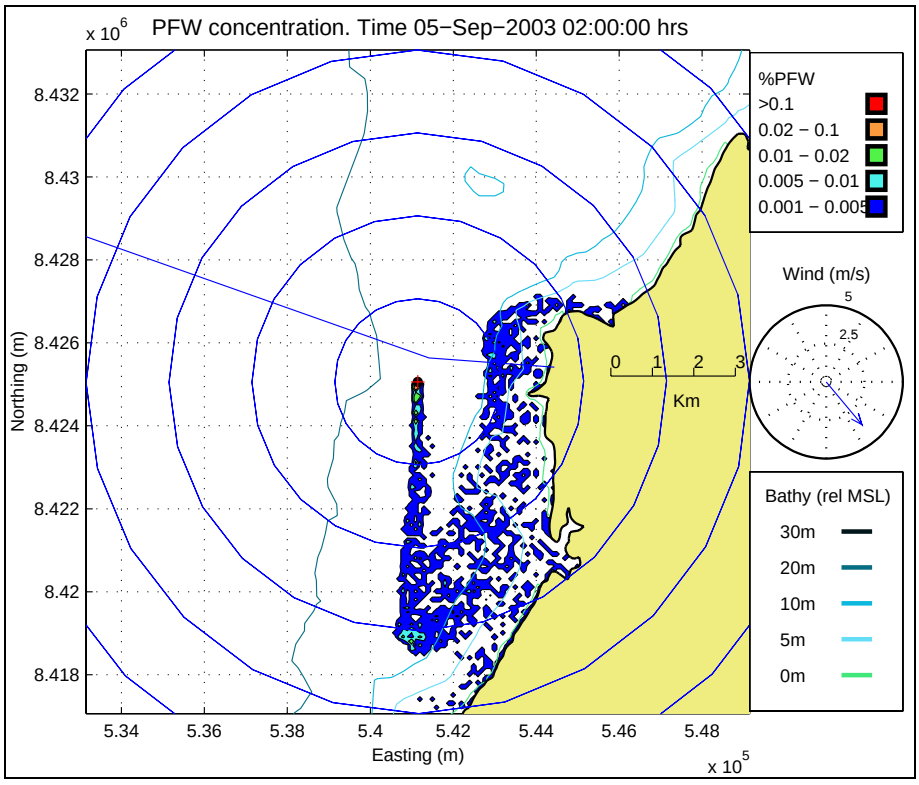


Note: Range rings are drawn at 2km intervals centred on the discharge point

(d) Mid flood

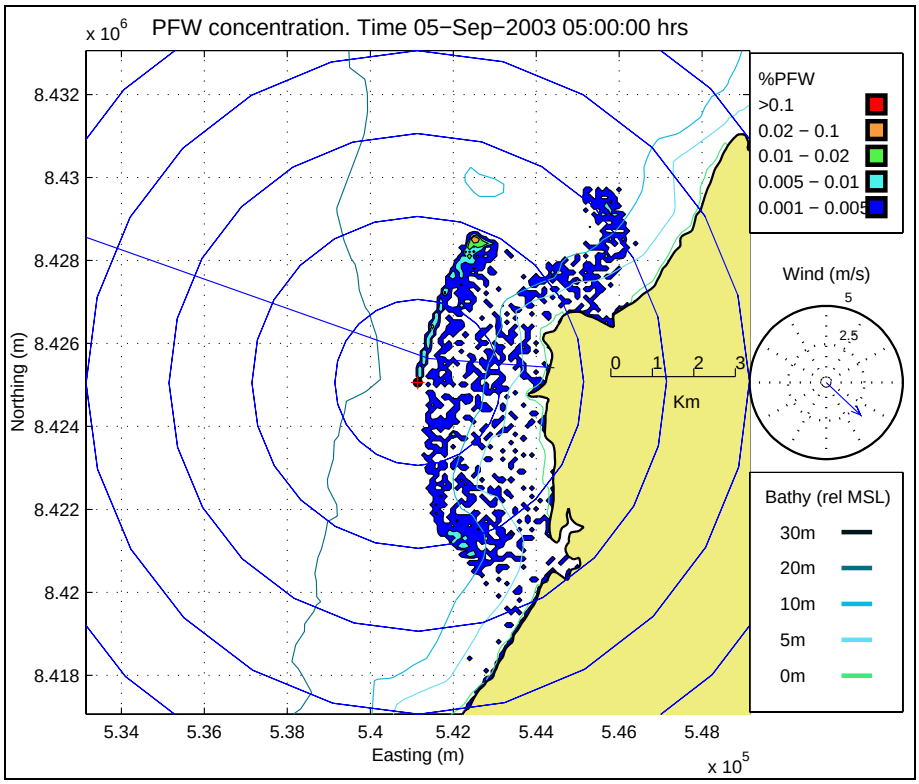


(e) High water

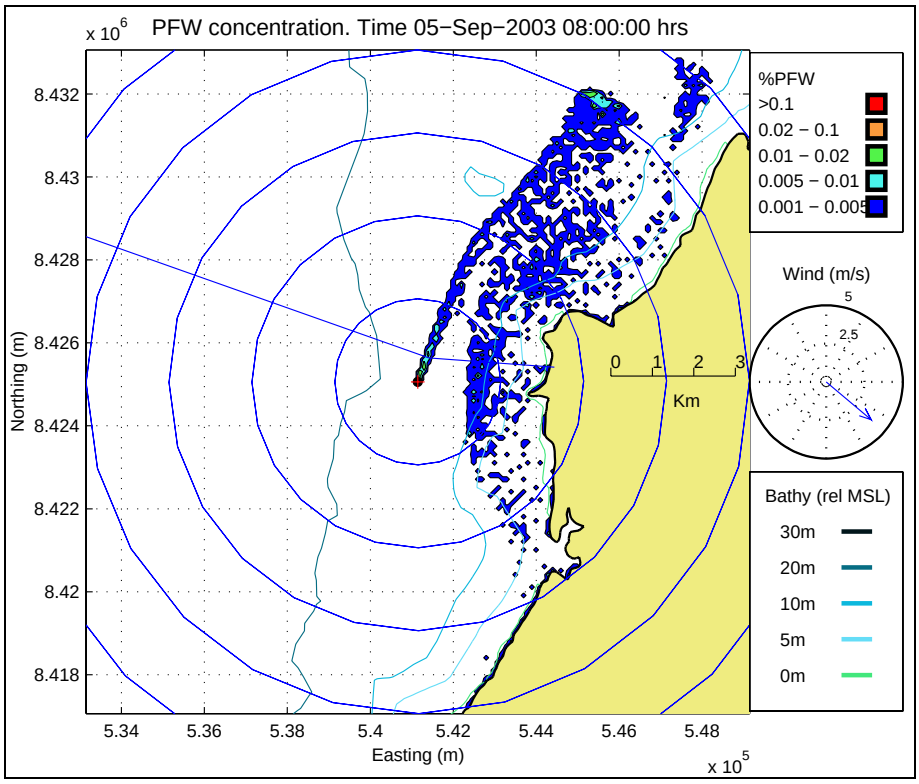


Note: Range rings are drawn at 2km intervals centred on the discharge point

(f) Mid ebb

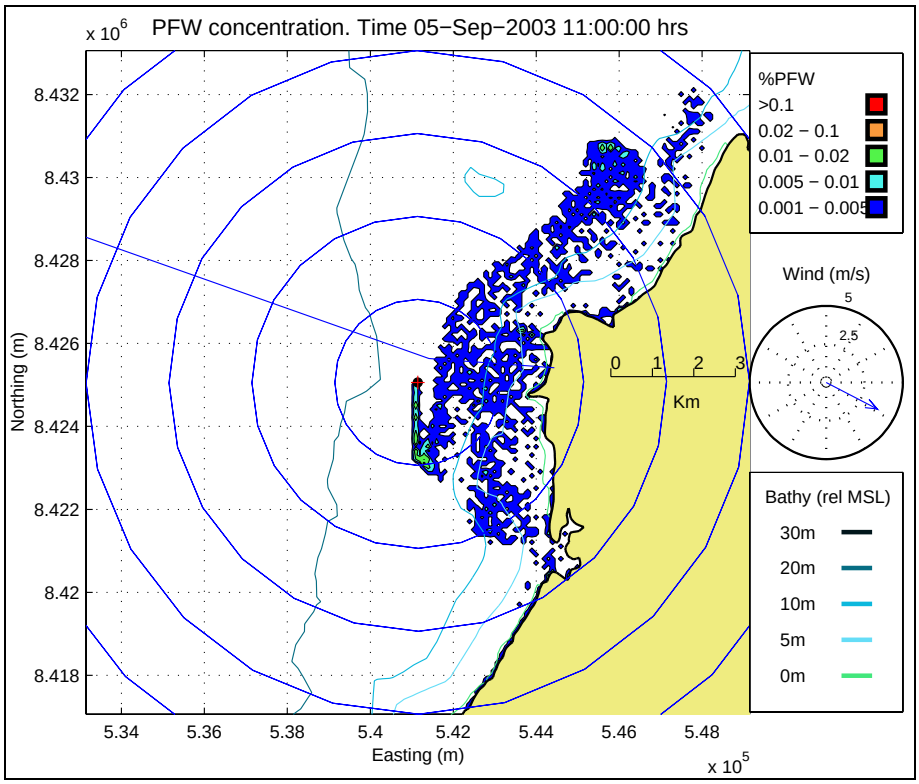


(g) Low water

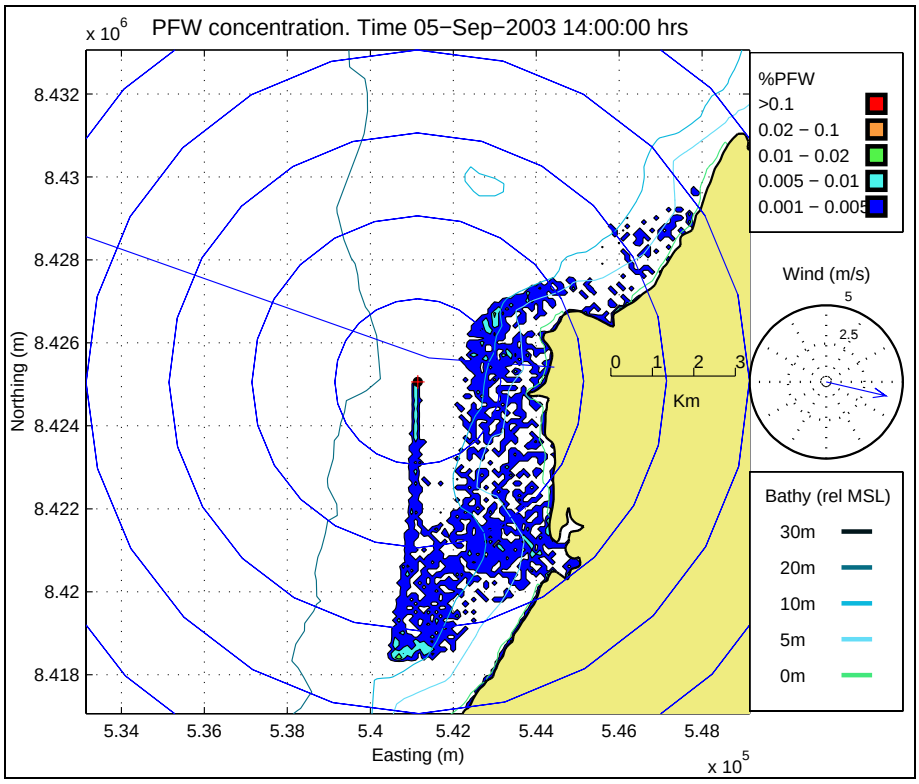


Note: Range rings are drawn at 2km intervals centred on the discharge point

(h) Mid flood.



(i) High water.



Note: Range rings are drawn at 2km intervals centred on the discharge point

4.3.7 Risk Assessment

The traditional PEC/PNEC approach was used to assess the risk. As described in Section 2.5.3, this approach demonstrates the zone of potential affect by calculating and presenting contours of the PEC/PNEC ratio. Any value over one then indicates a potential zone of impact. In the absence of any ecotoxicology data for the PFW, the PNEC was set at 0.1% PFW, the lowest no observed effect concentration (NOEC) measured from all WEL's assets on the North West Shelf (IRCE, 2003a).

Figure 4.12 – Figure 4.15 show (a) the maximum predicted PFW concentration that occurred over the three tidal cycle simulation and (b) the corresponding PEC/PNEC ratio contours, for model layers one to 4, respectively. Highest concentrations occur in the surface waters around the discharge location. These peak at just over 0.1% PFW within the surface waters, up to 400m from the discharge point. The highest concentrations would occur for short periods of time as the tides turn at slack waters. PEC/PNEC ratios therefore exceed one for only a short duration.

4.3.8 Evaluation of Environmental Effects

General

The PEC/PNEC approach is highly conservative as it assumes an ecological response immediately on contact with PFW exceeding the PNEC. In contrast, the PNECs are derived from ecotoxicology studies in which organisms are exposed to the PFW for durations that are unlikely to be experienced in the field. The objective of this section is to present a more intuitive assessment of the risk posed to biological communities from the PFW being discharged from the Blacktip outfall. These communities include:

- benthos;
- plankton;
- sessile Invertebrates (communities attached to the platform);
- fish;
- marine mammals; and
- sea birds.

Benthos

Benthos communities are found in or around the seabed. They are unlikely to be affected because the plume disperses rapidly in the water column and does not impact directly on the seabed. Furthermore adsorption onto suspended sediment particles will be low, limiting the extent of sedimentation to the seabed.

Plankton

Planktonic organisms live freely in the water column and drift with the water currents. Plankton may also include the early stages (eg. egg, larva and spores) of non-planktonic

species (fish, benthic invertebrates and algae). Figure 4.16 illustrates the typical exposure period for passive floating organisms. Once discharged to the receiving environment, dilution reduces the concentration of toxic chemicals in the PFW. Under the present discharge rate and configuration, initial dilutions are high. For a worst-case scenario, a freely floating organism passing directly over the discharge pipe may be exposed to PFW concentrations above the PNEC value in the mixing zone for a short duration. There is therefore the potential for impact, however, the exposure concentration will be continually diluting and only organisms residing directly in the plume would be impacted, which constitutes a small proportion of the community.

Sessile marine invertebrates

Sessile marine invertebrates are those that are attached to the substrata and infrastructure surrounding the discharge. These do not have the opportunity to move to avoid toxic affects and potentially are the most exposed communities to the plume. Even though these organisms cannot move, the plume would be continually moving around them depending on the direction and speed of ambient currents. Sessile invertebrates may therefore be impacted sporadically by high concentrations of PFW, however, when they encounter clean seawater, they would have the opportunity to release accumulated hydrocarbons.

Fish

Figure 4.16 shows the typical exposure periods for motile organisms such as fish. These have the ability to swim and might move in and out of the plume. Exposure periods are therefore sporadic and unlikely to be at levels which would harm the organism. Moreover, the volume of water exposed to concentrations above PNEC values is relatively small both under present and projected discharge rates.

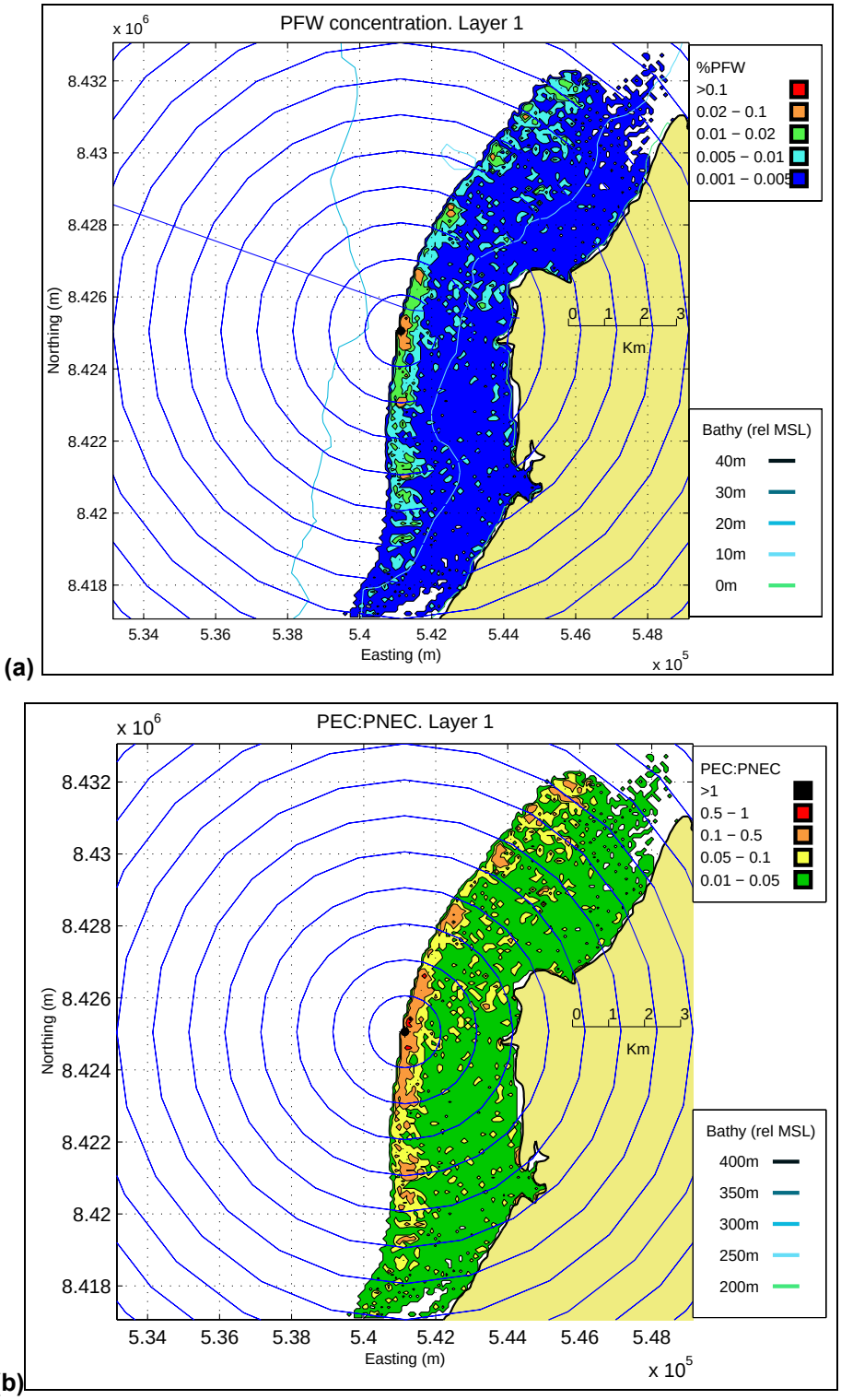
Marine mammals

As marine mammals feed on fish and/or plankton, they are most likely to be affected by trophic transfer (ie, bioaccumulation of chemicals from food) and potential biomagnification. However, vertebrates are able to metabolise and excrete the type of chemicals that contribute most to the risk. They are also generally migratory so individuals are not likely to be affected by any localised contamination that may occur.

Seabirds

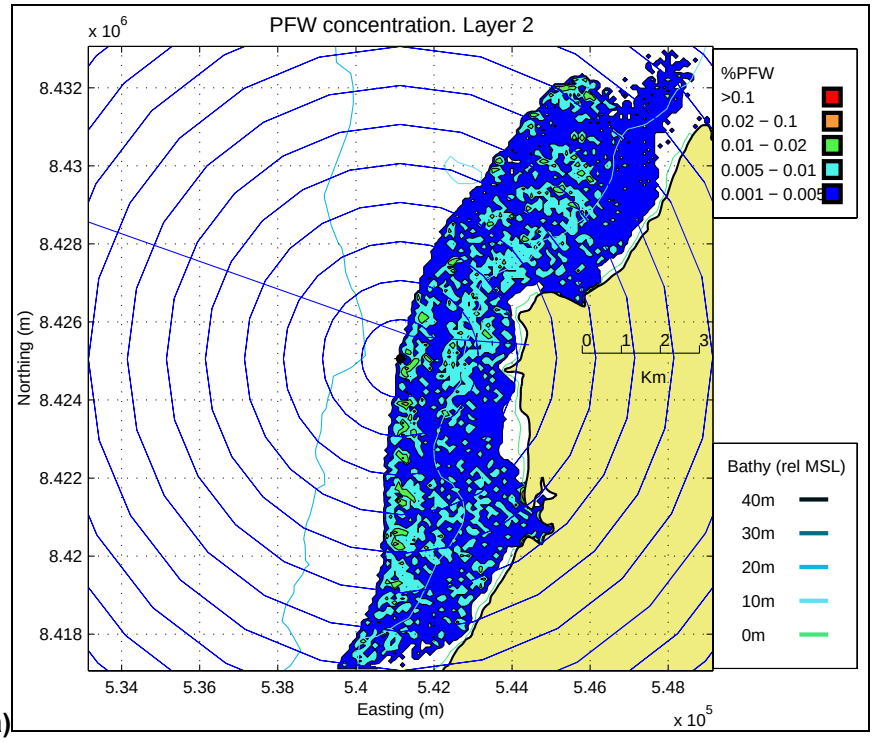
Seabirds are harmed mainly by the physical properties of floating oil and not the toxicity. (Furness and Camphuysen, 1997). As with the marine mammals, there is the potential for trophic transfer and indirect effects such as changes in the availability of food sources. As the food source is not likely to be impacted, the risk to sea birds is low.

Figure 4.12. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer one (0-2 m) on a neap tide

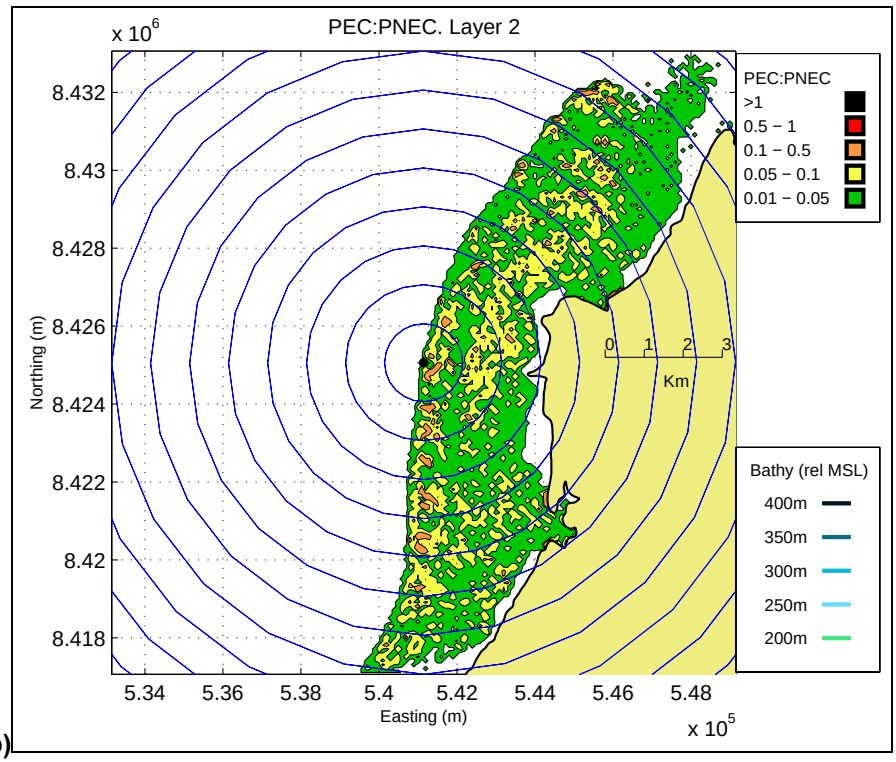


Note: Range rings are drawn at 1km intervals centred on the discharge point

Figure 4.13. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer two (2-4 m) on a neap tide



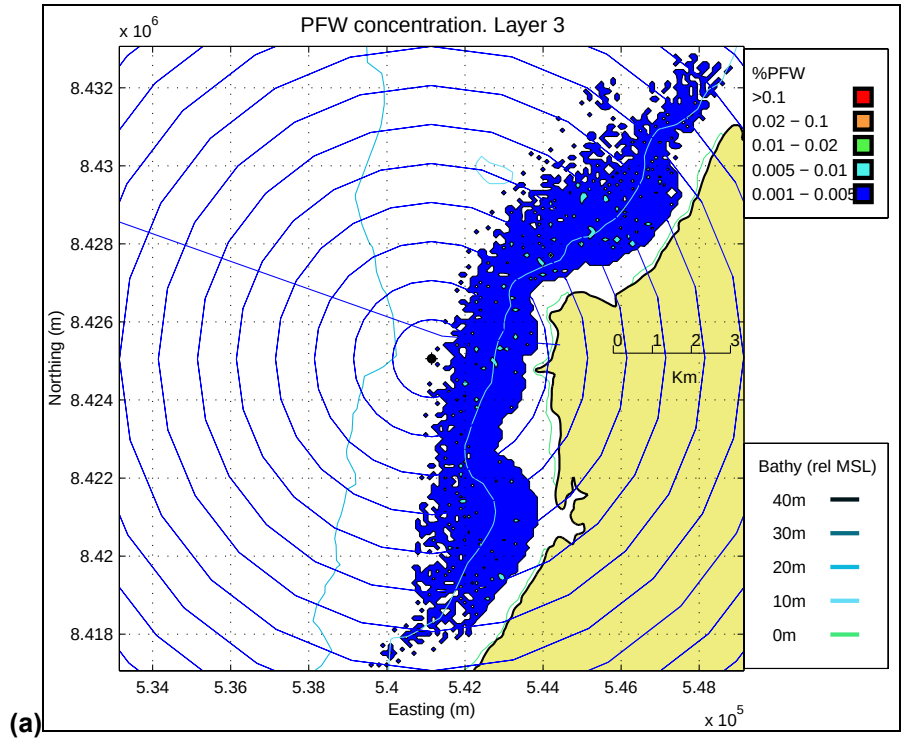
(a)



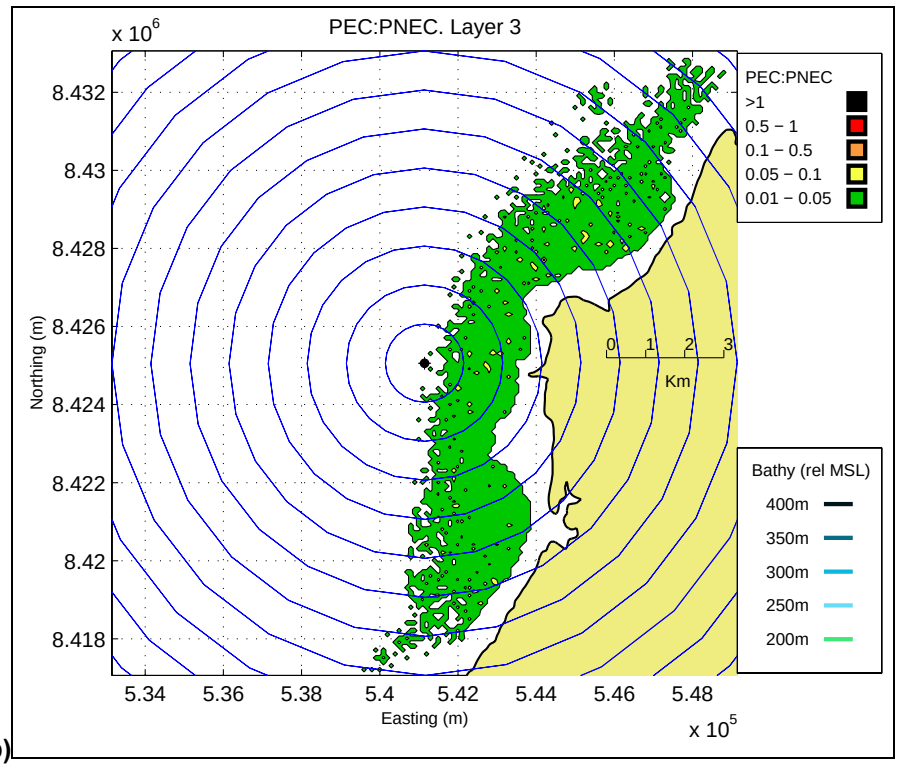
(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.14. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer three (4-6 m) on a neap tide



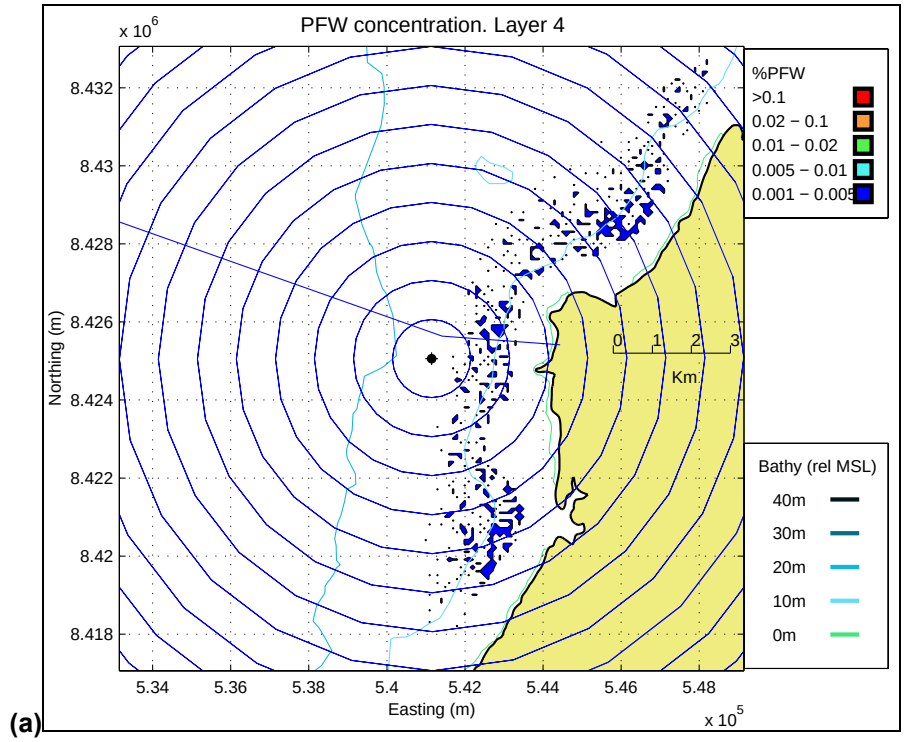
(a)



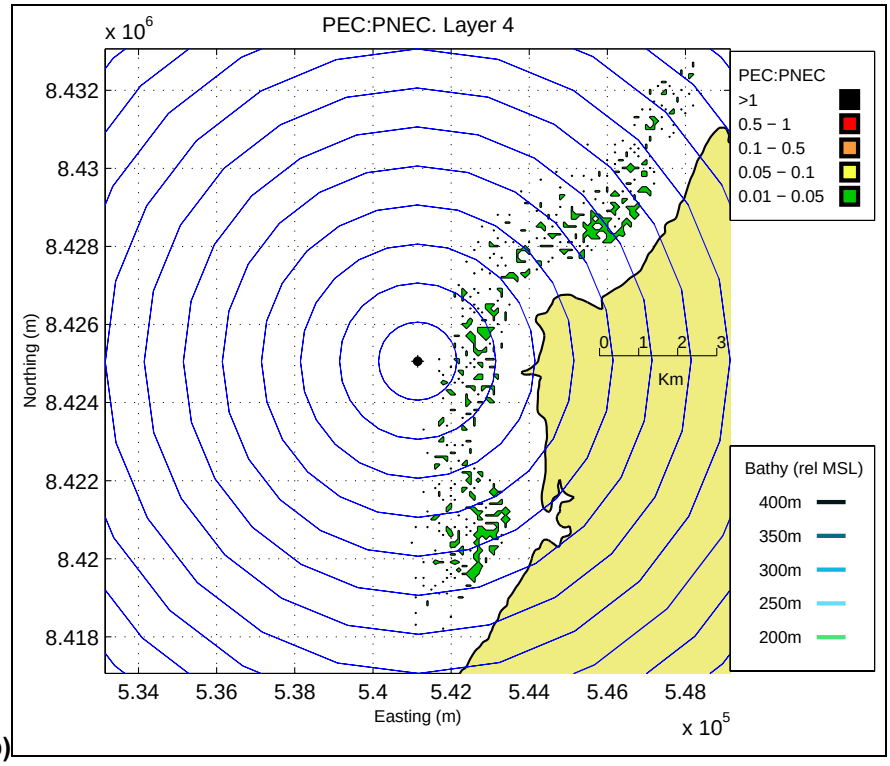
(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.15. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer four (6 - 10 m) on a neap tide



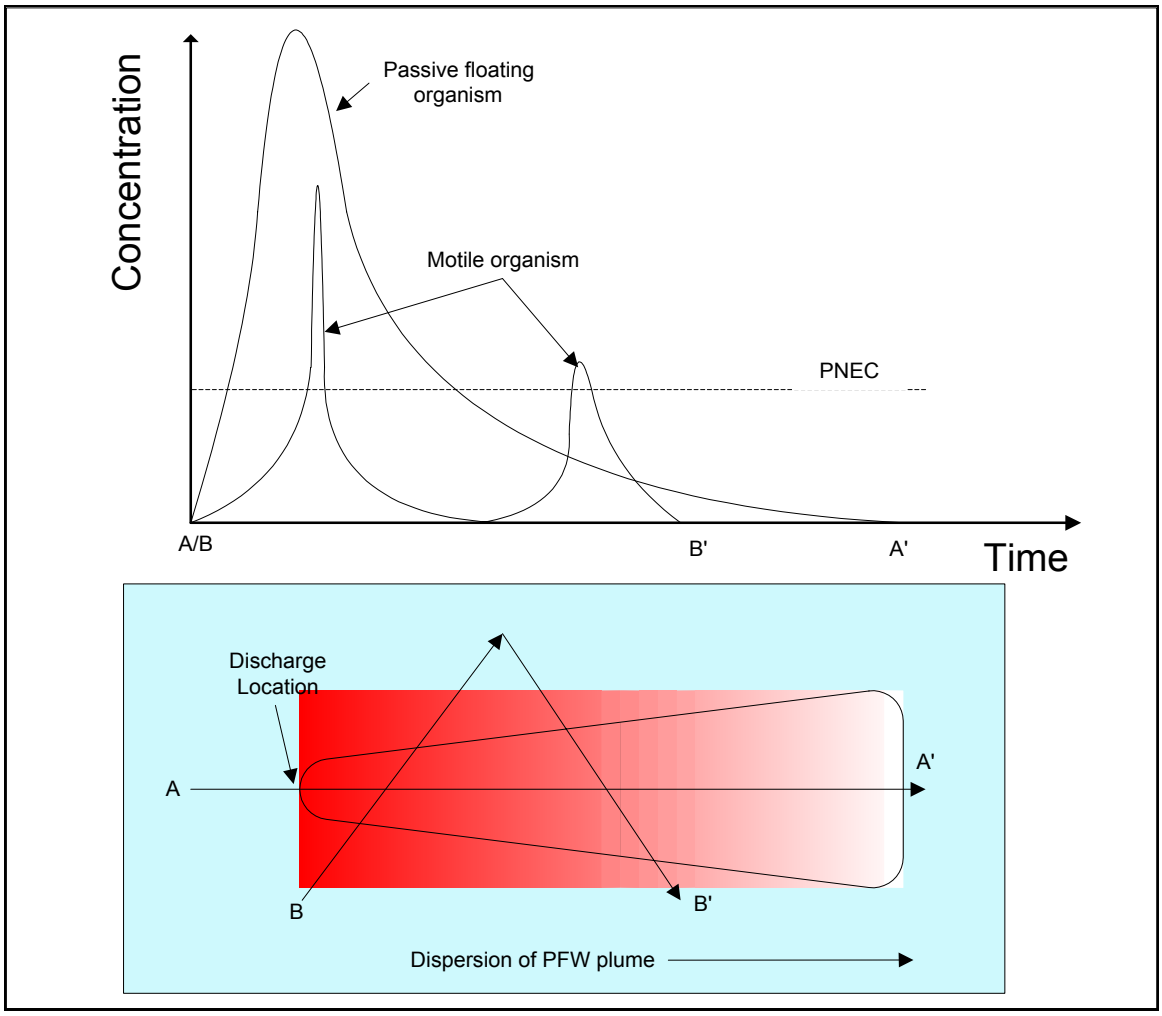
(a)



(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.16 Conceptual model for PFW exposure times for passive and motile organisms



4.4 Dissolved Oxygen

4.4.1 General

Prior to discharge PFW is likely to have little or no DO. This should not be a problem as even under worst-case conditions the discharged plume should receive 700 initial dilutions (see Section 2.3.5), which mean that by the time the plume reaches the sea surface DO concentrations should be virtually back to ambient levels. However, the PFW discharge will contain a range of organic compounds and chemicals that will start to decompose and utilise oxygen immediately on discharge. The rate at which oxygen is utilised is measured by the Biochemical Oxygen Demand (BOD) of the effluent.

This section presents an assessment on the likely impact of this oxygen utilisation on DO levels in the receiving waters. From this analysis, maximum BOD concentrations are given that will most likely maintain oxygen levels above 90% saturation limits as required by the ANZECC guidelines.

4.4.2 Receiving Waters

The concentration of DO is highly dependent on temperature, salinity, biological activity (microbial primary production) and rate of transfer from the atmosphere. Based on water temperatures (26 to 30°C) and salinity (34psu) of the receiving waters in the vicinity of the Blacktip PFW discharge, DO saturation levels will vary from 6.22mgL^{-1} to 6.64mgL^{-1}. The 2000 ANZECC guidelines for fresh and marine water quality recommend that DO in tropical Australia should not normally permitted to fall below 90% saturation, determined over at least one tidal cycle. For Blacktip, this equates to 5.6mgL^{-1}.

4.4.3 Biochemical Oxygen Demand

The BOD provides a measure of the rate at which oxygen is consumed by bacterial activity and is thus an indirect measure of the organic content of wastewater. Experiments have shown that BOD decays exponentially with time, t, according to the equation:

$$BOD_c = BOD_0 e^{-K_{BOD}t}$$

where:

BOD_c is the concentration at time t;

BOD_0 is the original concentration; and

K_{BOD} is the BOD decay rate.

K_{BOD} is temperature dependant and can be calculated from:

$$K_{BOD}^{T_1} = K_{BOD}^{T_2}\theta^{(T_1-T_2)}$$

where:

$K_{BOD}^{T_1}$ is the decay coefficient at temperature T_1;

$K_{BOD}^{T_2}$ is the decay coefficient at 20°C (typically between 0.2 and 0.3); and

θ is the temperature coefficient for reaction rates (typically 1.056 for T>20°C).

For temperatures of 28°C and $K_{BOD}^{T_2}$ of 0.26 this yields a value of 0.4 day^{-1}.

4.4.4 Oxygen Utilisation

Oxygen utilisation (D_{O2}) in a bounded stream can be predicted using a modified version of the classic Streeter-Phelps oxygen sag equation (Metcalf and Eddy, 1991), given by:

$$D_{O2} = \frac{K_{BOD}BOD_0}{K_{O_2} - K_{BOD}}\left(e^{-K_{BOD}t} - e^{-K_{O_2}t}\right)$$

where:

K_{O2} is the reaeration coefficient.

The graphical representation of the Streeter-Phelps oxygen sag equation is given in Figure 4.17, using the values specified in Table 4.4. For illustration purposes, the initial BOD concentration was set at 5000mgL^{-1}. After 700 initial dilutions this decreases to 7.14mgL^{-1}. As can be seen from the DO curve, oxygen utilisation commences immediately after discharge. It will continue to fall until a critical point is reached when the rate of oxygen utilised by waste decomposition equals the rate of atmospheric reaeration. Thereafter DO concentrations increase as the rate of reaeration exceeds the rate of utilisation.

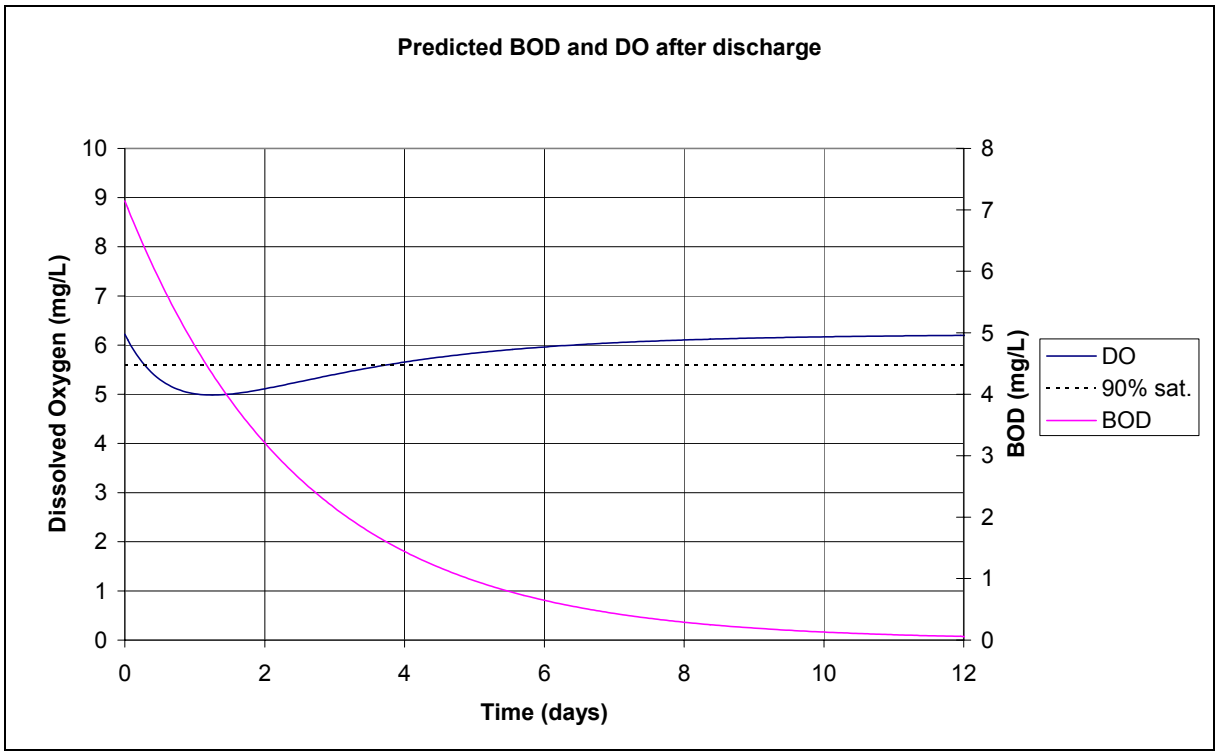
Table 4.4 Summary of values used in Streeter Phelps equation

Parameter	Value
$O_{2\ sat.}$	6.22 mgL^{-1}
BOD_0	7.14 mgL^{-1} (5,000 mgL^{-1} prior to initial dilution of 700)
K_{BOD}	0.4 day^{-1}
K_{O2}	1.4 day^{-1}

The principle is the same for the open ocean, however, in addition to the decay process, BOD concentrations reduce through dispersion of the plume in the receiving waters. This may be countered in regions of slow moving currents by build up due to poor flushing and recirculation of the plume over itself.

In studies undertaken for the European Urban Wastewater Treatment Directive it was estimated that where BOD levels deviate by less than 1.5mgL^{-1} from background levels, the resulting impact on DO will be less than 0.5 mg/l. (CSTT; 1993). This can also be seen from the oxygen sag and BOD concentration curve in Figure 4.17. In the dispersion modelling presented next, 1.5mgL^{-1} was used as the threshold value below which there should be no adverse effect in the environment from reduced oxygen levels.

Figure 4.17 Concentrations of BOD and DO predicted by the Streeter-Phelps equation.



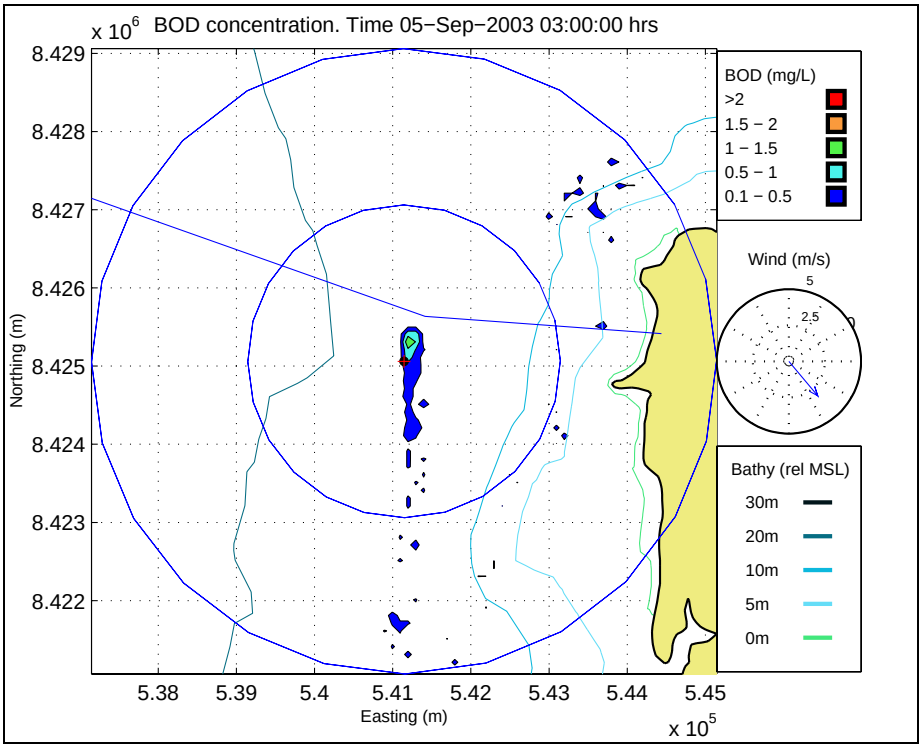
4.4.5 Dispersion Modelling

BOD was simulated using the PFW dispersion model with the objective of deriving a maximum value for the effluent discharge. The scenario undertaken was identical to that described in Section 4.3.6, with the exception that BOD was modelled instead of a conservative tracer. The initial BOD concentration was set at 1,200mgL^{-1} and the decay coefficient at 0.4 day^{-1}.

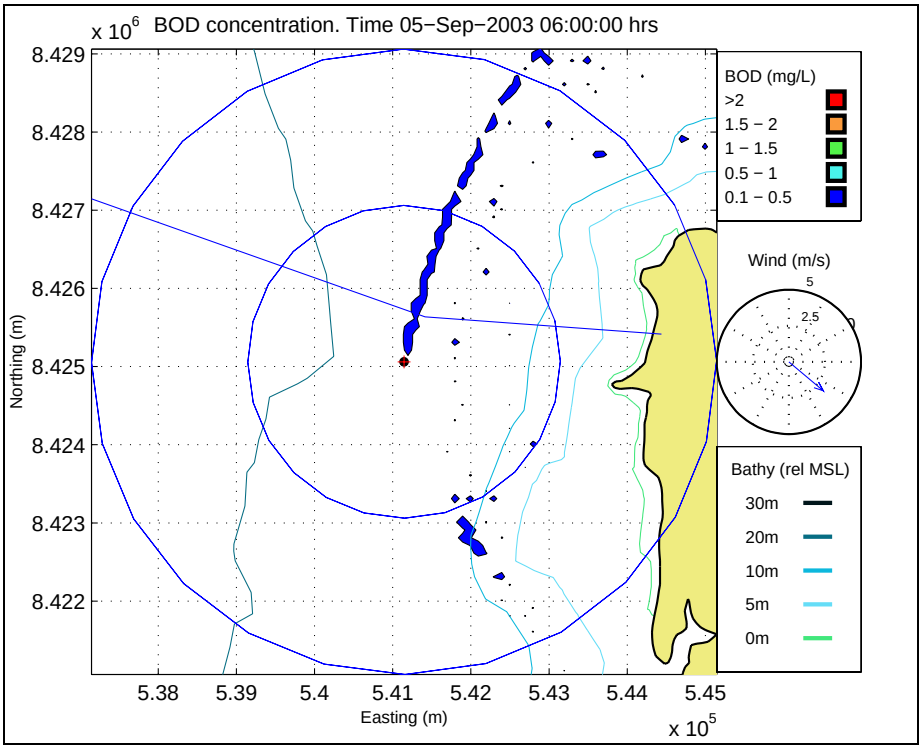
Figure 4.18 (a) – (d) present a series of plots showing the predicted concentration of BOD at three hourly intervals for maximum future flows under “worst-case” ambient conditions (neap tide and typical “wet season” winds). At high water (Figure 4.11(a)), the plume pools at slack water and BOD concentrations increase to a maximum of 1.5mgL^{-1}. On the ebb tide, the plume is advected parallel to the bathymetry contours for a distance of approximately 12km towards the north. With the increasing ambient flow, there is additional dilution and concentrations reduce to less than 0.5mgL^{-1}. At low water the discharge pools and once again concentrations peak at 1.5mgL^{-1}. The flood tide advects the plume about 10km towards the south.

Figure 4.18. Predicted BOD concentration on a neap tide

(a) High Water

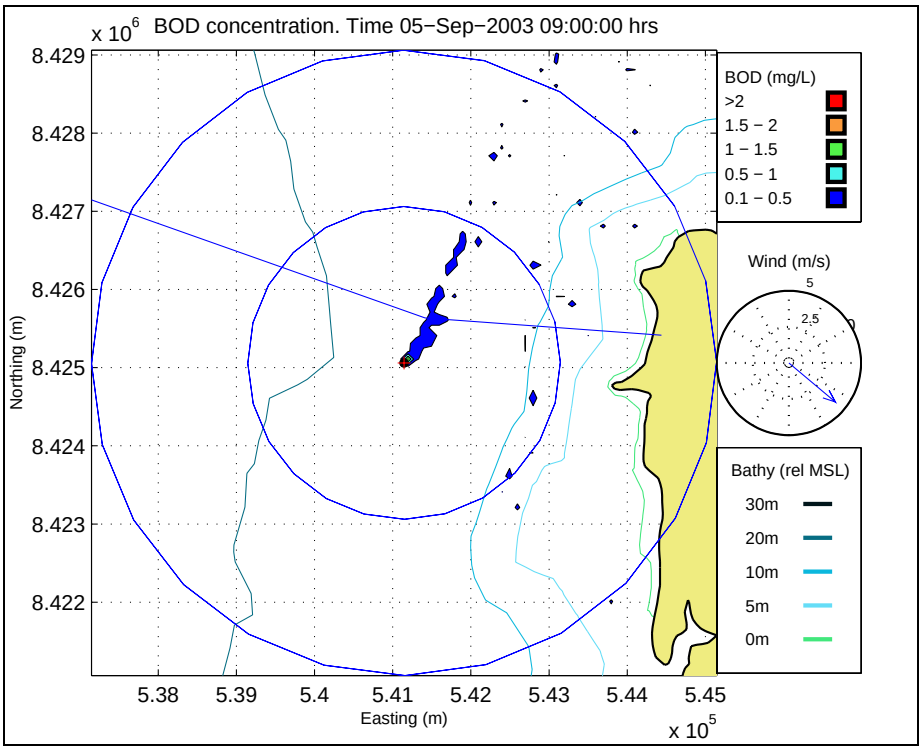


(b) Mid ebb

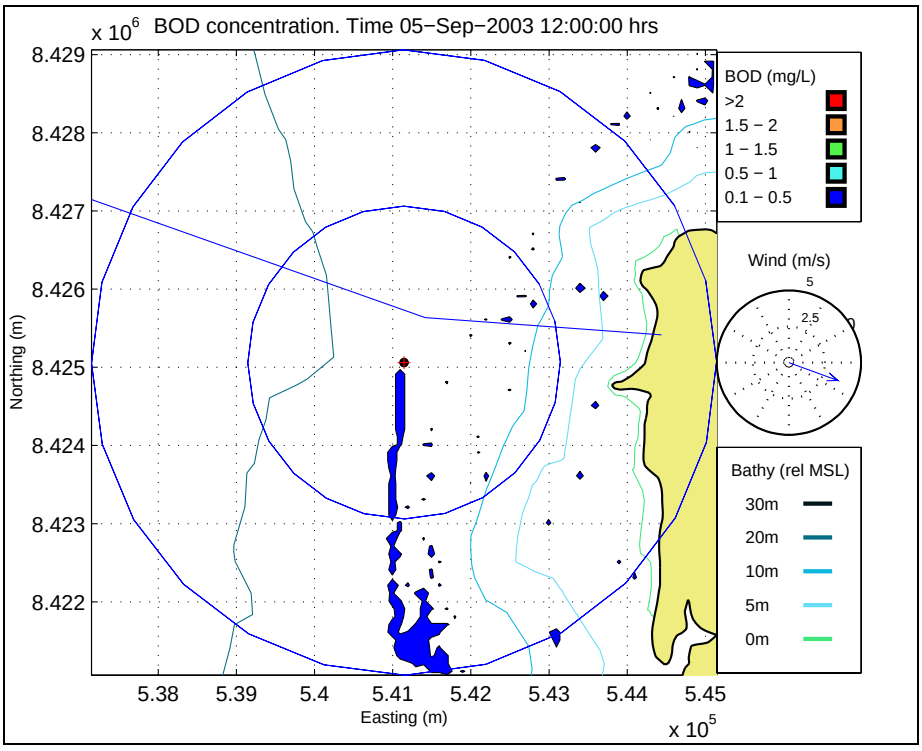


Note: Range rings are drawn at 1km intervals centred on the discharge point

(c) Low water



(d) Mid flood



Note: Range rings are drawn at 1km intervals centred on the discharge point

4.4.6 Risk Assessment

The traditional PEC/PNEC approach was used to assess the risk. As described in Section 2.5.3, this approach demonstrates the zone of potential affect by calculating and presenting contours of the PEC/PNEC ratio. Any value over one then indicates a potential zone of impact. The PNEC was set at 1.5 mg/L BOD. As stated above, this is the concentration at which the change in DO levels will be less than $0.5mgL^{-1}$.

Figure 4.19 and Figure 4.20 show (a) the maximum predicted BOD concentration that occurred over the three tidal cycle simulation and (b) the corresponding PEC/PNEC ratio contours, for the top two layers in the model, respectively. Highest concentrations occur in the surface waters around the discharge location. These peak at about $1.5mgL^{-1}$ BOD within 100m from the discharge point. The PEC/PNEC ratios peak at about one suggesting that the change in DO levels will be less that $0.5mgL^{-1}$ at all times.

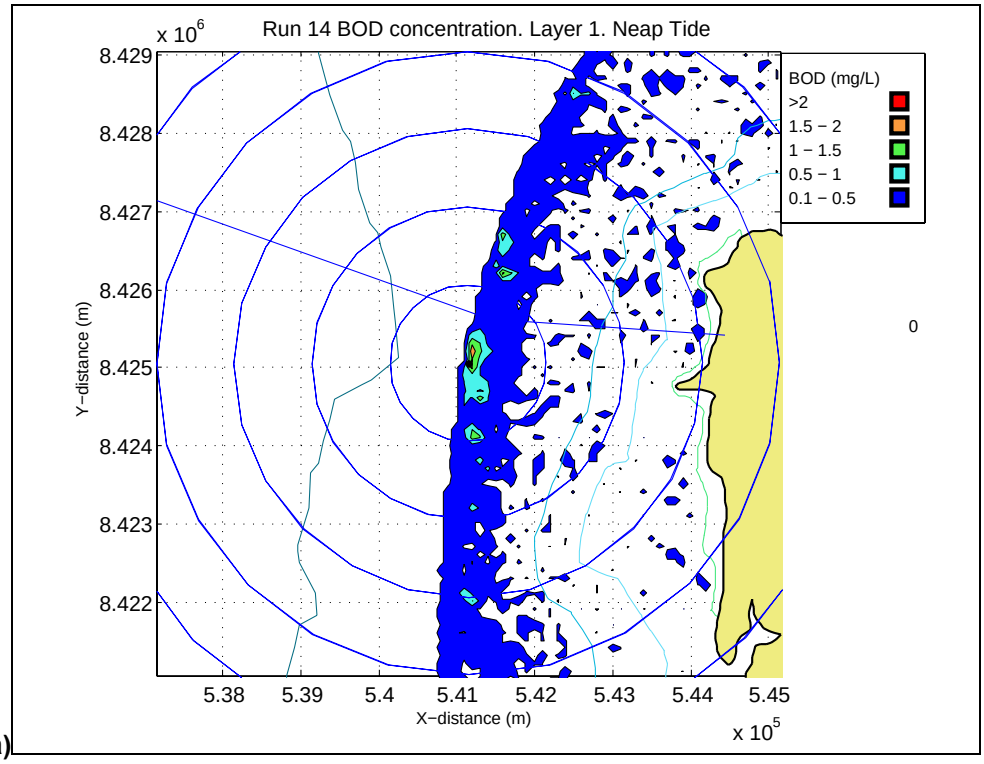
4.4.7 Recommended maximum BOD Concentrations

A BOD concentration of $1,200mgL^{-1}$ was found to be the limit for the design rate of 6000 bbl day^{-1} to maintain BOD levels in the receiving environment below the critical value of $1.5mgL^{-1}$. This value was used to scale BOD concentrations for the other design flow rates. Results are presented in Table 4.5.

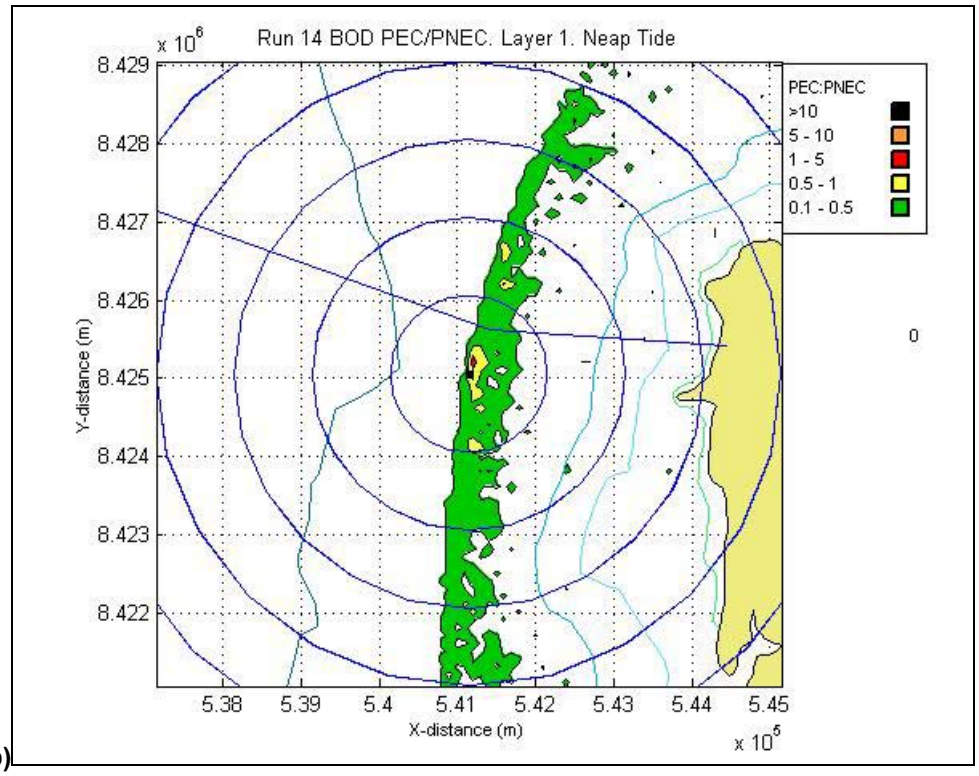
Table 4.5 Recommended maximum BOD concentrations for each design flow rate.

Design flow rate (bbl day^{-1})	Maximum BOD conc. (mgL^{-1})
6000	2,500
2000	7,500
200	75,000

Figure 4.19. Scenario 14: (a) maximum BOD concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer one (0-2 m) on a neap tide



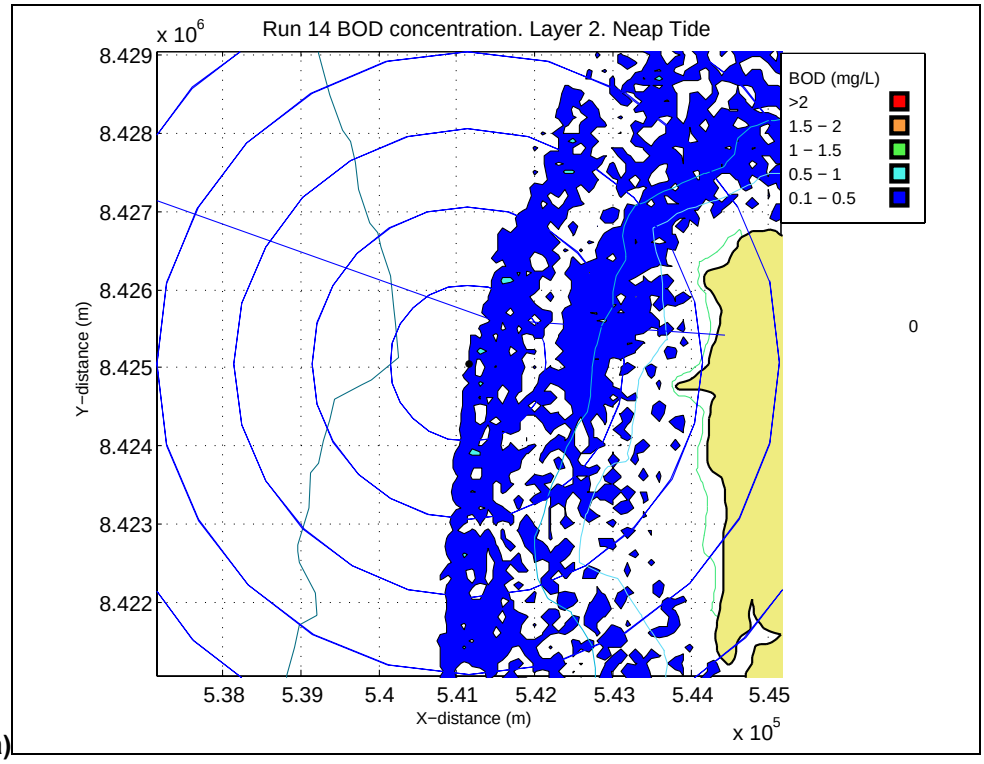
(a)



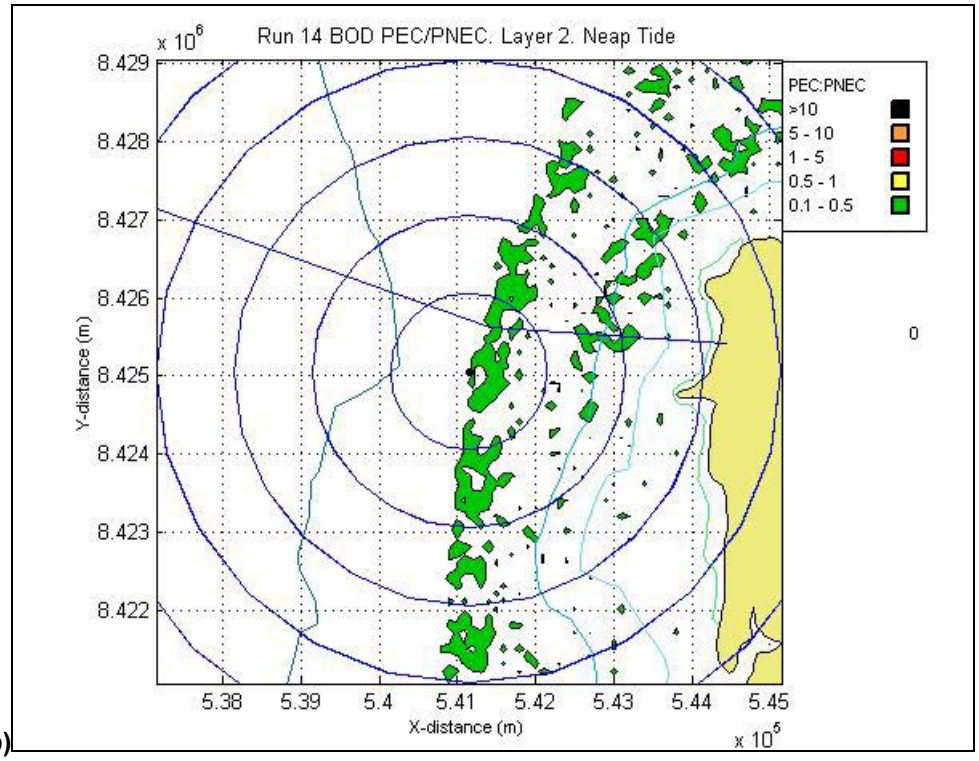
(b)

Notes:

Figure 4.20. Scenario 14: (a) maximum BOD concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer two (2-4 m) on a neap tide



(a)



(b)

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

It is common practice in the petroleum industry to remove as many hydrocarbons as possible from PFW by physical or enhanced separation techniques and then discharging directly to the ocean. It is recognised that the separation process is not 100% effective and trace concentrations of chemical contaminants can remain in the discharge. Hydrocarbons and process chemicals are the contaminants of most concern in PFW.

Ecotoxicology experiments under laboratory conditions have demonstrated that undiluted PFW can be toxic to marine organisms. In contrast, detecting a measurable impact on marine ecosystems in the vicinity of PFW discharges has proved difficult. The reason for this is that dilution and biodegradation in the receiving environment reduces contaminant concentrations to levels below which they can have an impact on marine organisms. Where concentrations do exceed thresholds, exposure times for free-moving organisms are generally short.

The preferred disposal option for Blacktip PFW is onshore treatment followed by discharge through a long sea outfall. The discharge location will be near the Swamp Mooring, which lies in 15m of water. Corrosion inhibitors, hydrate inhibitor and demulsifiers will be added to the process stream. These will be selected based on their low toxicity and enhanced environmental performance. Onshore treatment allows more scope for treatment as there is not the space restriction of offshore facilities and contaminant concentration will be reduced to as low as practicable prior to discharge.

Numerical modelling has been undertaken to assess the environmental impact and to derive an effective discharge strategy for the Blacktip PFW. The assimilative capacity of the receiving water is high with strong tidal currents of up to $0.9ms^{-1}$ on a spring tides and $0.2ms^{-1}$ on neaps. Tides are semidiurnal and currents slacken four times a day.

Using a four port diffuser configuration, near field dispersion modelling showed that at least 700 initial dilutions would be achieved for the maximum future discharge rate. This would reduce PFW concentrations to 0.14%.

Far field modelling predicted that during slack waters PFW would build up and concentrations would reduce to a maximum of 0.1%PFW within 400m from the discharge. Based on ecotoxicology work previously undertaken by WEL on offshore facilities, this is below the predicted concentration at which there could be harm to marine organisms.

These exotoxicity values are believed to be conservative as the tests included sublethal endpoints and were undertaken on organisms in their most sensitive stages of life (eg larval development or fertilisation). Moreover, exposure times were greater than those likely to be experienced in the natural environment. Assuming that the treated Blacktip PFW is no more

toxic than PFW from other Woodside Assets, there should be minimal environmental impact from discharging it to the 15 m depth contour in the Joseph Bonaparte Gulf.

5.2 Recommendations

Once PFW becomes available, ecotoxicology tests should be undertaken and the toxicity of process chemicals should be reviewed. Ecotoxicity should include tests on juvenile prawns as this species constitutes an important fishery in the Joseph Bonaparte Gulf.

As well as reducing the concentration of dispersed oil, treatment should focus on removing PAHs and reducing the toxicity of process chemicals, the compounds of most concern in PFW. Model results should take into consideration any further benefits provided by the proposed treatment.

6 REFERENCES

ANZECC & ARMCANZ, 2000. *Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy No. 4.* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

AODC, 2004. Online Data and Services – Oceanographic Data: www.aodc.gov.au (information valid as at May 2000). Australian Oceanographic Data Centre, Canberra.

Australian Hydrographic Services, 2003. Australian national tide tables. Australian Hydrographic Publication.

Blanton, B.O., 1995. User's manual for 3-Dimensional drogue tracking on a FE grid with linear finite elements. OPNML.

Brandsma, M.G. and J.P. Smith, 1996. Dispersion modelling perspectives on the environmental fate of produced water discharges. Pages 215-224 In M Reed and S Johnson, Eds., Produced Water 2: Environmental Issues and Mitigation Technologies. Plenum Press New York.

Brookhaven National Laboratory, 1992. Human Health Risk Assessment for Radium Discharged Offshore in Produced Waters (Interim Report). Report to the U.S. Dept. of Energy, New Orleans, LA. BNL-47390. Brookhaven National Laboratory, Biomedical and Environmental Assessment Group, Upton, NY.

BOM, 2004. Climate information: www.bom.gov.au/climate/. Bureau of Meteorology, Perth.

Burns, K.A. and S. Codi, 1999. Non-volatile hydrocarbon chemistry studies around a production platform on Australia's North West Shelf. Estuarine, Coastal Shelf Science. 49:853-876.

Burns, K.A., S. Codi, M. Furnas, D. Heggie, D. Holdway, B. King and F. Mcallister. 1999. Dispersion and fate of produced formation water constituents inan Australian Northwest Shelf Shallow Water Ecosystem. Marine Pollution Bulletin, Vol 38, No 7, 593-603.

CSTT, 1993. Comprehensive Studies for the Purposes of Article 6 of Dir 91/271/EEC, the Urban Waste Water Treatment Directive. Report of the Comprehensive Studies Task Team of the Group Co-ordinating Sea Disposal Monitoring, for the Marine Pollution Monitoring Management Group. Edinburgh.

Cobby, G. L., 2002. Changes to the environmental management of produced formation water offshore Australia. APPEA Journal 2002.

DK, 2001. Background document on aromatic substances including PAH in produced water. Notes A, B and C submitted by Denmark to the Meeting of the OIC under the auspices of the OSPAR convention for the protection of the marine environment of the North-East Atlantic. OSPAR Commission OIC 01/8/8-E(L).

EC, 1996. Technical guidance document in support of commission directive 93/67/EEC on risk assessment for new notified substances and commission regulation (EC) No. 1488/94 on risk assessment for existing substances. Part I to iv, Office for official publications of the European Communities, ISBN 92-827-8011-2.

ECOSAR, 1998. ECOSAR clases v0.99d.

Le Provost, C., F. Lyard, J.M. Molines, and M.L. Genco, 1998. A hydrodynamic ocean tide model improved by assimilating a satellite altimeter-derived data set. Journal of Geophysical Research, 103, 5513-5529.

Sherwin, T.J. (Ed.), 1992. Methods for determining pollutant dispersion in tidal waters. UCES Rpt U89-5(I:3).

EPA (US Environmental Protection Agency). 1991. Assessment and control of bioconcentrateable contaminants in surface waters. Draft EPA, Office of Water, Washington, DC.

EPA (US Environmental Protection Agency). 1992. Quality Criteria for Water 1992. U.S. EPA, Office of Water, Criteria and Standards Division, Washington DC.

Flynn, S.A., E.J. Butler, and I. Vance, 1996. Produced water composition, toxicity and fate: a review of recent BP North Sea studies. Pages 69-80. In: M Reed and S Johnsen, Eds., Produced Water 2. Environmental Issues and Mitigation Technologies. Plenum Press, New York.

Frost, T.K., S. Johnsen and M. Hjelsvold, 2002. Environmental Risk Management of Discharges from E&P activities in the North Sea. SPE paper 73854.

Furness, R.W. and C.J. Camphuysen, 1997. Seabirds as monitors of the marine environment. ICES Journal of Marine Science, 54: 726-737.

Furuholt, E., 1996. Environmental effects of discharge and reinjection of produced water. Pages 275-288 In: M. Reed and S. Johnsen, Eds., 1996. Produced Water 2. Environmental Issues and mitigation technologies. Plenum Press, New York.

Genesis, 2000. Condensate in Produced Water. J3705/G/RE001.

IRCE, 2003a. North Rankin 'A' Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-NRA REV 1.

IRCE, 2003b. Goodwyn 'A' Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-GWA REV 1.

IRCE, 2003c. Cossack Pioneer Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-CP REV 1.

IRCE, 2003d. Ocean Legend Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-OL REV 0.

IRCE, 2003e. Northern Endeavour Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-NE REV 1.

Jirka, G.H., P.J. Akar and J.D. Nash, 1996. Enhancements to the CORMIX Mixing Zone Expert System: Technical Rep., DeFrees Hydraulics Laboratory, School of Civil and Environmental Engineering, Cornell University, 1996, (also to be published by U.S. Environmental Protection Agency, Tech. Rep., Environmental Research Lab, Athens, GA).

Johnsen, S., T.K. Frost, M. Hjelsvold and T.R. Utvik, 2000. The environmental impact factor – a proposed tool for produced water impact reduction, management and regulation. SPE Paper 61178.

King, B.A. and F.A. McAllister, 1998. Modelling the dispersion of produced water discharges. APPEA Journal 1998:681-691.

LDM, 1994. Exploration Drilling, EP32 And EP57 Joseph Bonaparte Gulf Northern Territory Environmental review report. Report to : Teikoku Oil.

Metcalf and Eddy Inc., 1979. Wastewater Engineering. 2nd Ed., revised by G Tchobanologus, McGraw-Hill Book Company, New York.

Neff, J.M., 1979. Polycyclic aromatic hydrocarbons in the aquatic environment. Sources, fates and biological effects. Applied Science Publishers, Barking, Essex, England. 262 pp.

Neff, J.M, 1987. Biological effects of drilling fluids, drill cuttings and produced waters. Pages 469-538 In D.F. Boesch and N.N. Rabalais, Eds., Long term environmental effects of offshore oil and gas developments. Elsevier Applied Science Publishers, London.

Neff, J.M., 2002. Bioaccumulation in Marine Organisms. Effects of contaminants from oil well produced water. Elsevier.

Neff, J.M. and K. Foster, 1997. Composition, fates and effects of produced water discharges to offshore waters of the Java Sea, Indonesia. Report to Pertimina/Maxus Southeast Sumatra, Jakarta, Indonesia. 103 pp.

Neff, J.M. and T.C. Sauer, Jr., 1996. An ecological risk assessment for polycyclic aromatic hydrocarbon bioavailability near offshore produced water discharges. Pages 355-366 In: M. Reed and S. Johnsen, Eds., Produced Water 2. Environmental Issues and Mitigation Technologies. Plenum Press, New York.

NL, 1999. Setting integrated environmental quality standards for substances in the Netherlands. Environmental quality standards for soil, water & air. Interdepartmental working party on setting environmental quality standards for substances, the Netherlands, January 1999.

North Sea Produced Water and Effect Task Force, 1994. North Sea produced water: Fate and effects in the marine environment. The E & P Forum Report No. 2.62/204.

Offshore Operators Committee, 1997. Gulf of Mexico Produced Water Bioaccumulation Study. Definitive Component. Technical report to the Offshore Operators Committee, New Orleans, LA, from Continental Shelf Associates, Jupiter, FL.

OGP, 2002. Aromatics in produced water: occurrence, fate & effects, and treatment. Report No: 1.20/324.

OSPAR Recommendations 2000/4 on a harmonised pre-screening scheme for offshore chemicals.

Ray, J.P. 1996. Session summary. Pages 3-5 In: M. Reed and S. Johnsen, Eds., 1996. Produced Water 2. Environmental Issues and mitigation technologies. Plenum Press, New York.

de Reus, J.A.M., 2004. Preliminary corrosion inhibitor selection for the Blacktip development. Draft Report. Shell Global Solution.

Roe Utvik, T I R, G S Durrel and S Johnsen, 1999. Determining produced water originating PAH in North Sea water: comparison of sampling techniques. Marine Pollution Bulletin, Vol 38. No. 11. pp 977 – 989.

Roe Utvik, T. I. 1999. Chemical characterisation of produced water from four offshore oil production platforms in the North Sea. Chemosphere 39:2593-2606.

SDA, 1998. Bonaparte Gulf WA 279-P and WA 280-P – Environmental Management Plan. Shell Development Australia (SDA).

Smith, J.P. 1993. Field observations of dilution of Ra-226 from produced water discharges – comparison with dispersion model predictions. Report to the Offshore operators Committee, New Orleans.

Smith, J.P. *et al*., 1996. Environmental impacts of produced waters in teh Java Sea, Indonesia. SPE Paper 37002. Pages 379-389 In: Proceedings of the International conference on Health, safety & Environment. Society of Petroleum Engineers, Richardson, TX.

Stephenson, M.T., *et al*., 1994. North Sea produced water: fate and effects in the marine environment. Report No. 2.62/204. E&P Forum, London, England. 48 pp.

Storr, G.M., Smith, L.A. and R.E. Johnstone, 1986. Snakes of Western Australia. WA Museum, Perth, Western Australia.

Stromgren, T., S.E., S.E. Sorstrom, L. Schou, I. Kaarstad, T. Aunaas, O.G. Brakstad and O. Johansen. 1995. Acute toxic effects of produced wateri n relation to chemical composition and dispersion. Mar. Environ. Res. 40:147-169.

Swan, J.M. J.M. Neff and P.C. Young, 1994. Environmental Implications of Offshore Oil and Gas Development in Australia – The Findings of an Independent Scientific Review. Australian Petroleum Exploration Association, Canberra, Australia.

Terrens G.W. and R.D. Tait, 1993. Effects on the marine environment of produced formation water discharges from Esso/BHPP's Bass Strait Platforms. Esso Australia Ltd., Melbourne, Australia. 25 pp.

Terrens G.W. and R.D. Tait, 1996. Monitoring ocean concentrations of aromatic hydrocarbons from produced formation water discharges to the Bass Strait, Australia. SPE 36033. Pages 739-747. In: Proceedings of the International conference on Health, safety & Environment. Society of Petroleum Engineers, Richardson, TX.

UKOOA, 2002. A review of Produced Water analysis results for UKCS Discharges 1999-2001. ERT (Orkney) Ref 02/029.

Veith. G.D. and P. Kosian, 1983. Estimating bioconcentration potential from octanol/water partition coefficients. Pages 269-282 In: D. Mackay, S. Patterson, and St.J. Eisenreich, Eds., Physical behaviour of PCBs in the Great Lakes. Ann Arbor Science Publishers, Ann Arbor, MI.

Westerink, J.J., R.A. Luettich, and J.C. Muccino, 1994. Modeling tides in the western north atlantic using unstructured graded grids. Tellus, 46A, 178-199.

Young, I.R., 1999. Seasonal variability of the global ocean wind and wave climate. International Journal of Climatology. 19: 931-950.

Walker D, F. Wells and J Russell Hanley, 1996. Marine biological survey of the eastern Kimberley, Western Australia. Unpublished report by UWA, WAM and MARNT.

Woodside, 2003. Shakespeare-1 Exploration Well, NT/P57 and Weasel-1 Exploration Well, WA-279-P Environment Penis Plan Doc. No. ENV-629 (DRIMS-no.192223)

Appendix K

Blacktip Oil Spill Risk Assessment Modelling prepared by International Risk Consultants Environment






This page has been left intentionally blank



Blacktip Oil Spill Risk Assessment Modelling

DATE: 18 AUGUST 2004

PROJECT: J03-187

DOC NO.: ENV-REP-03-187-002 REV 1.DOC

IRC Environment

26 Colin Street West Perth
Western Australia 6005
PO Box 418 West Perth
Western Australia 6872
Telephone 61 8 9481 0100
Facsimile 61 8 9481 0111
Email environment@intrisk.com
www.intrisk.com

© 2004 IRC Environment

DOCUMENT REVISION STATUS					
REV	**DESCRIPTION**	**AUTHOR**	**REVIEW**	**APPROVAL**	**DATE**
A	Internal Review	Rob Phillips	Peter Jernakoff		15/4/04
0	Issue to client	Rob Phillips	Peter Jernakoff	Kian Feng	20/4/04
1	Client Comments	Rob Phillips	Peter Jernakoff	Colin Wright	18/8/04

Title: Blacktip Oil Spill Risk Assessment Modelling	**Job Number:** J03-187	
	Report Number: ENV-REP-03-187-002 Rev 1.doc	
Client: Woodside Energy Ltd	**Author:** Rob Phillips	**IRC Office:** Perth
Industry Sector: Offshore Oil and Gas		

Key words:

Woodside, Oil Spill Trajectory Modelling, Blacktip, Joseph Bonaparte Gulf.

Abstract:

This report presents the results from a modelling study undertaken on behalf of Woodside Energy Ltd to assess the fate and likely consequence of an oil spill from the proposed Blacktip facility. Tanker operations were identified as the highest risk contributor and four credible spill events were analysed:

- small ($8m^3$), medium ($100m^3$) and large ($500m^3$) spills of Blacktip condensate during offload to the trading tanker; and
- a $500m^3$ heavy fuel oil spill from a ship fuel leak.

The risk assessment made use of an oil spill weathering model and coupled hydrodynamic and oil spill trajectory models for the Joseph Bonaparte Gulf. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under "worst-case" ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons in the Joseph Bonaparte Gulf.

Results show that oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. This probability is reduced substantially in the dry season.

Country:

Joseph Bonaparte Gulf, Northern Territory, Australia

Contents

ABBREVIATIONS **5**

EXECUTIVE SUMMARY **6**

1 INTRODUCTION **7**
1.1 Background 7
1.2 Objective 7
1.3 Scope 7

2 THE BLACKTIP PROJECT AND SPILL EVENTS **8**
2.1 Brief Description of the Development 8
2.2 Hydrocarbon Inventories 8
2.3 Oil Spill Scenarios 8

3 METHODS **11**
3.1 General 11
3.2 Hydrodynamic Model 11
3.3 Oil Spill Trajectory Module 15
3.4 Oil Spill Weathering Module 16

4 CONDENSATE CHARACTERISTICS AND PREDICTED WEATHERING BEHAVIOUR **19**
4.1 General 19
4.2 Blacktip Condensate 19
4.3 Heavy Fuel Oil 22

5 MODELLING RESULTS **24**
5.1 General 24
5.2 Event 1: Small Loadout Line Leak 24
5.3 Event 2: Medium Loadout Line Leak 25
5.4 Event 3: Large Loadout Line Leak 26
5.5 Event 4: Ship Fuel Leak 26

6 ENVIRONMENTAL IMPACT **39**
6.1 Blacktip Condensate Spills 39
6.2 Heavy Fuel Oil Spills 39

7 CONCLUSIONS **41**

8 REFERENCES **42**

ABBREVIATIONS

ADCIRC	Advanced Circulation Model
ADIOS2	Automated Data Inquiry for Oil Spills
AGSO	Australian Geological Survey Office
BOM	Bureau of Meteorology
FE	Finite Element
IRCE	IRC Environment
NOAA	National Oceanic and Atmospheric Administration
NWS	North West Shelf
OPNML	Ocean Processes Numerical Modelling Laboratory
OSCP	Oil Spill Contingency Plan
WEL	Woodside Energy Limited

EXECUTIVE SUMMARY

This report presents the results from a modelling study undertaken on behalf of Woodside Energy Ltd to assess the fate and likely consequence of an oil spill from the proposed Blacktip facility. Tanker operations were identified as the highest risk contributor and four credible spill events were analysed:

- small ($8m^3$), medium ($100m^3$) and large ($500m^3$) spills of Blacktip condensate during offload to the trading tanker; and
- a $500m^3$ heavy fuel oil spill from a ship fuel leak.

The risk assessment made use of an oil spill weathering model and coupled hydrodynamic and oil spill trajectory models for the Joseph Bonaparte Gulf. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under "worst-case" ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons in the Joseph Bonaparte Gulf.

Results show that oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. This probability is reduced substantially in the dry season.

Blacktip condensate is expected to be highly volatile and the majority will evaporate within a few days or less should a spill occur. Adverse effects are likely to be related to the toxicity of the condensate and marine organisms in the water column coming into direct contact with a fresh spill. Toxicity of spilled condensate should reduce with time as the oil dilutes into the receiving waters and as the aromatic components volatise. Sensitive areas such as tidal inlets and mangrove colonies should be boomed off in the event of a spill. Depending on the size of the spill, shoreline cleanup may not be necessary as beached condensate will continue to evaporate once stranded and will be washed away naturally by tide and waves. Any residual will eventually be removed by biodegradation and photo-oxidation processes.

Heavy fuel oil is much thicker than condensate and adverse effects resulting from a spill are more likely to be related to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils. Natural degradation rates for these heavy oils are very slow and, if left unattended, may persist on beaches for months to years. Recovery of oil from sea and on the shoreline is generally very effective if tackled early enough.

1 INTRODUCTION

1.1 Background

Woodside Energy Ltd (WEL) is planning to develop the Blacktip Gas Field in the Joseph Bonaparte Gulf. As part of WEL's responsibility for assessing the environmental risk of their operations, IRC Environment (IRCE) was commissioned to undertake quantitative oil spill risk assessment modelling for the project. The results from this work will form part of WEL's Environment Impact Statement and aid in the development of an effective Oil Spill Contingency Plan (OSCP) should the development go ahead.

1.2 Objective

The objective of the study is to analyse oil spill trajectories from accident events that could possibly occur during the lifetime of the Blacktip facility.

1.3 Scope

The scope of work included:

- a review of the oil properties;
- an assessment of oil weathering; and
- oil spill trajectory modelling, taking into account seasonal tide and wind conditions for the Joseph Bonaparte Gulf.

2 THE BLACKTIP PROJECT AND SPILL EVENTS

2.1 Brief Description of the Development

The Blacktip development will consist of an unmanned wellhead platform tied back to an onshore gas treatment station by a 100km subsea pipeline (Figure 2.1 and Figure 2.2). Landfall for the pipeline will be on the beach, 10km to the west of Wadeye.

Once ashore, well fluids will be separated. The gas will be exported to Gove (Nhulunbuy) for power generation at Alcan's alumina processing plant and the condensate will be stored for periodic export to an oil tanker.

2.2 Hydrocarbon Inventories

The main liquid hydrocarbon inventories associated with the Blacktip development will be:

- Blacktip condensate being produced from the reservoir, exported to the onshore gas plant for separation and storage and then offloaded to trading tanker;
- heavy fuel oil stored on the trading tanker; and
- diesel stored on support vessels and the drill rig.

Blacktip has a low oil-to-gas ratio so only a small percentage of condensate will be mixed in the reservoir fluids. Once separated from the water and gas at the onshore process plant the condensate will be stored until it is ready for offload to a trading tanker. The offloading process to the tanker and storage provides the greatest opportunity for an oil spill of any consequence to occur. As the volume of condensate produced by the project is low, only three or four tankers are expected per year.

2.3 Oil Spill Scenarios

Four credible spill events were identified for analysis:

- small ($8m^3$), medium ($100m^3$) and large ($500m^3$) spills of Blacktip condensate during offload to the trading tanker; and
- a $500m^3$ heavy fuel oil spill from a ship fuel leak.

Figure 2.1 Location of the Blacktip Gas Field and associated infrastructure (from WEL)

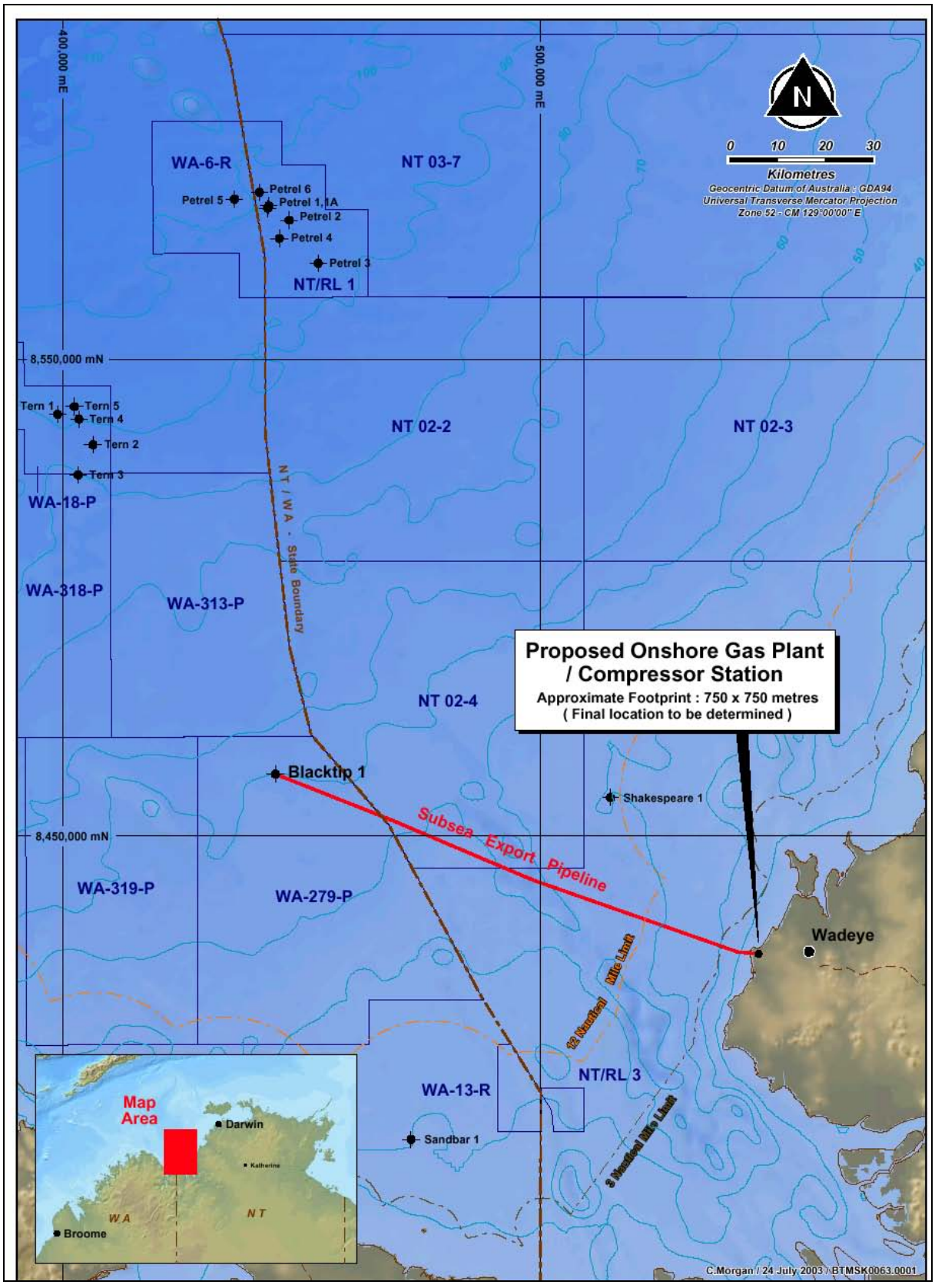
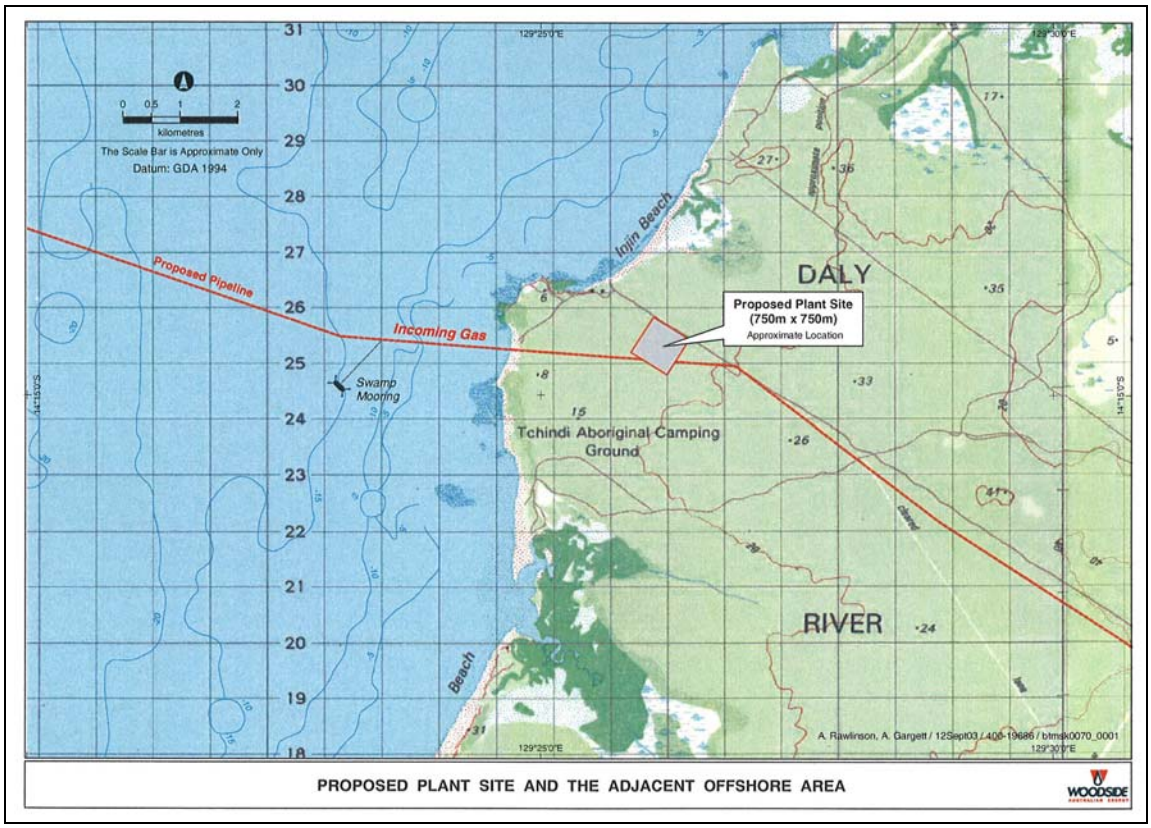


Figure 2.2 Shoreline crossing and proposed plant site (from WEL)



3 METHODS

3.1 General

The oil spill trajectory model is made up of three modules:

- a hydrodynamic module that provides the necessary velocity fields for the oil spill trajectory model;
- an oil spill weathering module that predicts the behaviour of the oil in the receiving environment; and
- an oil spill trajectory module that simulates the fate of the oil.

These modules are described in more detail in the following subsections.

3.2 Hydrodynamic Model

3.2.1 Overview

The hydrodynamics applied in the present study were computed using the ADvanced CIRCulation model (ADCIRC). This model is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions (Westerink *et al*., 1994). The algorithms that comprise ADCIRC utilise the finite element (FE) method in space and the model can be applied to computational domains encompassing the deep ocean, continental shelves, coastal seas and small scale estuarine systems.

3.2.2 Model Details

Figure 3.1 shows the hydrodynamic model grid for the Joseph Bonaparte Gulf. Elevations and currents were computed at 11,621 points (nodes) in the model domain. Using the significant flexibility provided by the FE method, grid resolution was increased considerably towards the coast and in particular towards the landfall for the Blacktip pipeline (Figure 3.2). The fine grid spacing is necessary to resolve the complex nearshore geometry of the coastline.

Node resolution varies from approximately 50km offshore to 50m inshore. Model bathymetry is shown in Figure 3.3. This was interpolated from the Australian Geological Survey Office (AGSO) database and, closer inshore, digitised from Admiralty Charts for the area. The model was forced from the open boundary by tidal elevations calculated from the M2, S2, N2, O1 and K1 tidal constituents. Amplitudes and phases for these were derived from the FES-95.2 global ocean model (Le Provost *et al*., 1998).

The model was validated against tidal stations around the coastline. Example vector fields in the vicinity of the pipeline shore crossing on a spring tide at mid ebb and flood are shown in Figure 3.4 (a) and (b), respectively. Generally, tides ebb in a northerly direction and flood

towards the south. Further inshore circulation is influenced by the coastal topography with a clockwise gyre forming in the bay on the ebb tide and an anticlockwise gyre forming on the flood tide.

Figure 3.1 Hydrodynamic model grid

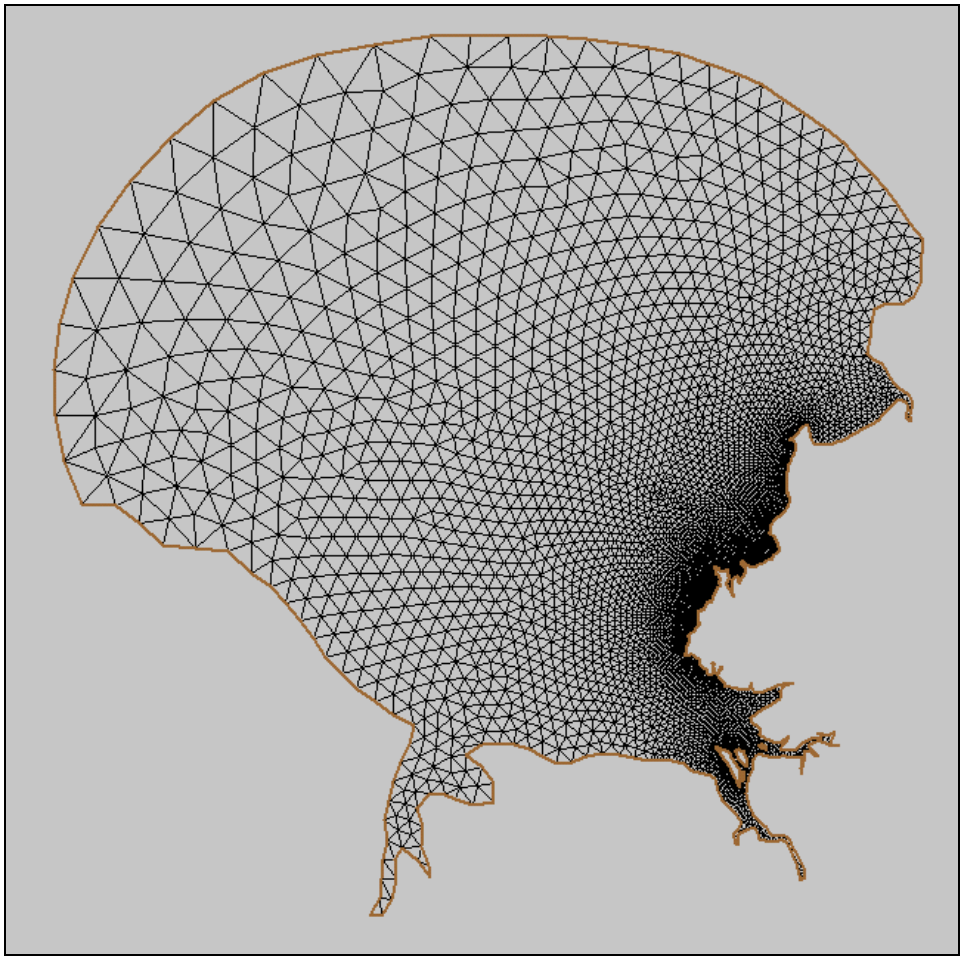


Figure 3.2 Details of the hydrodynamic model grid in the vicinity of the landfall

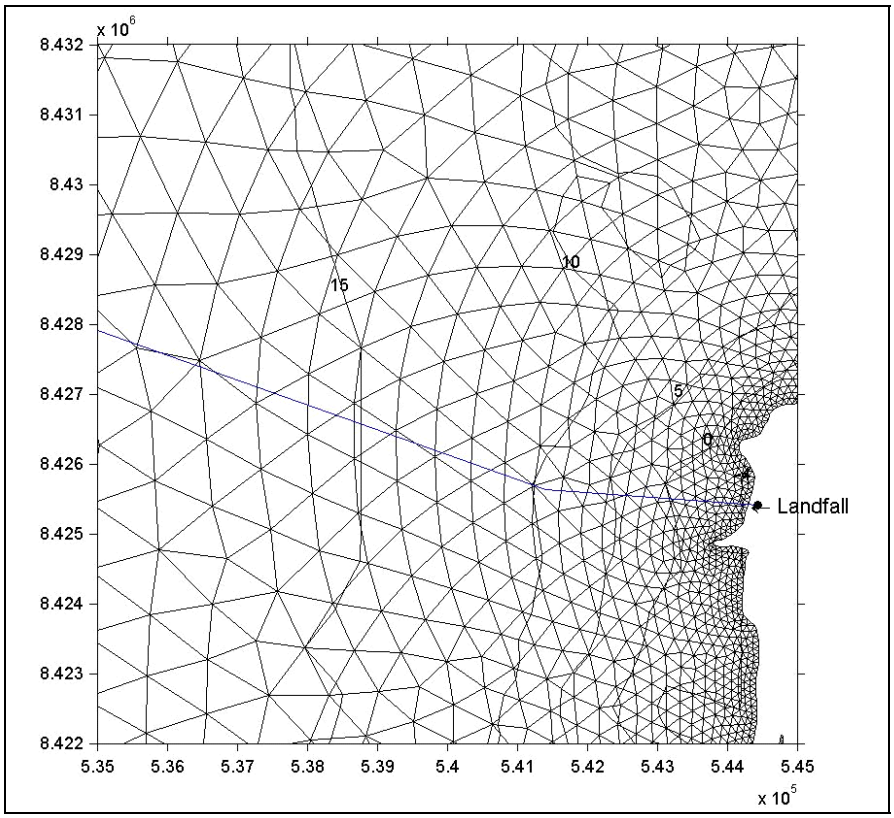


Figure 3.3 Model bathymetry in metres

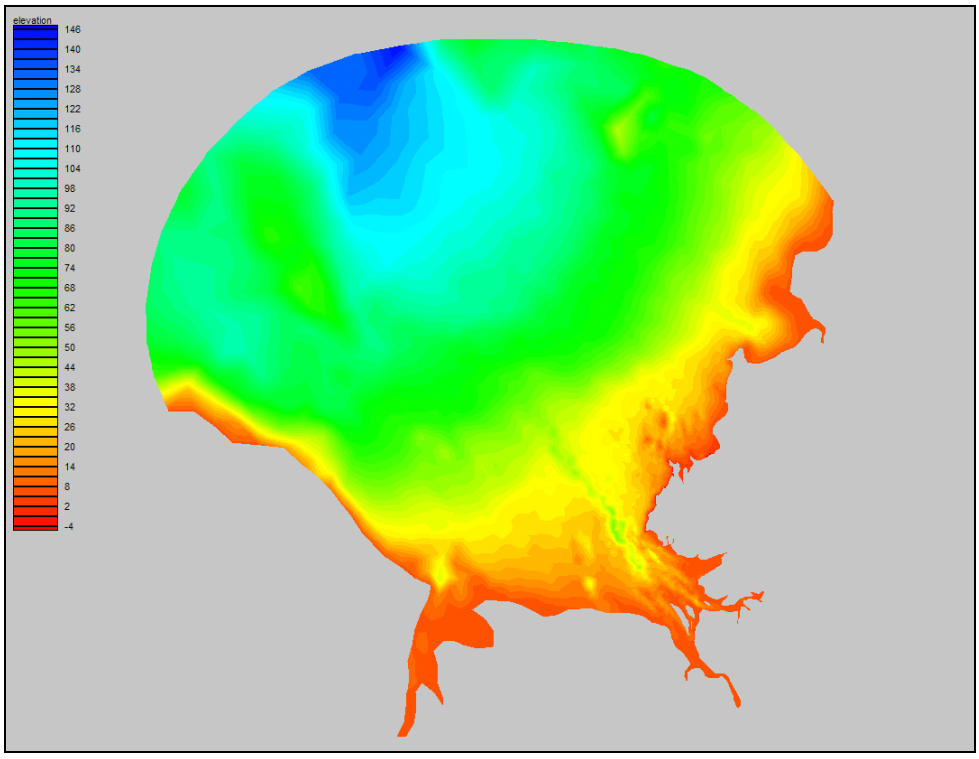
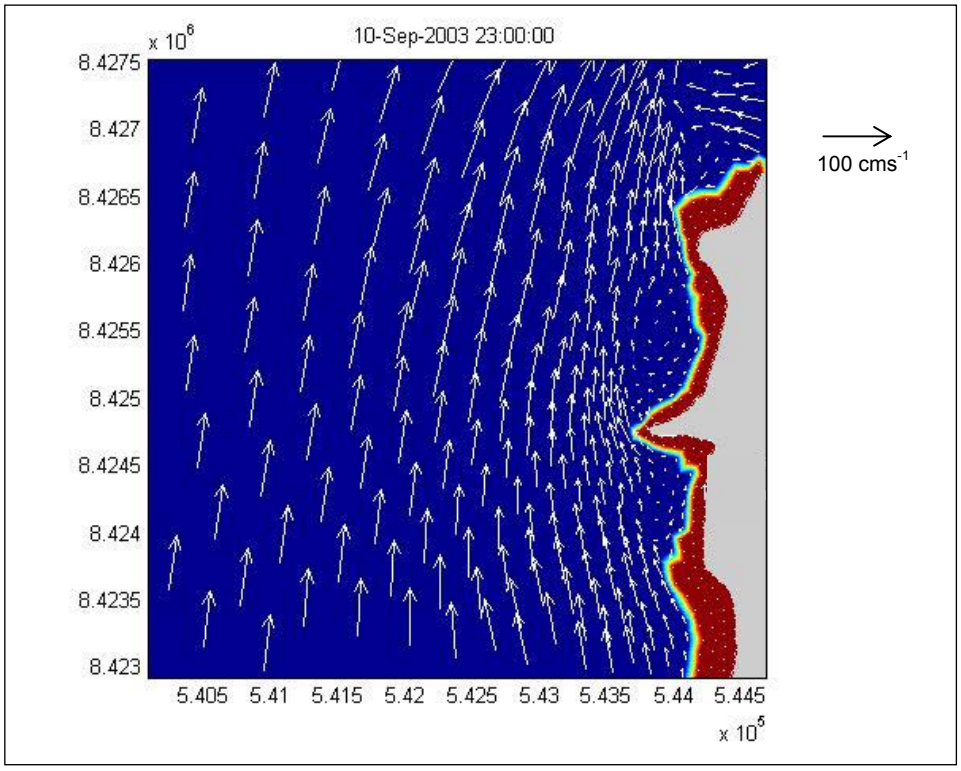
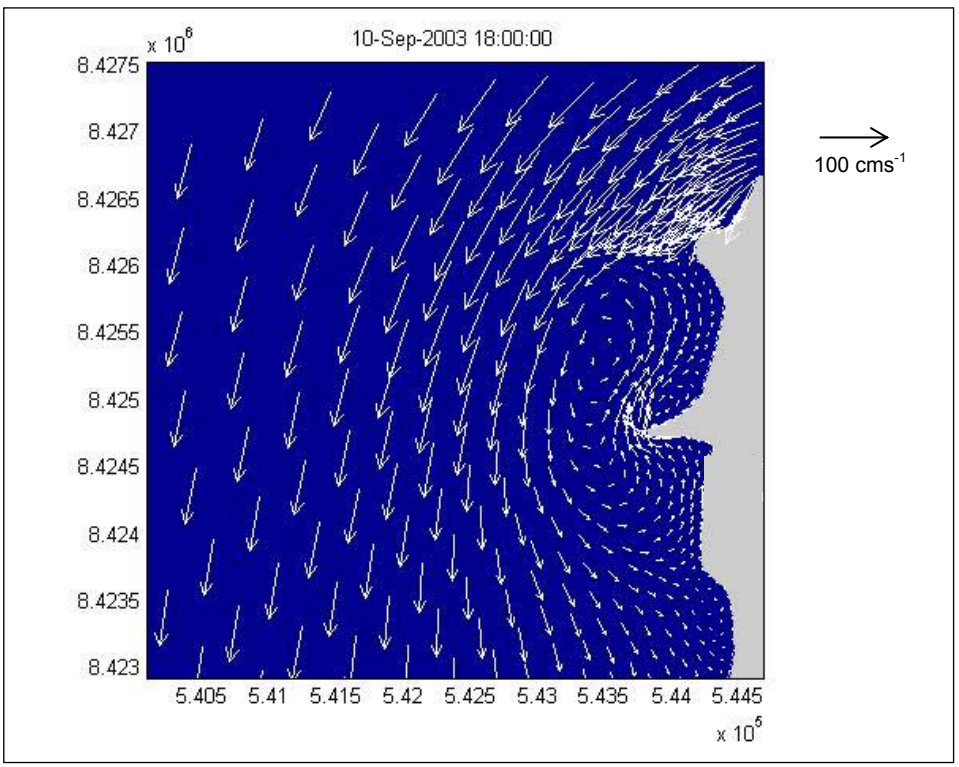


Figure 3.4 Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline

(a) Ebb Tide



(b) Flood Tide



3.2.3 Wind Data

Wind forcing for the model was based on historic wind data from the Port Keats meteorological station operated by the Australian Bureau of Meteorology. The anemometer for this station is positioned 28m above Australian Height Datum, readings are three hourly and cover the period from 2000 – 2003. Winds were corrected to 10m above sea level using a logarithmic wind profile given by:

$$\frac{U_{10}}{U_Z} = \frac{\ln(\frac{10}{z0})}{\ln(\frac{Z}{z0})}$$

where U_{10} = wind speed at 10m, U_z = wind speed at height Z and z0 is the roughness length, set at 0.002.

Monthly wind roses are shown in Figure 3.5. Two distinct seasons are evident:

- the “summer” wet season between September and February when winds are predominantly from the northwest; and
- the “winter” dry season between April and July when winds are predominantly from the southeast.

The months between the seasons, March and August, are termed the transitional periods when either summer or winter conditions can prevail resulting in more variable wind directions.

3.3 Oil Spill Trajectory Module

3.3.1 General

The oil spill module is based on the classic random walk particle tracking method (Sherwin, 1992) and assumes that the oil can be idealised as a large number of particles that move independently under the action of tide and wind. The oil spill trajectory model is integrally linked with the FE model and uses a highly accurate fourth order Runge-Kutta method to track particles (Blanton, 1995).

Water properties and atmospheric conditions were input to the model to predict the behaviour and fate of the oil. Industry standard algorithms were used to predict spreading (Fay; 1969), evaporation (Fingas, 1999), emulsification (Eley, *et al*.,1988) and entrainment (Delvigne and Sweeney, 1988) of hydrocarbons. The model was run in both deterministic and stochastic (statistical) modes.

3.3.2 Deterministic Simulations

In deterministic mode, a single simulation was undertaken to determine the fate and likely consequence of an oil spill under worst-case conditions. For Blacktip worst-case conditions

are considered to be a neap tide coinciding with a 5ms^{-1} onshore wind. Results are presented as plots showing:

- hourly concentration of oil at sea; and
- beached masses of oil.

3.3.3 Stochastic Simulations

To take into consideration the frequency of occurrence of a range of different tide and wind conditions, the model was also run in stochastic mode. In this mode, multiple simulations (100) were undertaken using randomly selected start dates for wind and current data for the defined season. Each simulation was run for 5 days and results presented as contour plots showing the probability of surface exposure to oil after 24 hours and five days, respectively.

3.4 Oil Spill Weathering Module

The National Oceanic and Atmospheric Administration's (NOAA's) Automated Data Inquiry for Oil Spills (ADIOS2) model was used to simulate detailed evaporation, dispersion and emulsification of the spill. Input data for ADIOS2 includes:

- oil properties (API, viscosity, distillation curves);
- spill details (volume and duration of the spill); and
- environmental data (wind and sea surface temperature).

Figure 3.5 Monthly wind roses for Port Keats (BOM (2000 -2003))

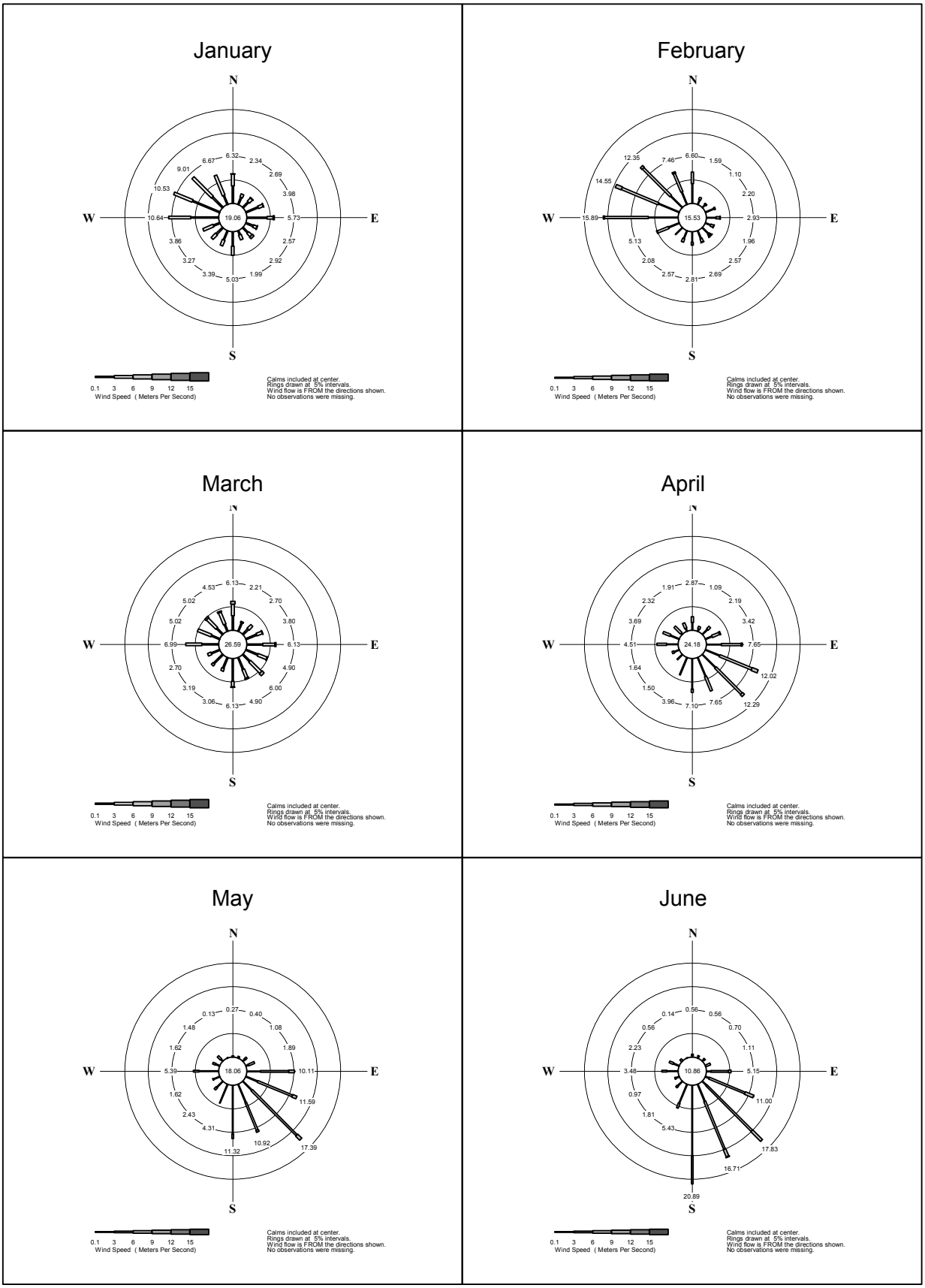
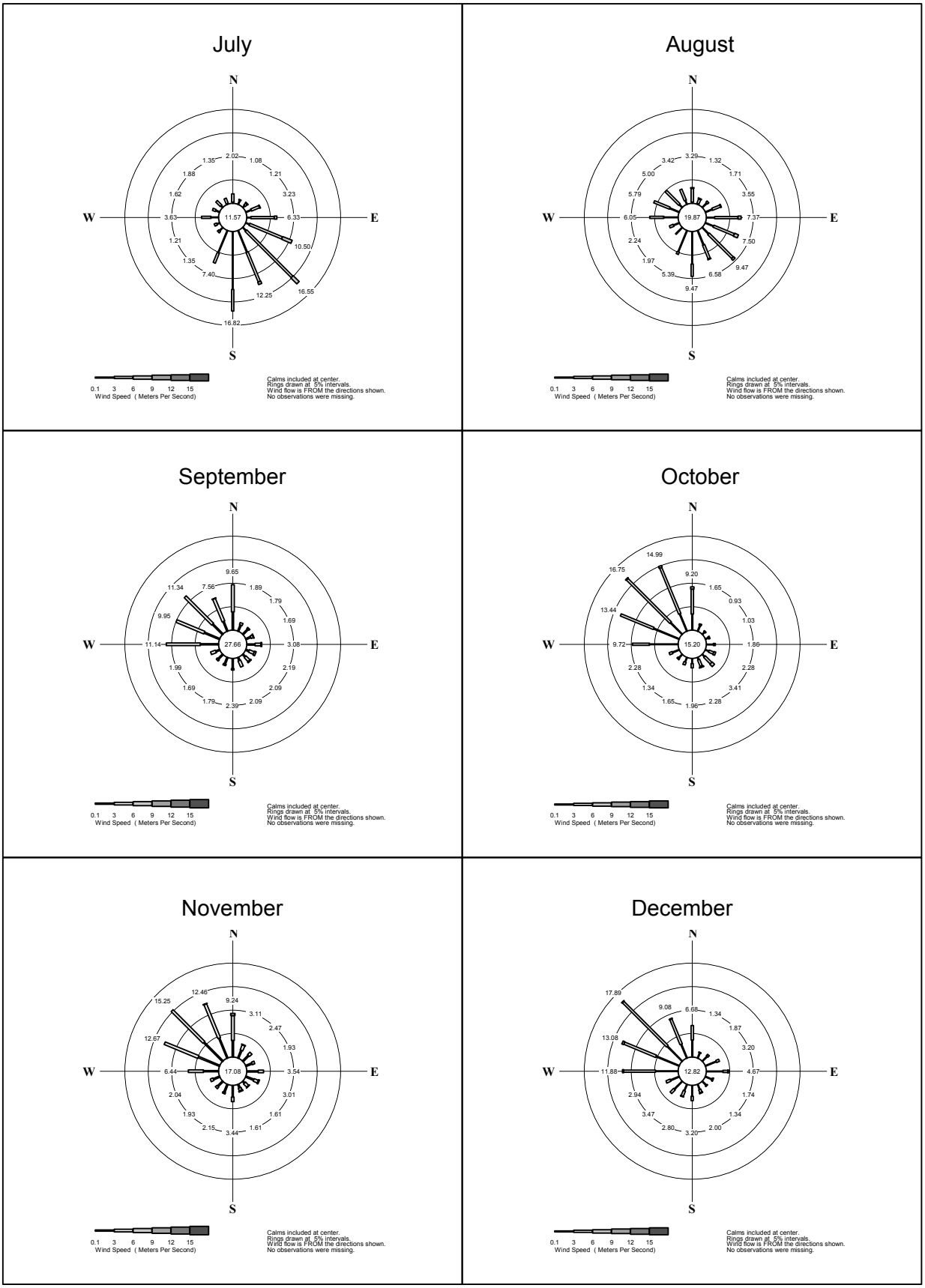


Figure 3.1 (cont.)



4 CONDENSATE CHARACTERISTICS AND PREDICTED WEATHERING BEHAVIOUR

4.1 General

The two types of oil modelled in the oil spill events were:

- Blacktip condensate; and
- Heavy Fuel Oil

4.2 Blacktip Condensate

The properties of Blacktip condensate are detailed in WEL (2003). Key characteristics relevant to the behaviour of oil spilt to sea are summarised in Table 4.1. Essentially it is light oil with a relatively narrow boiling range, meaning that most of the oil will evaporate or naturally disperse within a few days of being spilt. It is much lighter than seawater and if spilt to sea would spread rapidly to form a thin sheen. As wind and sea states increase wave action would physically disperse the oil into the water column, forming small droplets that are carried and kept in suspension by the currents.

Table 4.1 Condensate properties used in the model (based on NWS condensate)

Parameter	Blacktip Condensate
Specific Gravity	0.794
API (°)	49
Pour Point (°C)	<-30
Viscosity @ 20°C (cSt)	2.46
Distillation Cuts	
Temp	
(°C)	**Vol %**
95	5
108	10
123.5	20
135.5	30
149	40
164.5	50
185.5	60
207	70
238.5	80
274	90

Figure 4.1 to Figure 4.4 presents the predicted weathering results from the ADIOS2 model. Evaporation ranges from 85% for 8m^3 and 80% for 500m^3. Dispersion is minimal for wind speeds below 4ms^{-1}, however, for the larger 10ms^{-1} wind, dispersion increases accounts for 20% of the smaller volume and about 10% of the larger volume.

Figure 4.1 Predicted weathering of Blacktip condensate for a continuous release of 8m^3 over a duration of 1 hour for a 4ms^{-1} wind

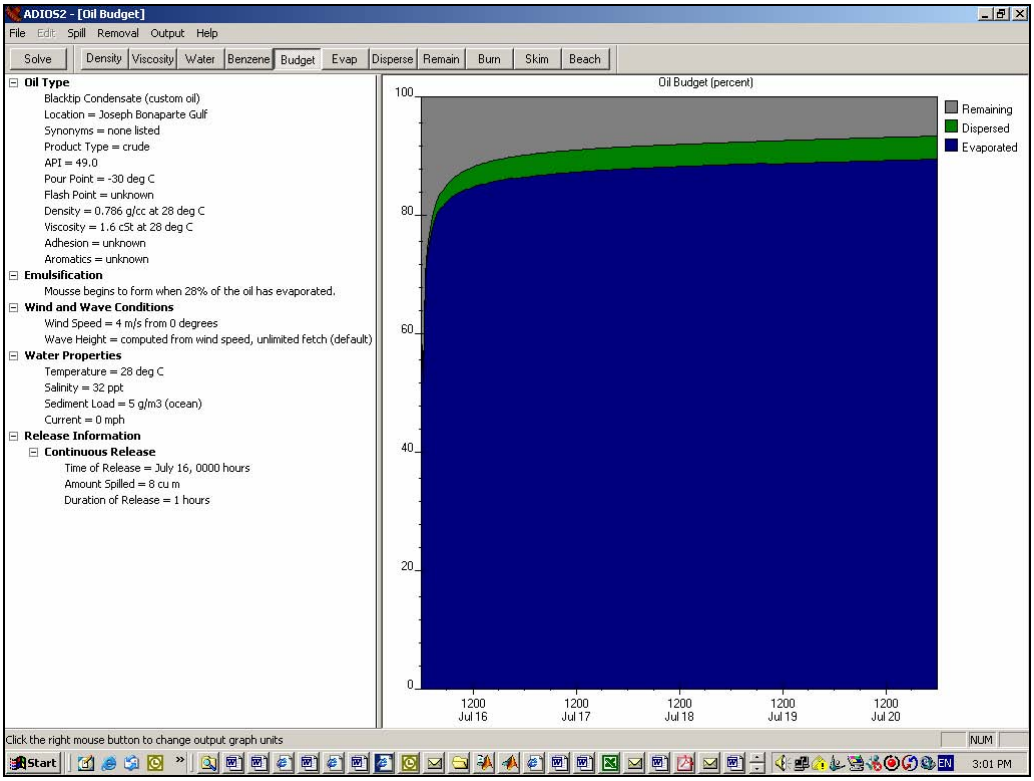


Figure 4.2 Predicted weathering of Blacktip condensate for a continuous release of 8m^3 over a duration of 1 hour for a 10ms^{-1} wind

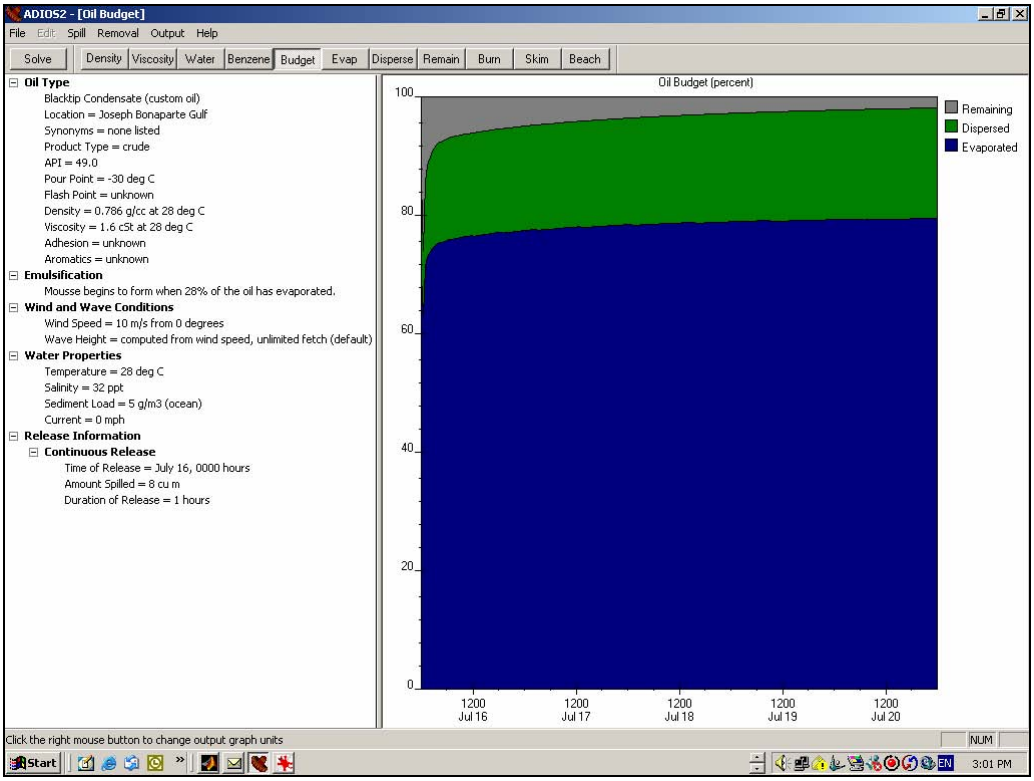


Figure 4.3 Predicted weathering of Blacktip condensate for a continuous release of 500m^3 over a duration of 3 hours for a 4ms^{-1} wind

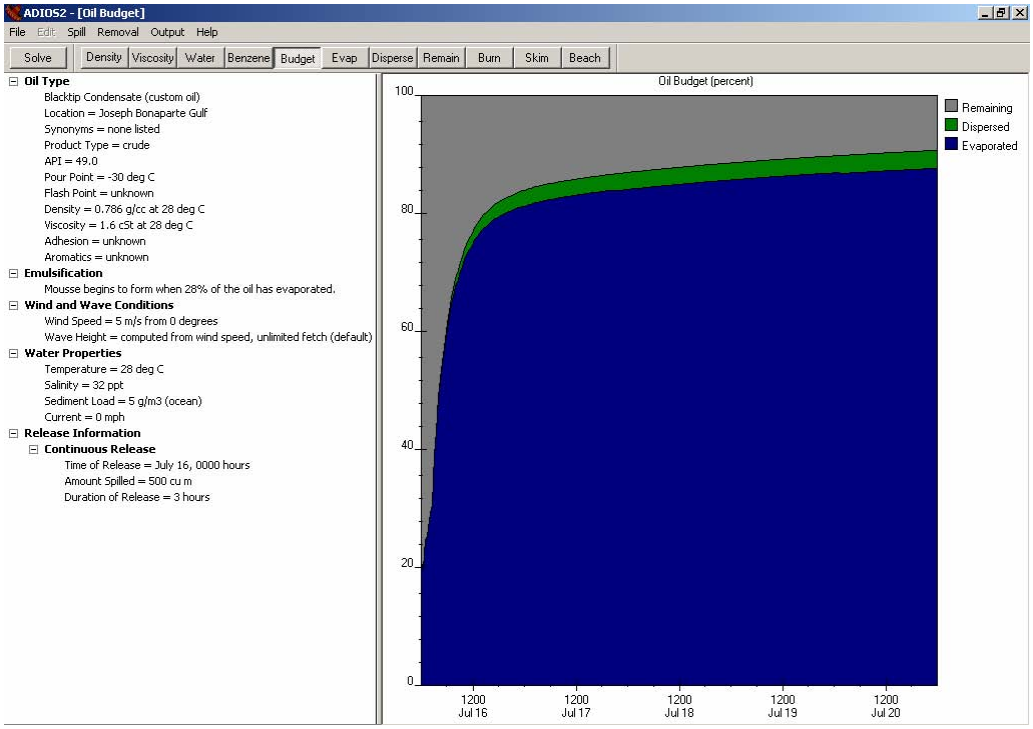
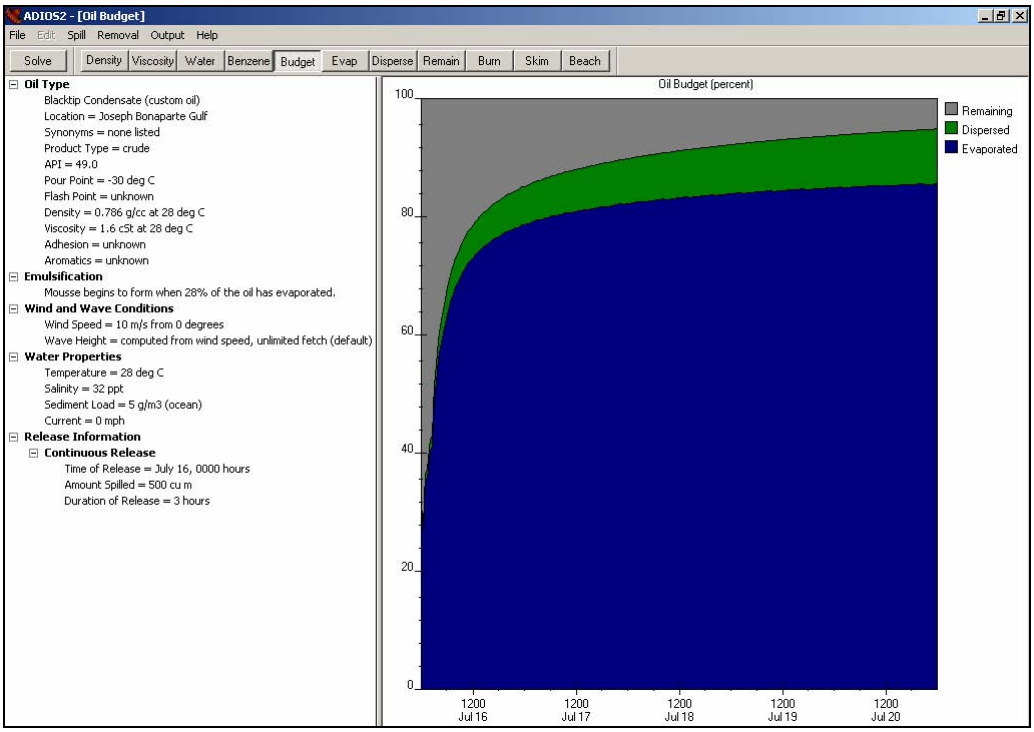


Figure 4.4 Predicted weathering of Blacktip condensate for a continuous release of 500m^3 over a duration of 3 hours for a 10ms^{-1} wind



4.3 Heavy Fuel Oil

Heavy fuel oil is a dense, viscous oil produced by blending heavy residual oils with a lighter oil (often No. 2 fuel oil) to meet specifications for viscosity and pour point. It is much denser than condensate with an API of 17.5° and is persistent (Table 4.2). Distillation cuts indicate that only 25% of the oil is volatile or semi-volatile suggesting that it does not readily evaporate.

Figure 4.5 and Figure 4.6 show the predicted weathering behaviour from the ADIOS2 model for light ($4ms^{-1}$) and moderate ($10ms^{-1}$) wind speeds, respectively. For light winds only 24% of the oil is predicted to evaporate after 24 hours with less than 1% being dispersed into the water column. For stronger winds, 25% evaporates and 7% disperses.

These oils can occasionally form an emulsion, but usually only slowly and after a period of days.

Table 4.2 Properties of heavy fuel oil used in the model

Parameter	Heavy Oil
API (°)	17.5
Viscosity (cSt)	750@15°C
Distillation Cuts	
Temp	
(°C)	**Vol %**
160	19
180	20
200	21
220	22
240	23
260	24
280	25

Figure 4.5 Predicted weathering of heavy fuel oil for a continuous release of 500m^3 over 3 hours for a 4ms^{-1} wind

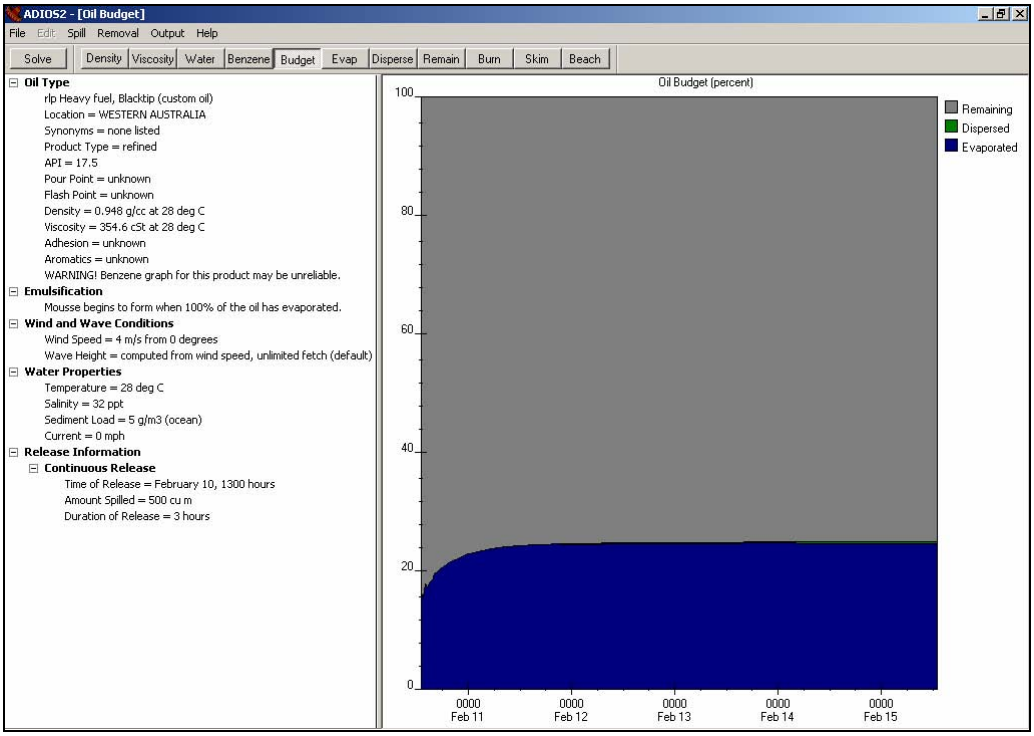
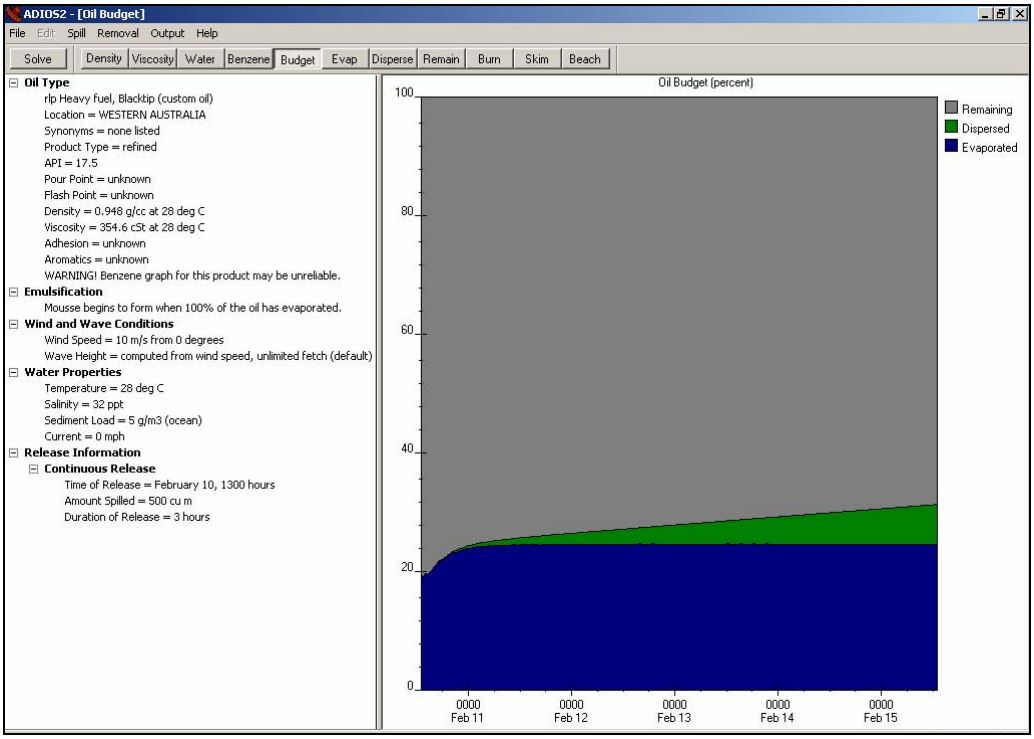


Figure 4.6 Predicted weathering of heavy fuel oil for a continuous release of 500m^3 over 3 hours for a 10ms^{-1} wind



5 MODELLING RESULTS

5.1 General

The four oil spill events simulated are summarised in Table 5.1. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under "worst-case" ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons.

Table 5.1 Summary of oil spill scenarios

Event	Description	Discharge Volume (m^3)	Spill Duration (hrs)	Oil type	Stochastic Simulation	Deterministic Simulation
1	Small Loadout line leak	8	0.5	Blacktip Condensate	Wet Dry	Neap Tide Wind: 5ms^{-1} NW
2	Medium Loadout line leak	100	3		Wet Dry	
3	Large Loadout line leak	500	3		Wet Dry	
4	Ship fuel leak	500	3	Heavy Fuel	Wet Dry	

[1]Due to the similarity with the loadout line leak scenario, results for the dry season are not presented.

5.2 Event 1: Small Loadout Line Leak

Scenario: 8m^3 condensate spill from the Swamp Mooring

Figure 5.1 presents the predicted surface oil concentrations for an 8m^3 condensate spill at the Swamp Mooring. With all the safeguards in place, this is the maximum likely spill volume that would result either due to human error or in the event of an offtake hose rupture.

The spill duration was set at 30 minutes and timed to coincide with ebb currents on a neap tide. A 500m slick was formed which was transported approximately 2km towards the northeast. On the turn of tide, the slick returned southwards and was entrained into the pipeline shore crossing bay where it came into contact with the shoreline. By the time oil impacted the beach concentrations had reduced to below 0.005kgm^{-2}. This is equivalent to about 7mLm^{-2}, which is unlikely to cause either a toxic or physical impact.

The model predicted that 86% of the slick would have evaporated by the time it reached the beach and that 800kg of oil would become stranded (Figure 5.2). Note that the model does not allow outwashing of the condensate so the masses shown in Figure 5.2 are cumulative with no further weathering applied. In reality, oil would continue to evaporate once on the beach. Any residual would be removed by biodegradation and photo-oxidation. Blacktip condensate is therefore unlikely to persist in the environment.

The above is just one example of the many possible combinations of wind and tide conditions that a spill could experience. The stochastic simulations aim to attach statistical probabilities to oil exposure for such an event. Probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons are shown in Figure 5.3 and Figure 5.4, respectively. The oil concentration limit was set at 0.005kgm^{-2}, below which no adverse environmental effects are assumed.

The probabilities after five days are similar to those after one day, which suggests that most of the condensate evaporates within 24 hours. For the wet season, the model predicts that about 40km of shoreline is at risk and that there is a 5 to 10% probability of impact. For the dry season it is unlikely that there will be any shoreline impact at all.

5.3 Event 2: Medium Loadout Line Leak

Scenario: 100m^3 condensate spill from the Swamp Mooring

Figure 5.5 presents the predicted surface oil concentrations for a 100m^3 condensate spill at the Swamp Mooring. This volume of condensate equates to a total loss of inventory from the pipeline extending from the beach to the swamp mooring.

The spill duration was set at three hours and timed to coincide with ebb currents on a neap tide. After the three hours release duration, a 4km slick had formed extending towards the northeast. On the turn of tide, the slick returned southwards and the trailing edge was entrained into the pipeline shore crossing bay where it came into contact with the shoreline. The leading edge continued southwards where it was progressively washed ashore. By the time oil impacted the beach concentrations had reduced to below 0.05kgm^{-2}.

The model predicted that 83% of the slick would have evaporated by the time it reached the beach and that a total of 12,000kg of oil would become stranded (Figure 5.6). As described previously, once on the beach, the oil would continue to evaporate and any residual would be removed by biodegradation and photo-oxidation.

Figure 5.7 and Figure 5.8 show the probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons, respectively. Again, the oil concentration limit was set at 0.005kgm^{-2}.

For the wet season, after 24 hours, the probability of shoreline impact is 25% and the length of coastline with a greater than 5% probability of being contacted is 25km. After five days the probability of shoreline impact is slightly greater and the length of coastline at risk about the same.

For the dry season, the contours are skewed towards the northeast, reflecting the prevailing wind direction. After 24 hours, the probability of shoreline impact is 5 to 10% and the length of coastline with a greater than 5% probability of being contacted is 15km towards the south and less than 10km towards the north. After five days the probability of shoreline impact and the length of coastline at risk are similar.

5.4 Event 3: Large Loadout Line Leak

Scenario: 500m^3 condensate spill from the Swamp Mooring

Figure 5.9 presents the predicted surface oil concentrations for a 500m^3 condensate spill at the Swamp Mooring. This volume of condensate equates to a total loss of inventory from the whole pipeline extending from the onshore treatment plant to the swamp mooring.

As before, the spill duration was set at three hours and timed to coincide with ebb currents on a neap tide. The distribution of the oil is similar to that described previously although oil concentrations are higher and the mass washed ashore increased to 75,000Kg (Figure 5.10).

Figure 5.11 and Figure 5.12 show the probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons, respectively.

For the wet season, after 24 hours, the probability of shoreline impact is 25% and the length of coastline with a greater than 5% probability of being contacted is 40km. After five days the probability of shoreline impact and the length of coastline at risk increased to 50% and 50km, respectively.

For the dry season, the contours are once again skewed towards the northeast, reflecting the prevailing wind direction. After 24 hours, the probability of shoreline impact is 5 to 10% and the length of coastline with a greater than 5% probability of being contacted is 20km towards the south and less than 10km towards the north. After five days the probability of shoreline impact and the length of coastline at risk are 10 to 25% and 40 km, respectively.

5.5 Event 4: Ship Fuel Leak

Scenario*: 500m^3 spill of heavy fuel from the Swamp Mooring*

In this simulation the maximum heavy fuel inventory of 500m^3 was spilt over a three hour duration under the same conditions used in the previous three scenarios. The predicted plume distribution is the same (Figure 5.13), however, as evaporation rates are much reduced, concentrations in the slick and masses washed ashore are greater (Figure 5.14). A total of 400,000kg of oil were predicted to be washed onto the shoreline. This is likely to be persistent and if left unattended is likely to cause a significant localised environmental impact.

Figure 5.15 and Figure 5.16 show the predicted probability of exposure to condensate for the wet and dry seasons respectively. Results are similar to the large condensate spill with a 25% probability of oil impacting shoreline within one day during the wet season and a 5 to

10% probability in the dry season. Probability envelopes generally extend over a wider area reflecting the persistence of fuel oil in the environment.

Figure 5.1 Predicted surface oil concentration for an 8m^3 spill of Blacktip condensate over 0.5 hrs during a neap tide and an onshore 5ms^{-1} wind (wet season).

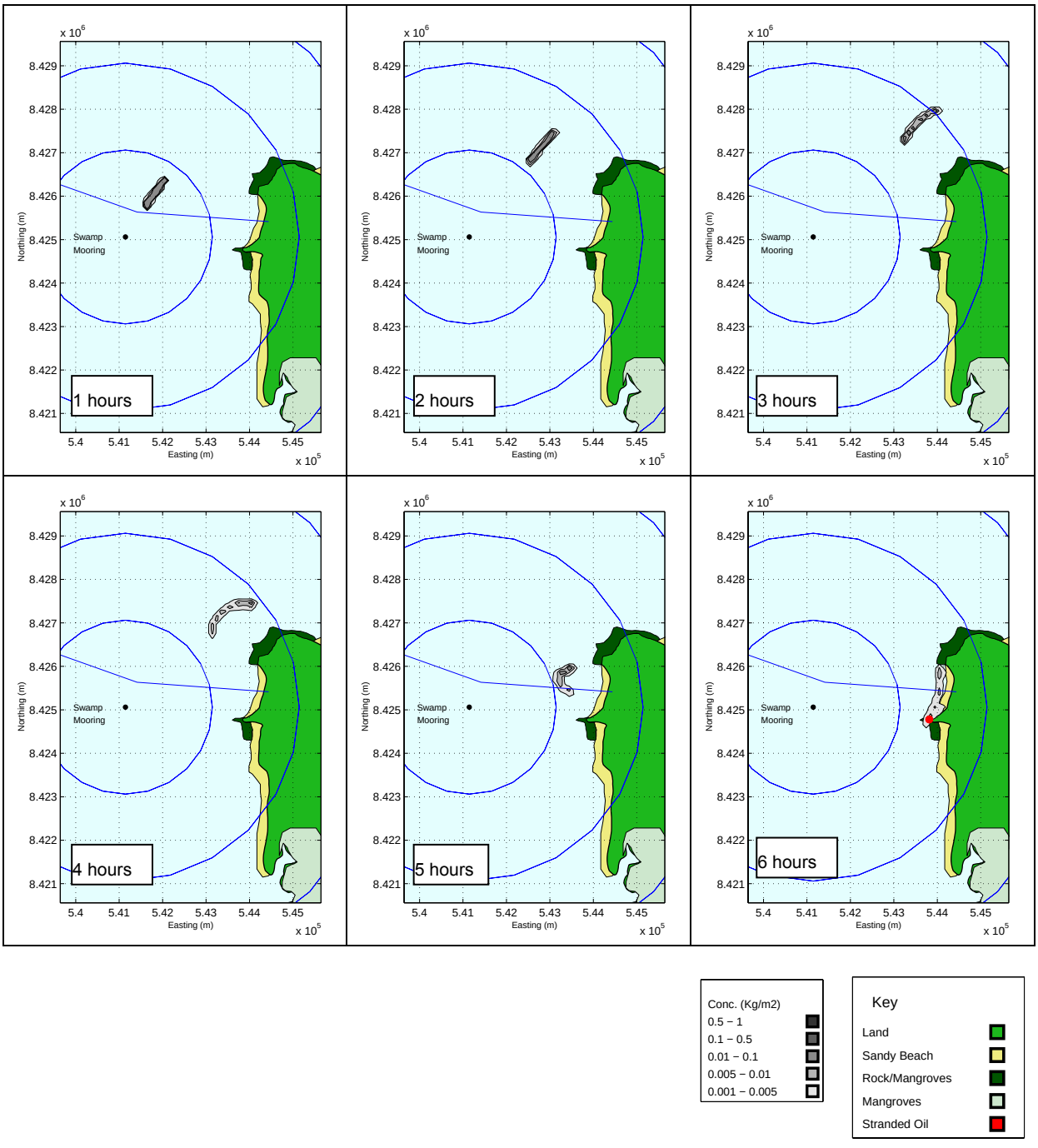
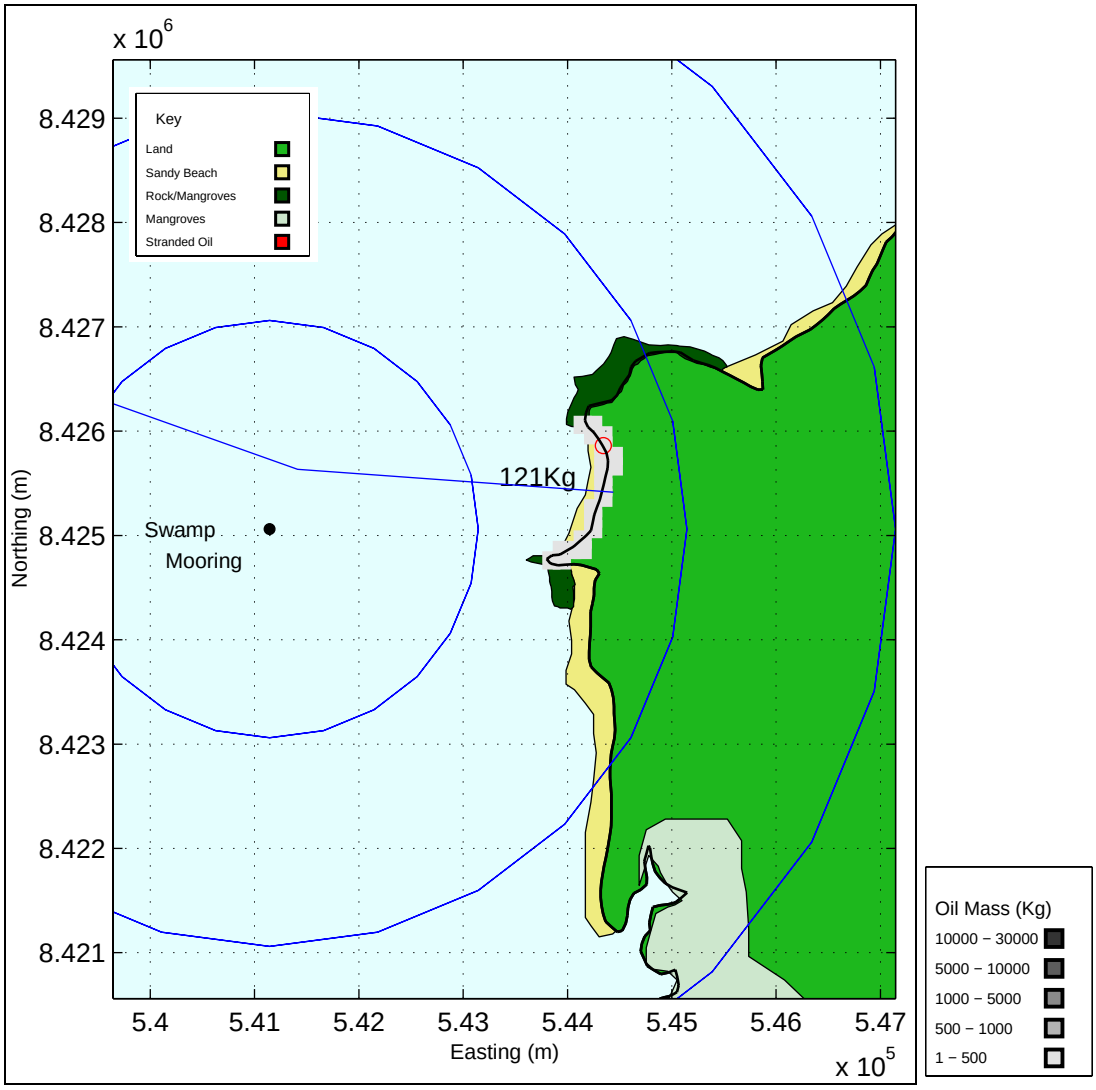


Figure 5.2 Predicted mass of beached oil for a 8m^3 spill of Blacktip condensate over 0.5 hrs during a neap tide in the wet season.



Notes for Figure 5.1 and Figure 5.2:

(1) Figure 5.1, shows the trajectory and predicted condensate concentration for an 8m^3 spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the figure above. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The red circle indicates the largest mass of oil washed up, which in this case is 121kg.

(2) Blacktip condensate is highly volatile and approximately 86% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photoxidation within a relatively short time frame.

(3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.

(4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.

(5) Range rings are drawn at 2 km intervals.

Figure 5.3 Probability of surface exposure resulting from a 8m^3 condensate spill over0.5 hours for the wet season

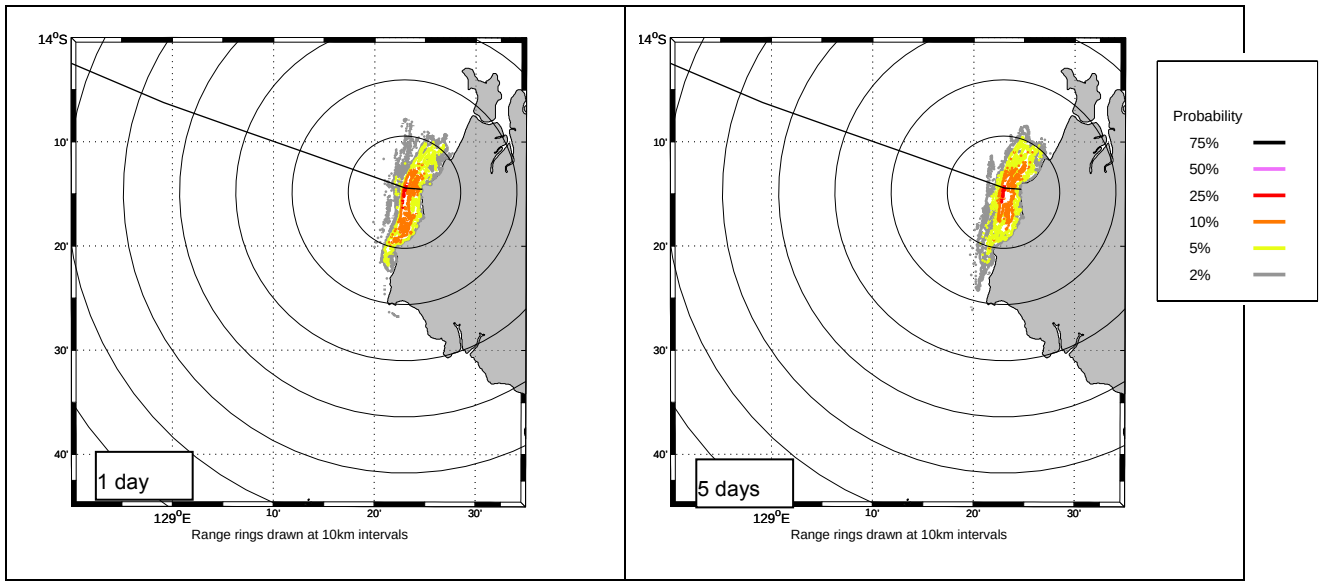
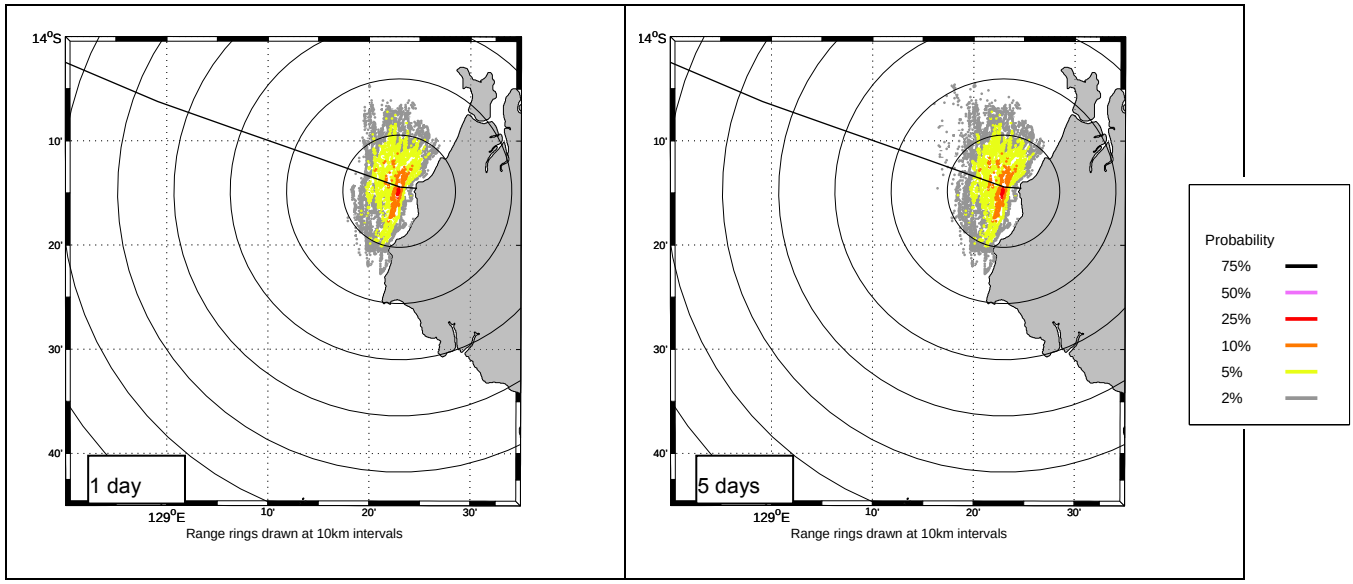


Figure 5.4 Probability of surface exposure resulting from a 8m^3 condensate spill over 0.5 hours for the dry season



Notes:

(1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.

(2) Significant oil concentrations assumed to be 0.005kg/m^2 (<10mL/m^2).

(3) Range rings are drawn at 10 km intervals.

Figure 5.5 Predicted surface oil concentration for a 100m^3 spill of Blacktip condensate during a neap tide and an onshore 5ms^{-1} wind (wet season).

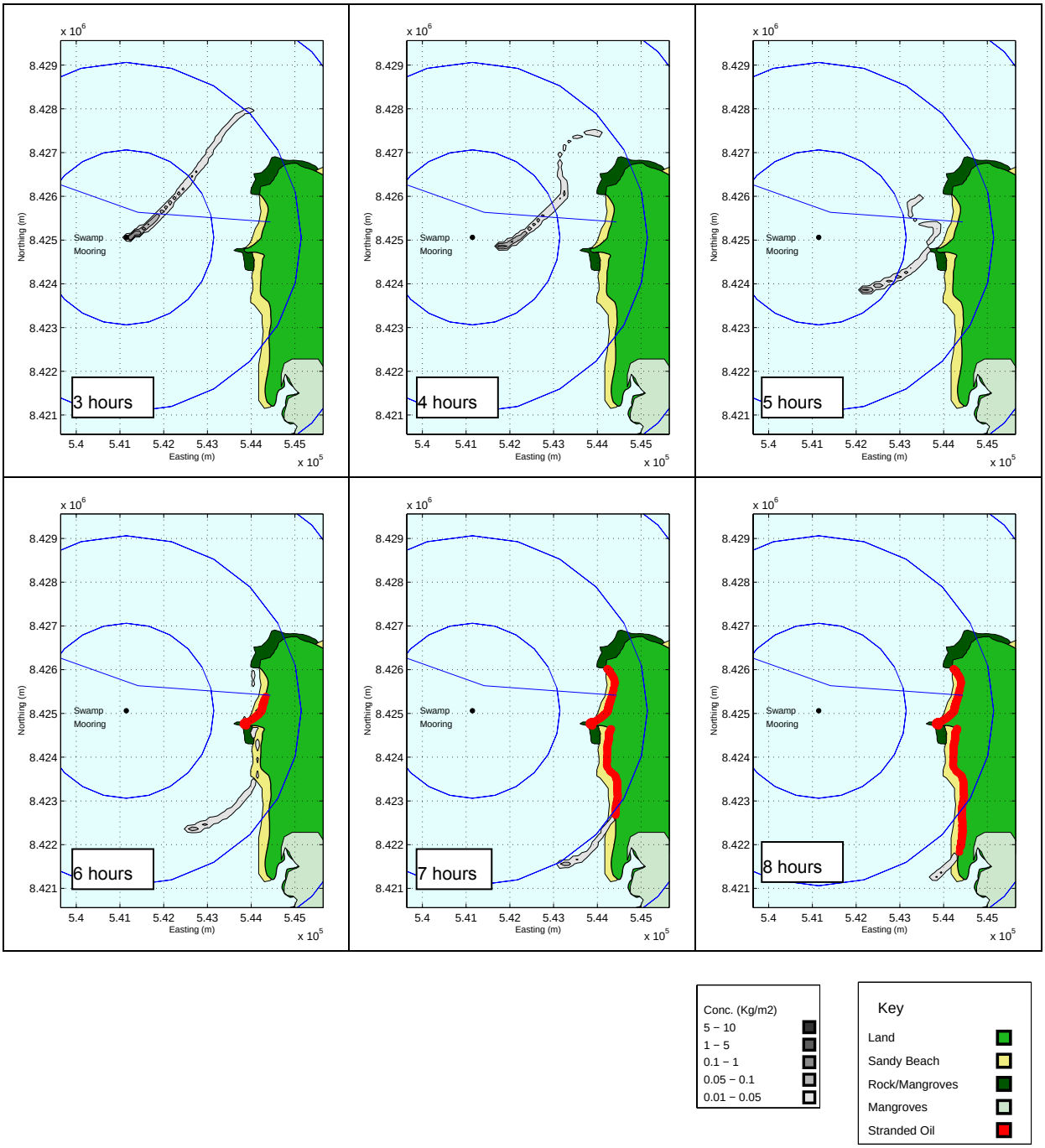
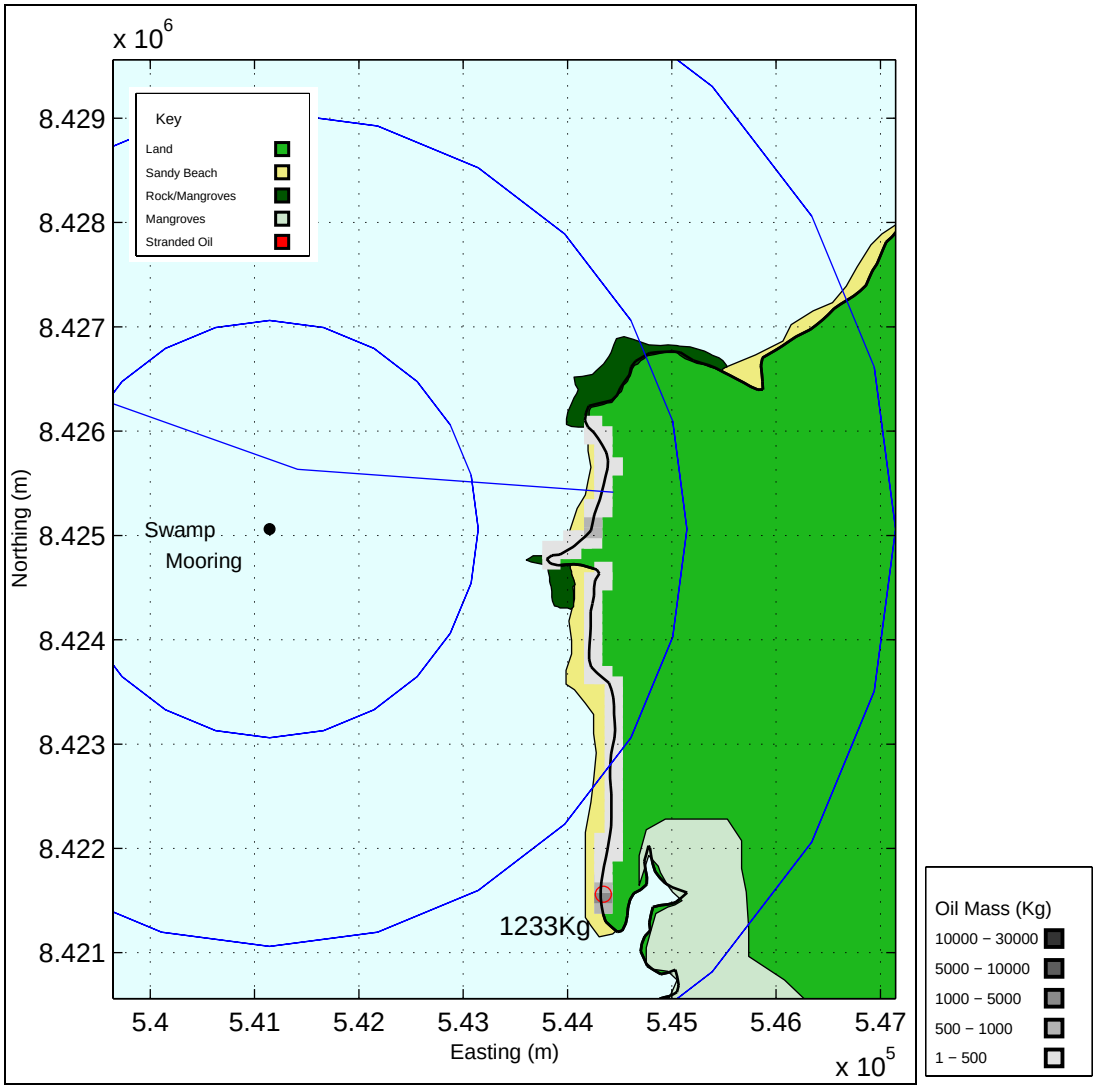


Figure 5.6 Predicted mass of beached oil for a 100m^3 spill of Blacktip condensate during a neap tide in the wet season.



Notes for Figure 5.5 and Figure 5.6:

(1) Figure 5.5 shows the trajectory and predicted condensate concentration for a 100m^3 spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The red circle indicates the largest mass of oil washed up, which in this case is 1,233kg.

(2) Blacktip condensate is highly volatile and approximately 83% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photoxidation within a relatively short time frame.

(3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.

(4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.

(5) Range rings are drawn at 2 km intervals.

Figure 5.7 Probability of surface exposure resulting from a 100m^3 condensate spill over 3 hours for the wet season

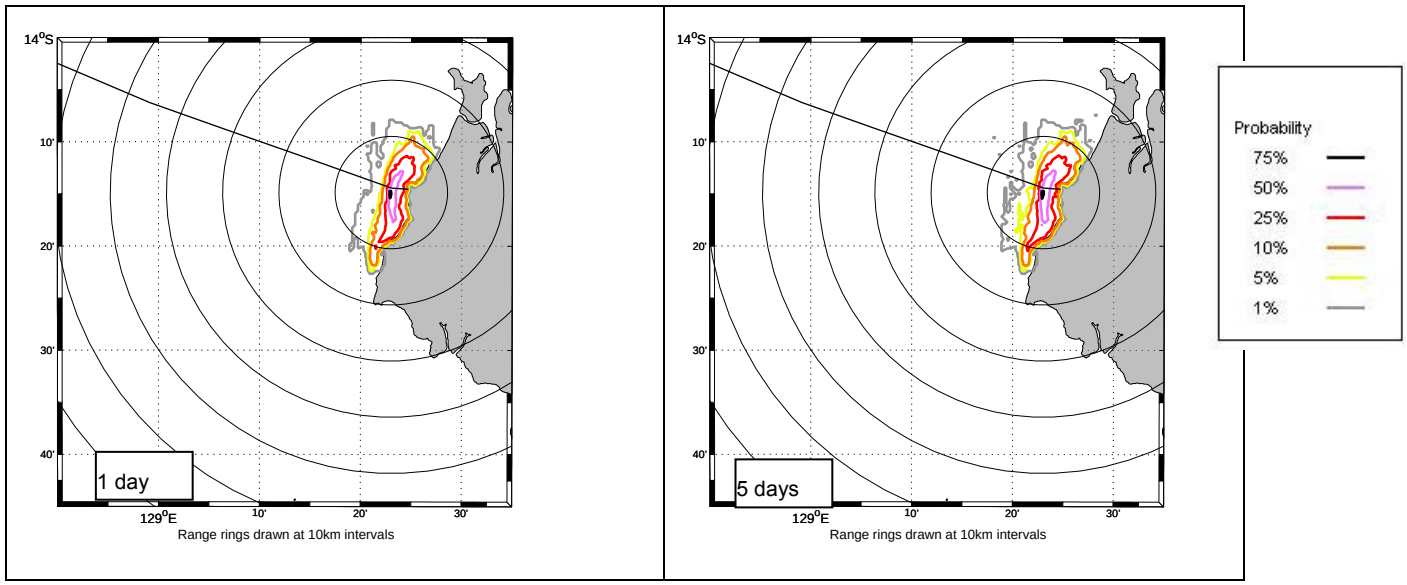
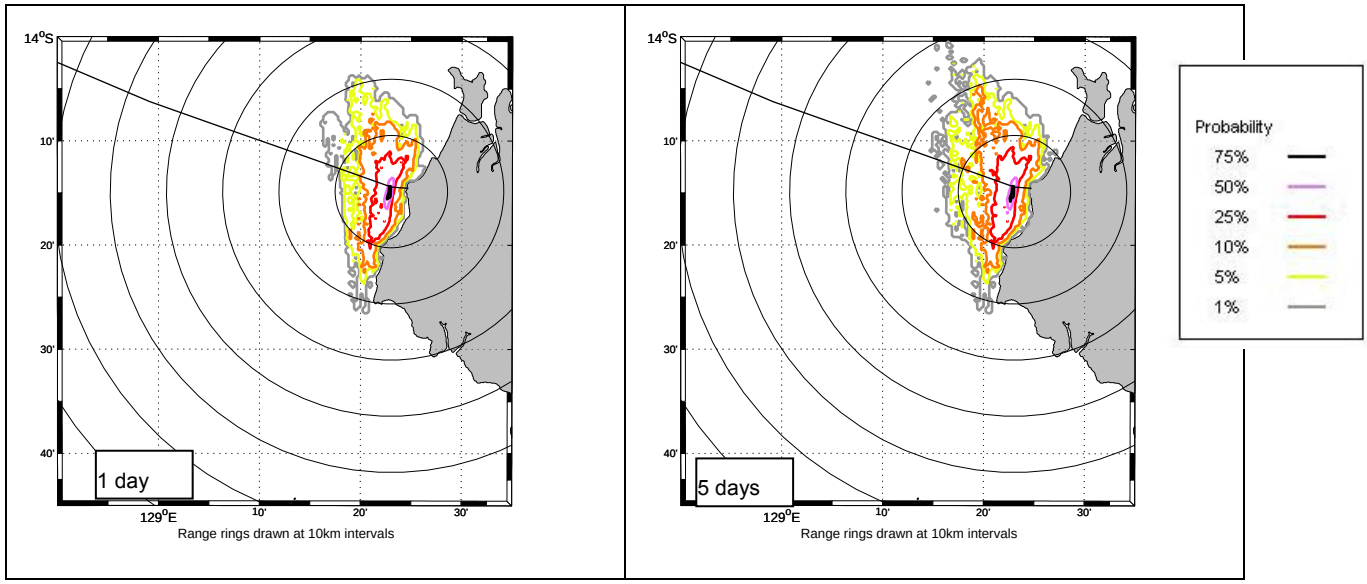


Figure 5.8 Probability of surface exposure resulting from a 100m^3 condensate spill over 3 hours for the dry season



Notes:

(1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.

(2) Significant oil concentrations assumed to be 0.005kg/m^2 (<10mL/m^2).

(3) Range rings are drawn at 10 km intervals.

Figure 5.9 Predicted surface oil concentration for a 500m^3 spill of Blacktip condensate during a neap tide and an onshore 5ms-1 wind (wet season).

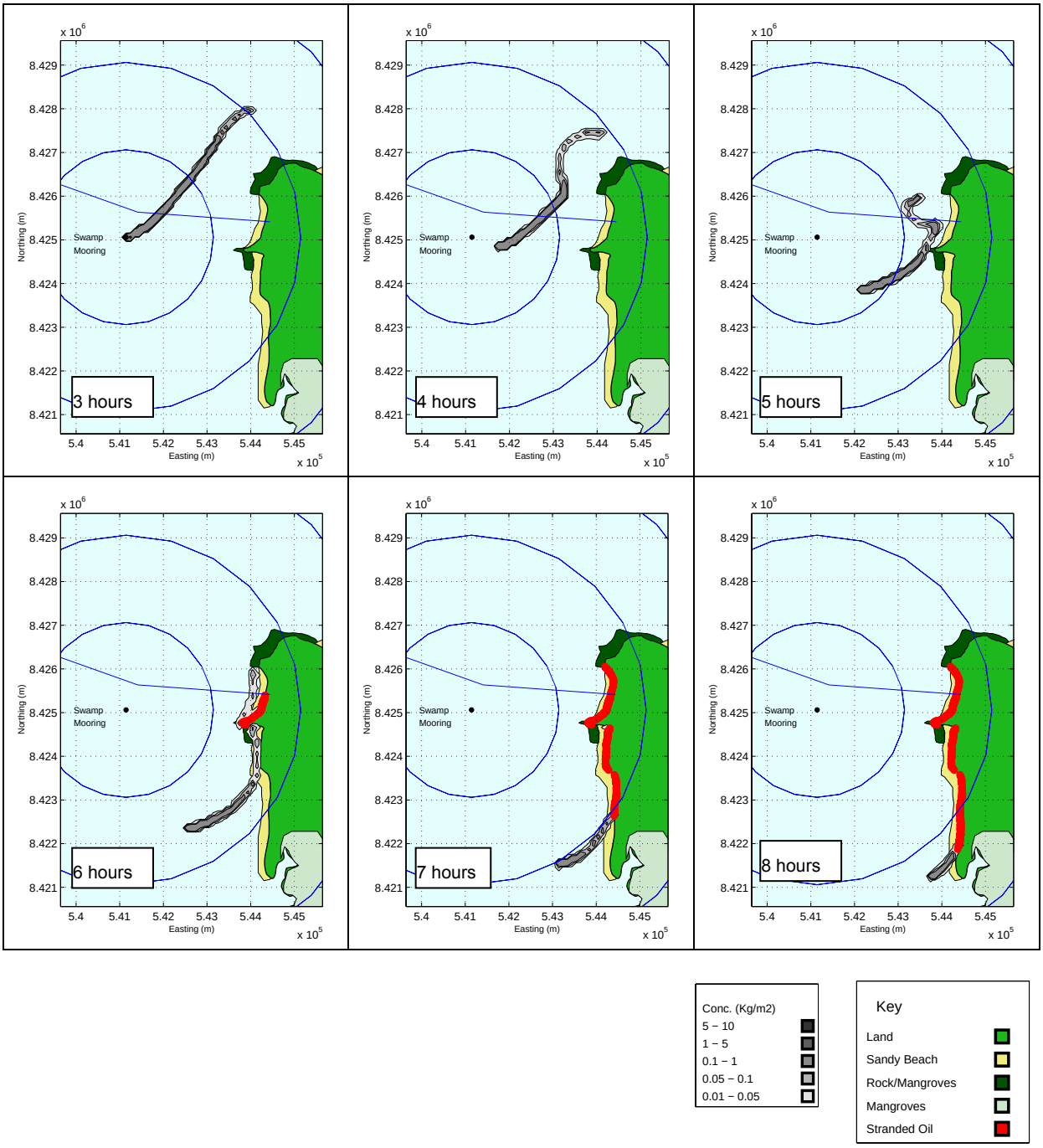
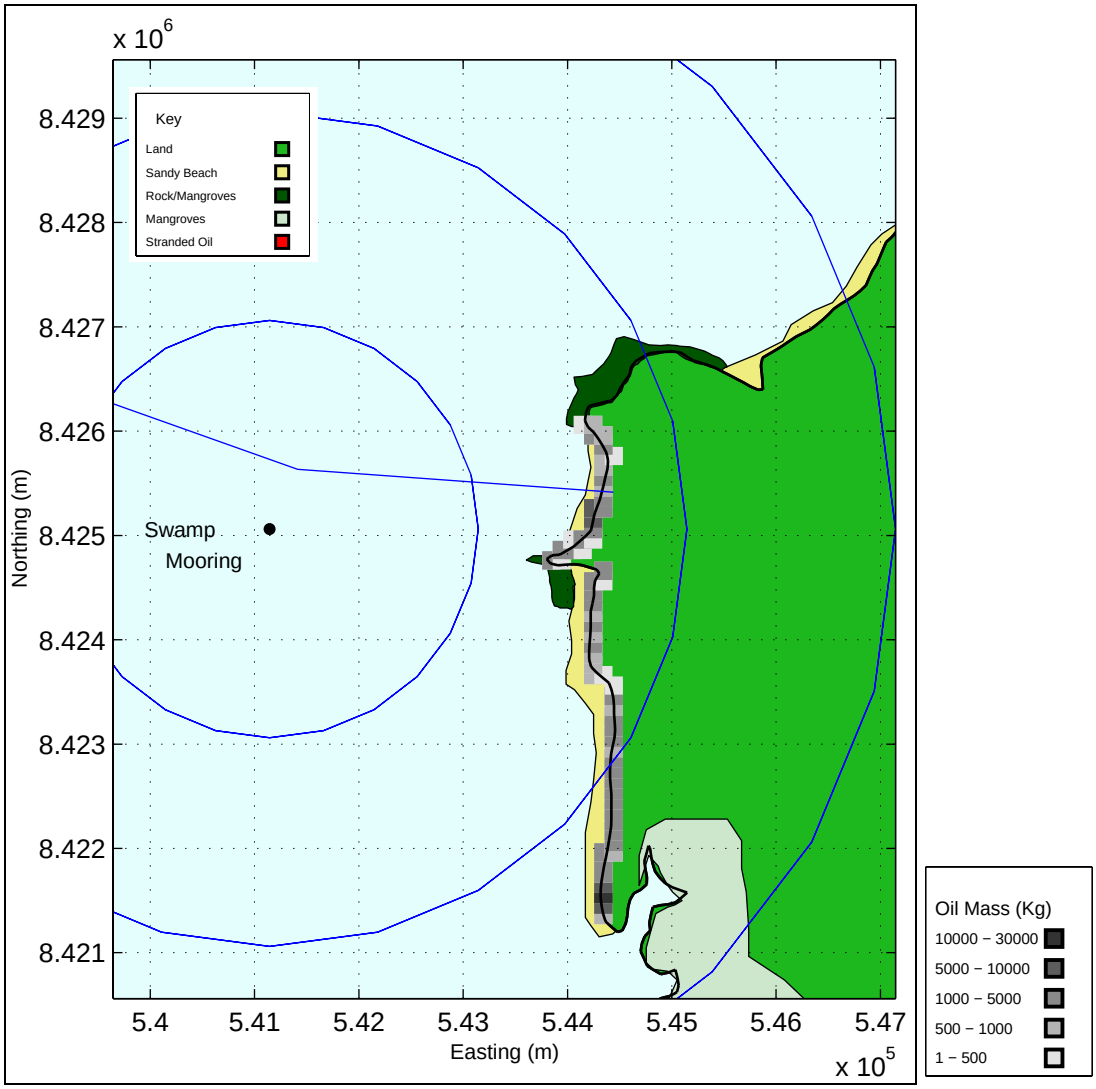


Figure 5.10 Predicted mass of beached oil for a 500m^3 spill of Blacktip condensate during a neap tide in the wet season.



Notes for Figure 5.9 and Figure 5.10 :

(1) Figure 5.9 shows the trajectory and predicted condensate concentration for a 500m^3 spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The largest mass of oil washed up is just under 6,000kg.

(2) Blacktip condensate is highly volatile and approximately 80% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photoxidation within a relatively short time frame.

(3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.

(4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.

(5) Range rings are drawn at 2 km intervals.

Figure 5.11 Probability of surface exposure resulting from a 500m^3 condensate spill over 3 hours for the wet season

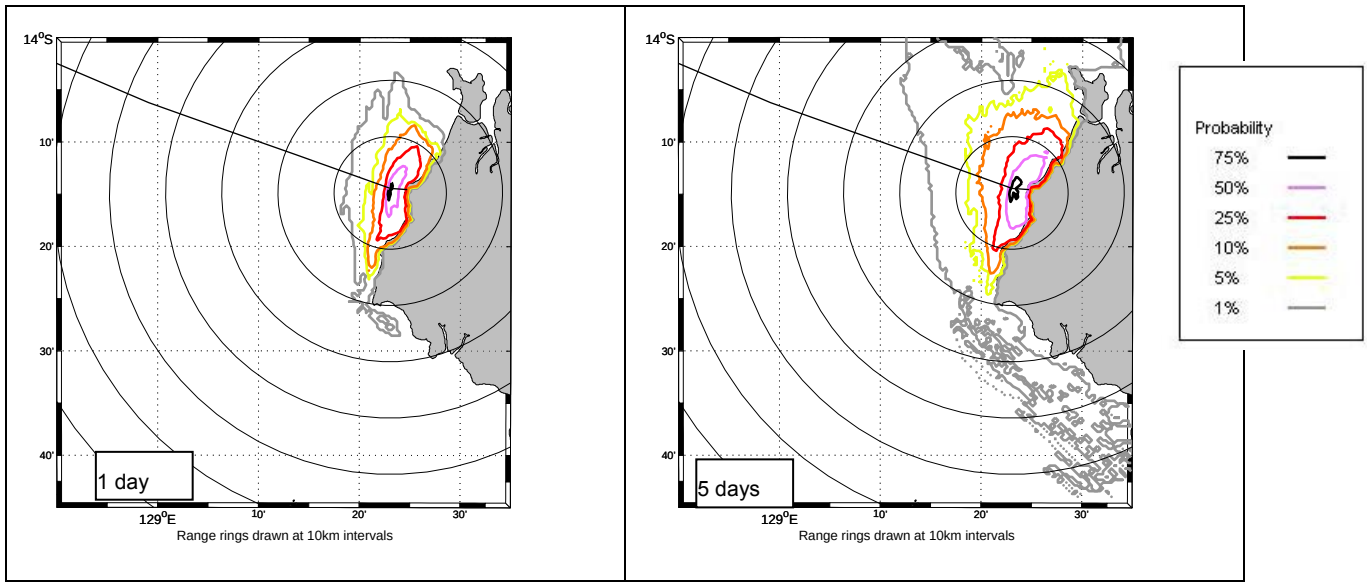
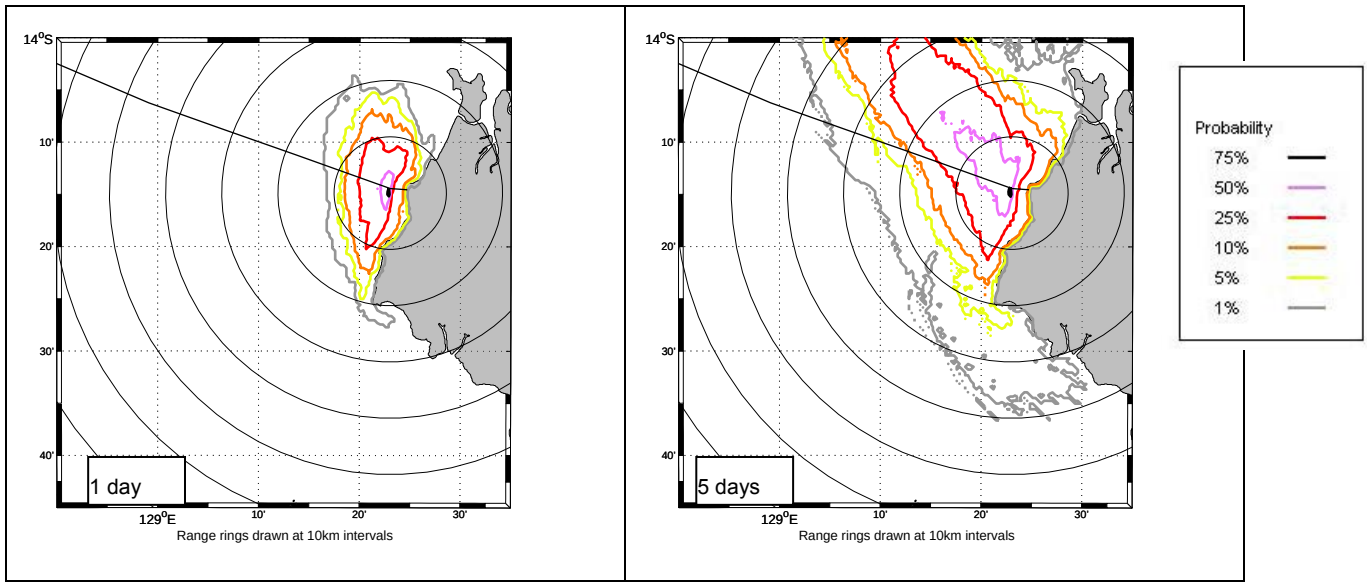


Figure 5.12 Probability of surface exposure resulting from a 500m^3 condensate spill over 3 hours for the dry season



Notes:

(1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.

(2) Significant oil concentrations assumed to be 0.005kg/m^2 (<10mL/m^2).

(3) Range rings are drawn at 10 km intervals.

Figure 5.13 Predicted surface oil concentration for a 500m^3 heavy oil fuel spill during a neap tide and an onshore 5 ms-1 wind (wet season).

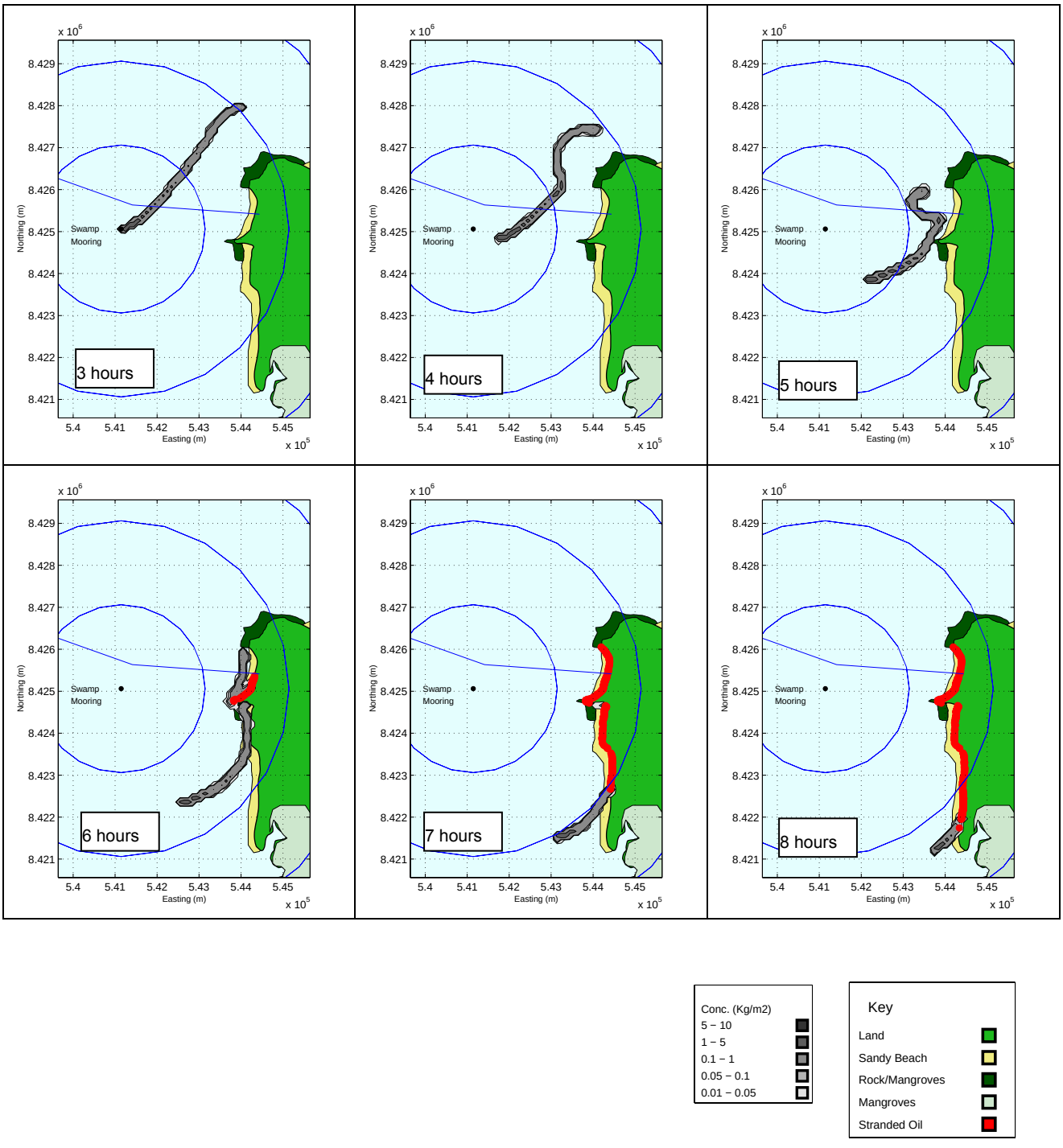
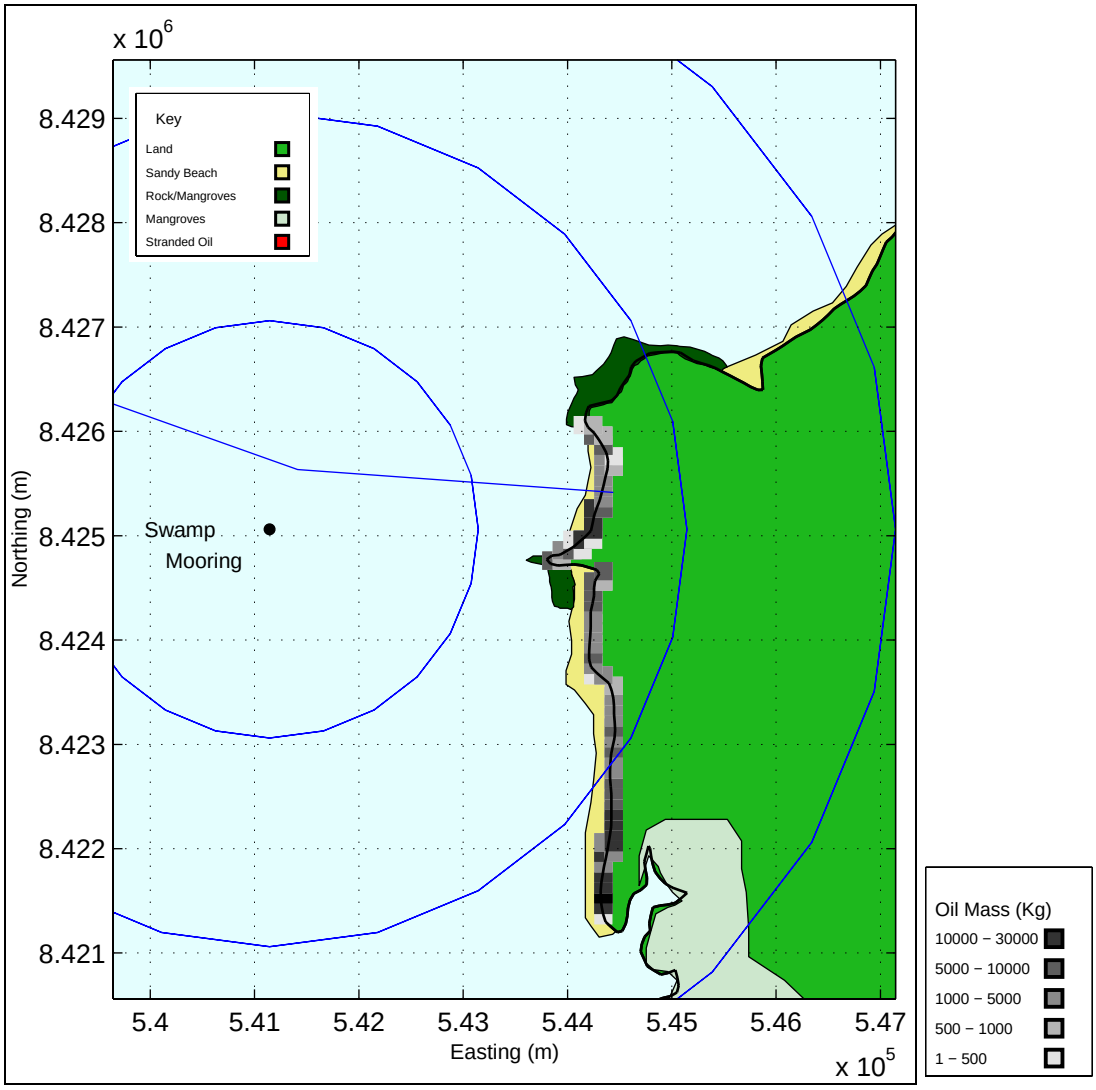


Figure 5.14 Predicted mass of beached oil for a 500m^3 heavy oil fuel spill during a neap tide in the wet season.



Notes for Figure 5.13 and Figure 5.14:

(1) Figure 5.13 shows the trajectory and predicted heavy fuel oil concentration for a 500m^3 spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The largest mass of oil washed up is 32,000kg over 100m.

(2) Stranded heavy fuel oil tends to remain on the surface rather than penetrate sediments. Natural degradation rates for these heavy oils are very slow and, if not cleaned up, the oil may persist on beaches for months to years.

(3) Shoreline cleanup would be required. Adverse effects of floating heavy fuel oils are related primarily to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils. The likely environmental consequence with cleanup would be moderate with a recovery time of 5 – 10 years.

(4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.

(5) Range rings are drawn at 2 km intervals.

Figure 5.15 Probability of surface exposure resulting from a 500m^3 heavy oil fuel spill over 3 hours for the wet season

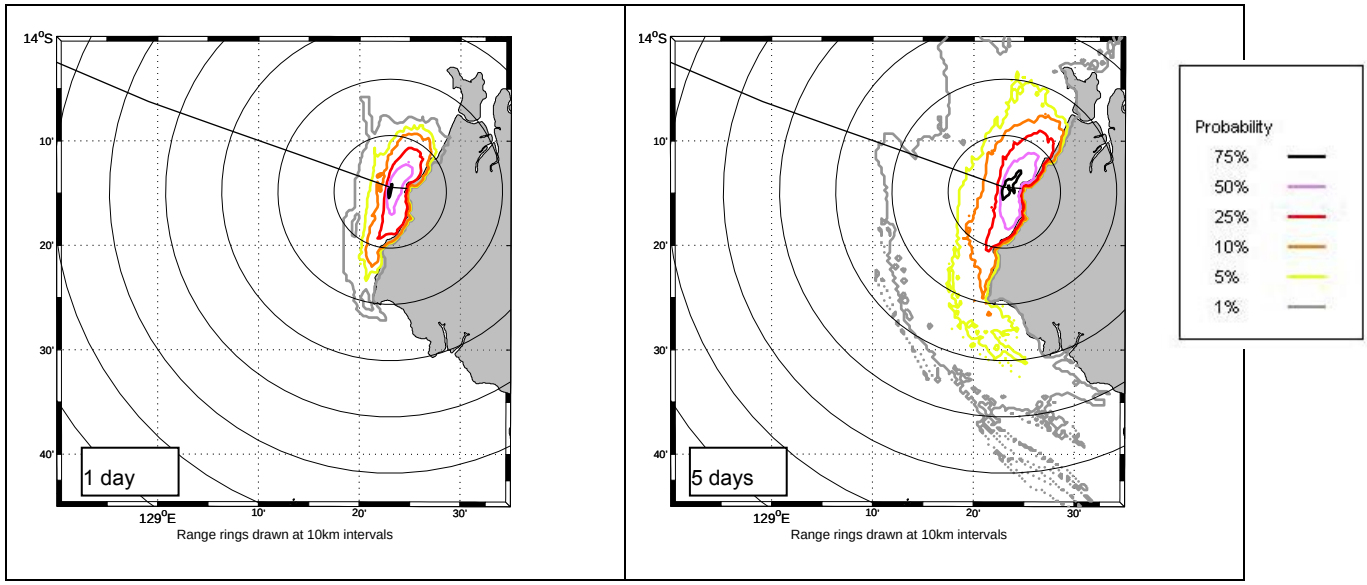
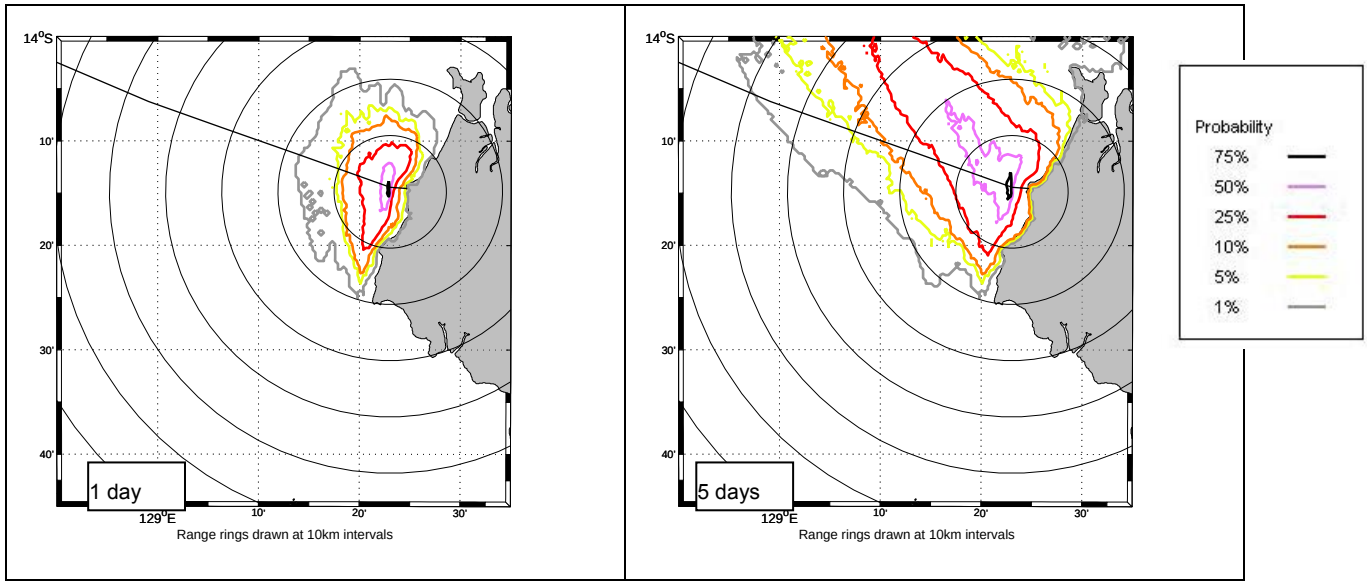


Figure 5.16 Probability of surface exposure resulting from a 500m^3 heavy oil field spill over 3 hours for the dry season



Notes:

(1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.

(2) Significant oil concentrations assumed to be 0.005kg/m^2 (<10mL/m^2).

(3) Range rings are drawn at 10 km intervals.

6 ENVIRONMENTAL IMPACT

6.1 Blacktip Condensate Spills

Small condensate spills will evaporate rapidly and are unlikely to reach environmentally sensitive areas in concentrations high enough to result in significant impact. In contrast, medium and large spills could persist at concentrations above toxic thresholds for longer durations. During the wet season there is a high probability that these will be washed ashore with minor, short term environmental damage.

Should condensate become stranded on the shoreline, it would tend to penetrate porous sediments and be washed away by waves and tidal currents. It would continue to evaporate and, over longer time scale of one to two months, any residual would be readily degraded by naturally occurring microbes. Shoreline cleanup should, therefore, not be required.

The condensate is likely to be acutely toxic and could cause mortality to floating and water column marine organisms that come into direct contact with a fresh spill. Toxicity will reduce with time as the oil weather and specifically as the aromatic component evaporates.

6.2 Heavy Fuel Oil Spills

When spilt on water, heavy fuel oil usually spreads into thick, dark coloured slicks, which can contain large amounts of oil. The most viscous oils will often breakup into discrete patches and tarballs when spilled instead of forming slicks. Oil recovery by skimmers and vacuum pumps can be very effective early in the spill. Very little of this viscous oil is likely to disperse into the water column.

Due to its high viscosity, beached oil tends to remain on the surface rather than penetrate sediments. Light accumulations usually form at the high-tide line; heavy accumulations can pool on the beach. Shoreline cleanup can be very effective, before the oil weathers, becoming stickier and even more viscous. Natural degradation rates for these heavy oils are very slow. The oil may persist on beaches for months to years.

Adverse effects of floating heavy fuel oils are related primarily to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils.

Direct mortality rates can be high for seabirds, waterfowl, and fur-bearing marine mammals, especially where populations are concentrated in small areas, such as during bird or marine mammal migrations.

Direct mortality rates are generally less for shorebirds because they rarely enter the water. Shorebirds, which feed in intertidal habitats where oil strands and persists, are at higher risk of sublethal effects from either contaminated or reduced population of prey.

The most important factors determining the impacts of heavy fuel oil contamination on mangroves are the extent of oiling on the vegetation and the degree of sediment contamination from the spill or disturbance from the cleanup. Many plants can survive partial oiling; fewer survive when all or most of the above-ground vegetation is coated with heavy oil. Recovery of oiled mangroves depends on the initial and residual loading as well as damages resulting from cleanup efforts.

7 CONCLUSIONS

Tanker operations were considered to pose the greatest risk for an oil spill accident. For the purposes of modelling, four credible tanker operation scenarios were analysed for two different oil types:

- small ($8m^3$), medium ($100m^3$) and large ($500m^3$) spills of Blacktip condensate during offloading to the trading tanker; and
- a $500m^3$ heavy fuel oil spill from a tanker fuel leak.

Blacktip condensate is a light oil that rapidly evaporates from the sea surface. Modelling indicates that more than 80% will be removed through evaporate within 24 hours of being spilt. Blacktip condensate is therefore non-persistent and is unlikely to result in long term environmental damage should a spill occur. In contrast heavy fuel oil is a viscous, non-volatile and persistent oil.

Oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. Shoreline is impact is possible in the dry season, however, the probability is substantially reduced.

Adverse effects resulting from a condensate spill are likely to be related to marine organisms in the water column coming into direct contact with a fresh spill. Toxicity of spilled condensate should reduce with time as the aromatic components volatise and the oil becomes diluted. Shoreline cleanup may not be necessary as beached condensate will continue to evaporate once stranded and will be washed away naturally by tide and waves. Any residual will be removed by biodegradation and photo-oxidation processes over time frames of one to two months.

Adverse effects resulting from a heavy fuel spill are more likely to be related to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils.

8 REFERENCES

Australian Hydrographic Services, 2003. Australian national tide tables. Australian Hydrographic Publication.

Blanton, B.O., 1995. User's manual for 3-Dimensional drogue tracking on a FE grid with linear finite elements. OPNML.

Delvigne, G.A. and C.E. Sweeney, 1988. Natural Dispersion of Oil. Oil & Chemical Pollution, 4:281-310.

Eley, D. D., M. J. Hey, and J. D. Symonds, 1988. Emulsions of Water in Asphaltene-Containing Oils 1. Droplet Size Distribution and Emulsification Rates, Colloids and Surfaces. Vol. 32, pp. 87-101.

Fay, J. A., 1969. The spread of oil slicks on a calm sea. Oil on the Sea. Plenum, New York, pp53 – 64.

Fingas, M.F., 1999. The evaporation of oil spills: Development and implementation of new dilution methodology. Proceedings of the 1999 International Oil Spill Conference. American Petroleum Institute, Washington DC, pp. 281-287.

Le Provost, C., F. Lyard, J.M. Molines,. and M.L. Genco, 1998. A hydrodynamic ocean tide model improved by assimilating a satellite altimeter-derived data set. Journal of Geophysical Research, 103, 5513-5529.

Sherwin, T.J., 1992. Methods for determining pollutant dispersion in tidal waters. UCES Report: U89-5(I:3). March, 1992.

Westerink, J.J., R.A. Luettich and J.C. Muccino, 1994. Modeling tides in the western north atlantic using unstructured graded grids. Tellus, 46A, 178-199.

WEL, 2003. Blacktip Development Phase 2B: Gas Condensate Assay. DRIMS# 348190.

Appendix L

Assessment of Species with Indigenous Conservation Values and Related Environmental Cultural Values in the Vicinity of the Proposed Blacktip Gas Pipeline and Processing Plant near Wadeye in the Northern Territory prepared by Smyth and Bahrdt Consultants






This page has been left intentionally blank

ENVIRONMENTAL CULTURAL VALUES AT WADEYE

Assessment of species with Indigenous conservation values and related environmental cultural values in the vicinity of the proposed Blacktip gas pipeline and processing plant near Wadeye in the Northern Territory

Prepared for Woodside Energy Ltd

By Smyth and Bahrdt Consultants

October 2004

CONTENTS

Acknowledgements **2**

1. Background **3**
1.1 Summary of Blacktip proposal 3
1.2 Meeting EIS Guidelines 3
1.3 Interpretation of "Indigenous conservation values" 4

2. Methodology **4**
2.1 Preparation for field visit 4
2.2 Collaboration with Traditional Owners 4
2.3 Consultation with Thamarrurr Rangers 5
2.4 Consultation with Wadeye Aboriginal Languages Centre 5

3. Results **6**
3.1 Cultural values and connection to country 6
3.1.1 Summary of environmental cultural values 10
3.2 Impact of Blacktip proposal on environmental cultural values 10
3.2.1 Disturbance to environments & species of cultural significance 11
3.2.2 Status of environmental cultural knowledge and practice 12
3.3 Current Initiatives supporting environmental cultural values 13
3.3.1 Thamarrurr Rangers 13
3.3.2 Wadeye Aboriginal Languages centre 14

4. Conclusions **15**

References **16**

Acknowledgments
I would like to sincerely thank Yak Maninh and Yak Dimininh Traditional Owners who welcomed me to their country and gave of their time and knowledge to enable this assessment of their environmental cultural values to proceed. I would also like to acknowledge the great assistance and support provided by Northern Land Council field staff, anthropologist and consultants, and to thank staff of Thamarrurr Rangers and Wadeye Languages Centre for sharing their valuable information and experience. Thanks and appreciation also to the Woodside staff, camp manager and chef who provided such excellent logistical support during my visit to Wadeye.

Dermot Smyth
October 2004

1 BACKGROUND

1.1 Summary of the Blacktip proposal

Woodside Energy Ltd (Woodside) is developing a proposal to bring gas and condensate from the Blacktip gas field 107 km offshore via a pipeline to a processing plant to be located approximately 2.5km inland, and about 12km west of Wadeye Aboriginal Community. The intention is to transport the gas via an underground pipeline about 940 km to Nhulunbuy in northeast Arnhemland to fuel an aluminium processing plant. The condensate will be piped back out to sea for removal by ship.

1.2 Meeting Environmental Impact Assessment (EIS) Guidelines

EIS Guidelines set by the Australian and Northern Territory governments require Woodside to undertake a range of assessment studies, including baseline descriptions and assessments of the potential impact of the proposal on the biophysical and social environments in the Wadeye region.

Section 4.4.1 of the EIS Guidelines requires a baseline assessment of the ecology of the area to be undertaken, including a description of the fauna, flora and biological communities (including marine, estuarine, terrestrial and aquatic). This Section also states that:

> *Species with Indigenous conservation values should also be described.*

Smyth and Bahrdt Consultants were commissioned to specifically address this aspect of the EIS. In discussions between representatives of Woodside, the Northern Land Council (NLC) and the consultant it was decided to address this EIS requirement within the broader context of considering environmental cultural values held by Traditional Owners in the area. This broadening of the project objective arose from recognition that “Indigenous conservation values” apply not only to individual species but also to the biological communities, habitats and environments in which those species live. It was further decided to consider the potential impact of the Blacktip proposal not only on species and environments with Indigenous conservation values, but also on the Indigenous conservation values themselves. A methodology was therefore developed to address the following objectives:

1. To describe species with Indigenous conservation values;

2. To gain an understanding of the nature and scope of those values;

3. To assess potential impacts (positive and negative) on species with Indigenous conservation values; and

4. To assess the potential impact (positive and negative) on environmental values held by Traditional Owners.

1.3 Interpretation of "*Indigenous conservation values"*

The term "Indigenous conservation values" is not commonly used in EIS documentation or as a component of general environmental planning jargon. Representatives of the NLC and Woodside explained that the term had been introduced to the EIS to ensure that species of importance to Traditional Owners for cultural, economic, nutritional, medicinal or other reasons were considered in the environmental assessment process. The term is therefore used in this report to mean species about which Traditional Owners hold values which give the species significance to Traditional Owners over and above the significance of the species as members of biological communities, or as rare, threatened or endangered etc.

This approach allows species of particular interest to Traditional Owners to be considered as a subset of the values that make up the relationship between Aboriginal people and their traditional Country. That relationship is based on inherited rights and responsibilities of particular groups of people to particular areas of land and sea, combined with complex culture-specific knowledge, kinship and belief systems. While this project was initiated to address a component of the ecological requirements of the EIS, the broadening of the objectives means that the project also contributes to aspects of the *Historic and Cultural Heritage Values* (Section 4.10.2.1), which states in part:

> *Identify Indigenous and non-Indigenous places of historic or contemporary cultural significance, including:*
>
> - *Areas of special values to indigenous and non-indigenous people (e.g.* ***traditional land use****,* ***landscape****, visual environment, recreational, commercial,* ***fisheries****, scientific,* ***educational****, marine archaeological sites)* (emphasis added).

2 METHODOLOGY

2.1 Preparation prior to field visit

Preparation prior to visiting Wadeye and the project site included:

- Familiarisation with anthropological literature for the area (Ward 1983);
- Familiarisation with ethnobiological literature for relevant ecological regions in the NT (Raymond et al 1999, Blake et al 1998);
- Reading relevant sections of the Draft EIS for the Blacktip project, in particular those sections dealing with ecology, fauna, flora, cultural heritage, archaeology and social impact assessment.

2.2 Collaboration with Traditional Owners

The primary tool for assessing environmental cultural values is collaboration with Traditional Owners, who are the holders of the values under

consideration (Smyth 2002). With the assistance of NLC Field Officers and anthropologist, Traditional Owners from Yak Maninh and Yak Dimininh clans were invited to collaborate in the assessment of environmental cultural values for their respective traditional areas (clan estates) potentially affected by the Blacktip proposal.

Field work for this aspect of the EIS took place over four consecutive days. While this was sufficient time to visit each of the key locations potentially impacted by the Blacktip proposal with representatives of the appropriate clan groups for each location, it was not possible or intended to undertake a detailed study of Aboriginal environmental knowledge and values in the region. Rather, the intention was to undertake a scoping study to explore the spectrum of cultural values associated with key environments and species, to gain an understanding of potential impacts and to propose appropriate management responses.

Collaboration with Traditional Owners involved the following activities:

- Discussing the project with individuals and small groups at various locations (including Traditional Owners' houses/camps, Woodside camp, Thamarrurr Ranger base);

- Discussing Aboriginal use, knowledge and significance of particular species, habitats and environments during visits on Country – including the identification (language names, English names and scientific names) of some animals and plants at each location;

- Discussing the preservation, transmission and presentation of Aboriginal cultural information about plants and animals;

- Looking through existing ethnobiological publications (including Blake *et al.,* 1998; Nambatu *et al.,* 2004; and Raymond *et al.,* 1999).

2.3 Consultation with Thamarrurr Rangers

The Thamarrurr Rangers were established in Wadeye in 2001 as an outcome of the Top End Aboriginal Land Management and Employment Strategy (TEALMES). TEALMES is a multi-agency agreement to develop land management activities and create employment opportunities within the Daly River / Port Keats Aboriginal Land Trust. TEALMES seeks to formalise Indigenous land management through operational and financial support from the NLC, the NT Dept of Business, Industry and Resource Development, the Indigenous Land Corporation, the Dept of Workplace relations and the NT Dept of Employment, Education and Training.

Discussions were held with Thamarrurr Rangers and their co-ordinator (Scott McIntyre) to gain an understanding how species, habitats and environments of significance to Aboriginal people are currently being managed in the Wadeye region, and the role of the Ranger program in the protection and transmission

of associated environmental cultural values these issues are currently being addressed within the Thamarrurr region.

2.4 Wadeye Aboriginal Languages Centre

Discussions were held with the coordinator of the Wadeye Aboriginal Languages Centre (Mark Crocombe) to gain an understanding of current initiatives to document, protect and transmit environmental Aboriginal knowledge of plants, animals and associated environmental cultural values in the Wadeye region.

3. RESULTS

3.1 Cultural values and connection to Country

Yak Maninh and Yak Dimininh Traditional owners, and the other Aboriginal groups of the Wadeye region, have a holistic view of their traditional country, in which all elements (land, sea, estuaries, rivers, animals, plants, people etc.) are linked through creation stories, tracks of creation ancestors, kinship systems, traditional knowledge, subsistence use and other cultural mechanisms (Ward 1983). In this broad sense, therefore, all species and other elements of country potentially have "Indigenous conservation values".

Visits were made with Traditional Owners to discuss the cultural significance of country and species at the following locations:

With Yak Maninh Traditional Owners

- Coastal area in vicinity of proposed pipeline shore crossing;
- Proposed route of pipeline corridor between the shore and gas plant;
- Proposed gas plant site;
- Proposed route of all-weather access road.

With Yak Dimininh Traditional Owners

- Proposed route of all-weather access road.

Within these locations Traditional Owners identified distinct environment types in the local Murrinh Patha language. Traditional Owners from both clan groups have a detailed knowledge of the names, properties, seasonality, ecological relationships, cultural attributes and uses of a large number of animals and plants in each of these environments. Each of the environments visited contain species that are used for food, medicines, implements or other cultural purposes, but country is valued by traditional owners for more than just the usefulness of particular species that live there. Traditional owners expressed a strong sense of responsibility to country, to look after it, to keep it healthy and to protect it for the generations to come. Some of the key resources for each environment category are summarised in Table 1, though, as noted above, the cultural significance of these environments is not limited to these resources.

Detailed information about the languages names, uses and other cultural significance of plants and animals in the Wadeye region has been recorded by

the Wadeye Aboriginal Languages Centre. Some of this information has been transcribed into a draft report on Aboriginal knowledge of flora and fauna from the Wadeye and Kuy regions (Nambatu et al 2004).

To date the Wadeye Aboriginal Languages Centre has collected Aboriginal language names, uses and other associated cultural information for 206 plant species and 434 animal species. While it is not appropriate to report details of this Aboriginal knowledge in a public EIS document, Tables 2 and 3 provide an indication of the scope of Aboriginal knowledge and cultural significance of plants and animals in the Wadeye region. The attributes listed in these tables are based on information collected by the Wadeye Aboriginal Languages Centre, supplemented by information provided by Yak Maninh and Yak Dimininh Traditional Owners during consultations for this report. To protect intellectual property associated with this knowledge, no attributes or language names are identified with individual species.

Environment (English name)	Environment (Murrinh Patha name)	Key resources*
Deep sea	*Langarr*	Dugong, turtles (several species), fish (many species)
Beach	*Darrimun*	Turtle eggs & some food plants
Mangrove	*Dara*	Molluscs, crustaceans, fish & mangrove worms
Rocky shelf	*Kalpa*	Fish, crabs, oysters
Jungle (notophyll vine forest)	*Da Dunpungu*	Yams and other food plants, fibre, dyes, shade trees
Dune woodland	*Da Pangkin*	Yams and other food plants, fibre, dyes
High ridge (open woodland)	*Da Bengkunh*	Food plants, honey, mammals, birds, reptiles, invertebrates
Pandanus / Mellaleuca community	*Da Bepi*	Food plants, fibres, water

Table 1: Summary of key resources within Yak Maninh and Yak Dimininh environments associated with the Blacktip proposal
*The cultural significance of these environments is not limited to the resources listed.

Category	Attribute and uses
Food	Fruit flesh Pith / shoots Fruit seeds Tuber Nectar and sap Water source
Plant and animal associations	Edible animals associated with specific plants Food for animals Calendar plants (indicating seasonality or species availability)
Implements	Clap-sticks Didgeridoos Digging sticks Fighting sticks Fire carriers Fire sticks Spears Throwing sticks Tools Water craft (dugout and bark canoes) Woomeras
Material culture	Carrying baskets Water carriers Caulking compounds (for repairing leaks) Dyes Fibres Fish poisons Glues Harmful / poisonous Insect repellent Ornament / decoration Sandpaper Shelter / bedding Smoking pipes Tobacco Toys Drinking cups Straws Stone axe handles
Medicines	Respiratory ailments Skin ailments Headaches Others
Other uses	Firesticks Firewood and kindling Wrapping food for cooking Ceremonies Shade

Table 2: Some attributes and uses of Aboriginal knowledge of plants
Based on information from Nambatu et al (2004) and consultations with Yak Maninh and Yak Dimininh Traditional Owners.

Category	Attribute / Uses
Food	Flesh of mammals, birds. Fish, reptiles, amphibians Eggs or birds and reptiles Marine and terrestrial invertebrates Bait
Spiritual	Many species are totems for particular people and groups Dreaming sites associated with particular species Particular species of spiritual importance to men Particular species of spiritual importance to women Particular species feature in creation stories
Clothing and decoration	Feathers Shells
Medicine	Some species have medicinal properties
Calendar species	Some species indicate seasonal changes and availability of particular plant foods
Other uses	Water carriers Smoking pipes Lead people to water Look after country

Table 3: Some attributes and uses of Aboriginal knowledge of animals
Based on information from Nambatu (2004) and consultations with Yak Maninh and Yak Dimininh Traditional Owners.

3.1.1 Summary of Indigenous environmental cultural values:

The plant and animal species in the vicinity of the proposed Blacktip gas plant, pipeline, shore crossing and access road form part of Yak Maninh and Yak Dimininh cultural landscapes. A large number of species have specific utilitarian and other cultural values, and collectively they are an integral part of country for which traditional owners have an inherited responsibility. All country has inherent value to traditional owners, over and above the value or usefulness of particular animal and plant species within it.

The gas plant site and access road corridor are located in open woodland environments that are well represented elsewhere in Yak Maninh and Yak Dinininh clan estates. While this does not diminish the cultural value of environments at the gas plant site and along the road corridor, traditional owners reported that culturally significant resources available at these locations are also available elsewhere within their clan estates.

Marine and terrestrial environments adjacent to the shore crossing (mangrove, rocky platform, intertidal zone, beach, vine thicket etc.) are rich in culturally significant resources and comprise only a small portion of traditional owners' clan estates.

3.2 Impact of Blacktip proposal on environmental cultural values

There are two potential types of impact on environmental cultural values from the Blacktip proposal:

1. Temporary or permanent damage to environments and biological communities including species of cultural significance; and

2. Change in status of cultural knowledge and practices associated with species and environments, as a result of economic and social change over time.

3.2.1 Disturbance to environments and species of cultural significance

The construction of the pipeline, gas plant and access road will cause temporary or permanent disturbance to some environments and biological communities including species of cultural significance to Traditional Owners. In particular, plant and animal communities living at the gas plant site and on the access road corridor will be totally removed.

The gas plant site is part of an extensive open woodland area periodically used for hunting, gathering and collection of other cultural material, particularly by traditional owners residing at a nearby outstation. Clearing of the site and construction of the gas plant will therefore to some extent reduce the area available for traditional owners to carry out these activities. The extent to which clearing of the gas plant site will impact on Aboriginal resource use will be determined not only by the size of the clearing, but its ecological impact in the surrounding area, as well as the ecological impact of the construction and operation of the gas plant. Factors impacting on Aboriginal use of animal and plant resources in the vicinity of the gas plant will therefore include:

- Loss of animals and plants within the area of clearing;
- Changes in ecology of surrounding area caused by clearing;
- Ecological impacts of construction and nearby road use;
- Ecological impacts of operation of the gas plant (e.g. caused light, noise, vehicle use etc.).

Plant and animal communities along the pipeline corridor, shore crossing and on the sea bed will be disturbed during the construction phase. The extent to which this disturbance will impact on long term Aboriginal resource use will depend on the care taken during construction, success of rehabilitation after construction and control of weeds.

Traditional owners made the following observations concerning the potential impact of the Blacktip proposal on their country and resources:

- Habitats and species to be permanently removed along the access road corridor and at the gas plant site are well represented elsewhere within Yak Maninh and Yak Dimininh clan estates.
- Although some loss of resources will occur as a result of road and gas plant construction, the scale of the impact is not expected to significantly

reduce access to plant and animal resources that are available elsewhere in their clan estates.

- Country damaged during the laying of the undersea pipeline, shore crossing and pipeline corridor to the gas plant should recover in a relatively short period, with no long term loss of resources expected in these areas.
- Construction of the undersea pipeline, shore crossing and pipeline corridor to the gas plant must avoid mangroves and jungle patches, which are culturally very significant and which make up only a small proportion of clan estates.
- Every effort must be made to avoid disturbing nesting turtles during the construction of the undersea pipeline and shore crossing.
- All country has value to traditional owners, over and above the value of particular species or environments on country.

3.2.2 Status of cultural knowledge and practices

Traditional Owners stressed the importance of maintaining environmental cultural values within their clan groups and within the broader Wadeye society. Knowledge of plant and animal language names, uses and other cultural attributes are currently widely held by people in Wadeye community, and this information is passed on to younger generations through family outings, time spent on outstations, hunting, gathering and fishing trips etc, as well as through formal programs at the local school.

Nevertheless, Traditional Owners are aware that social changes in the Wadeye region over the last couple of generations, and particularly more recently, are impacting on the extent to which cultural knowledge and practices are passed on and will continue into the future. These social changes include:

- Trends to more sedentary lifestyles;
- Increasing formal education opportunities;
- Access to TV and internet;
- Availability of processed foods;
- Access to manufactured medicines;
- The transition of their local economy from a total reliance on local resources to a mixed subsistence/welfare/employment economy.

Some of these social changes are also contributing positively to the maintenance of cultural values, for example through cultural lessons at school, the use of computers and other technology to record and access cultural information, and access to transport and other resources to establish outstations on country.

The Blacktip proposal is part of this pattern of social change and therefore has the potential to impact both negatively and positively on environmental and other cultural values in the region. Education, training and employment

associated with the construction and operation of the gas plant and pipeline, while bringing economic benefits to individuals and the community, may further contribute to weakening the traditional link between Traditional Owners and the environmental resources of their clan estates. Conversely, initiatives associated with the Blacktip proposal that support the relationship between Traditional Owners and their country have the potential to contribute to the maintenance of environmental cultural values held by Aboriginal people of the Wadeye region.

3.3 Current initiatives to support environmental cultural values

In addition to the cultural education provided within family and clan groups, there are two significant initiatives underway at Wadeye to support the management of country and the maintenance of environmental cultural values. These are the Thamarrurr Rangers and the Wadeye Aboriginal Languages Centre.

3.3.1 Thamarrurr Rangers

The broad objectives of the Thamarrurr Rangers, as outlined in McIntyre (2003) are:

1. *Drawing together people from different land owning groups to work together to look after Country;*

2. *Facilitating the traditional passing down of knowledge and stories from elders to the young; and*

3. *By making sure the country is in good condition, providing land management conservation and development opportunities for future generations*

Current and planned activities of the Thamarrurr Rangers, outlined in their *Land and Sea Management Plan* (Thamarrurr Rangers 2003), include:

- Weed control
- Feral animal control
- Exotic disease monitoring
- Revegetation and erosion control
- Waste recycling
- Monitoring turtle nesting
- Fire management
- Family-based planning for managing country;
- Enterprise development based on natural resources (e.g. aquaculture)
- Development of a system for managing land access
- Cooperation with the Wadeye Aboriginal Language Centre in collecting and documenting traditional knowledge of country.

Thamarrurr Rangers have received some funds from the NT Government to supplement Thamarrurr Regional Council and Commonwealth Community

Development Employment Project funding, but they are currently severely under-funded to carry out their existing and proposed environmental and associated cultural activities. They are actively seeking project based funding as well as more strategic recurrent funding to enable the Ranger program to further develop their capacity to meet the needs of Traditional Owners to look after country and culture.

3.3.2 Wadeye Aboriginal Languages Centre

The Wadeye Aboriginal Languages Centre (WALC) is co-located with the Kanamkek Yile-Ngala Museum in a building constructed by local Aboriginal people in the 1960s and formerly used as the community hospital. WALC aims to preserve local Aboriginal languages and document information relating to:

- Traditional knowledge of Country, including stories;
- Mapping of Country and place names;
- Bush foods, medicines and other uses of plants and animals;
- Educational materials for use in the local school;
- Oral histories.

Since October 2002 WALC has been collecting Aboriginal knowledge of plants and animals from the Wadeye region, as part of a collaborative project with the Merrepen Art Centre at Nauiyu, the Batchelor Institute of Indigenous Tertiary Education and the Department of Infrastructure, Planning and Environment, with initial funding from the Australian Institute of Aboriginal and Torres Strait Islander Studies. To date the project has accumulated a large amount of data and produced a draft document "*Marri Ngarr and Magati Ke Plants and Animals".* Subject to availability of further funding, WALC aims to publish a book and interactive computer data base containing comprehensive information about the ethnobiology of the Wadeye region, including names of plants and animals in all local languages, including Murrinh Patha (the language spoken by the Yak Maninh and Yak Dimininh clans), with colour photographs of each species.

The WALC coordinator expressed the view (Crocombe pers com, September 2004) that there is an urgent need to document detailed linguistic and associated cultural knowledge of older Aboriginal people in the region, so that this information will be available for future generations. WALC is seeking funding partners to enable it to complete the collection, processing of environmental cultural data and production of the ethnobiology publication and computer program. WALC is also in need of strategic funding to cover long term professional and administrative costs.

4 CONCLUSIONS

A summary of the key potential impacts and management measures for species with Indigenous conservation values are presented below.

- Species, habitats and biological communities with Indigenous conservation values exist in all environments potentially impacted by the Blacktip proposal.
- All country impacted by the Blacktip proposal has value to traditional owners over and above the value of particular species living within that country.
- Clearing of the gas plant site and road corridor will to some extent reduce the area available for hunting, gathering and other cultural resource use by traditional owners. The extent of this reduction will depend on several factors, including the size of the cleared area and the ecological impact in the surrounding are of the construction and operation of the plant and access road.
- Traditional owners reported that culturally significant resources at the gas plant site and along the road access corridor are also available in similar open woodland environments elsewhere in the clan estates.
- The areas of diverse habitat adjacent to the proposed shore crossing are particularly culturally significant, because of the diversity of resources they contain, and because these environments comprise a relatively small proportion of country within clan estates.
- Traditional knowledge, practices and other environmental cultural values are widely held by Yak Maninh and Yak Dimininh and other Aboriginal people in the Wadeye region.
- Ongoing social and economic changes in the Wadeye region, including the Blacktip proposal, have the potential to impact both negatively and positively on the status of environmental cultural values held by Aboriginal people.
- There are opportunities for Blacktip to contribute positively to the maintenance of environmental cultural values by supporting community initiatives already underway, including projects being undertaken by the Thamarrurr Rangers and the Wadeye Aboriginal Languages Centre.

These issues can be addressed by Woodside, in collaboration with traditional owners and appropriate organisations, through the development of strategies and actions to minimise and monitor the impact of the Blacktip proposal on species and environments of cultural significance, and to support Indigenous environmental values where possible. These strategies and actions could form part of the proposed Cultural Heritage Management Plan. Key strategies and actions could include:

- Collecting baseline data on Aboriginal resource use and other cultural values relating to environments potentially impacted by the Blacktip proposal;

- Devising methods to minimise the impacts on culturally significant species and environments during the construction and operational phases of the project;

- Monitoring the impact of construction and operation of Blacktip infrastructure on environments and species of cultural significance, including the impact on hunting resources in the surrounding region;

- Developing and/or supporting projects to strengthen environmental cultural values, knowledge and practices in collaboration with traditional owners, the Thamarrurr Rangers and the Wadeye Aboriginal Languages Centre.

REFERENCES

Blake, N.M., Wightman, G. and Williams, L. 1998. *Iwaidj Ethnobotany: Aboriginal plant knowledge from Gurig National Park, North Australia.* Centre for Indigenous Natural and Cultural Resource Management Occasional Paper No. 1; N.T. Botanical Bulletin No.23, Parks and Wildlife Commission of the N.T., Palmerston.

McIntyre, S. 2003. *Development of a formal natural resource management structure within the Thamarrurr Regional Council.* Project proposal to Thamarrurr Regional Council, Wadeye.

Nambatu, J., Nudjulu, P., Nama, J., Wawul, M., Jongmin, J., Munar, R., Chula, M., Kungul, B., Marrfurra, Kungul, A., Ford, L., Crocombe, M. and Wightman, G. 2004. Draft *Marri Ngarr and Magati Ke plants and animals – Aboriginal knowledge of flora and fauna from Wadeye and Kuy areas, north Australia.* AIATSIS, Wadeye Aboriginal Languages Centre, Merrepen Aboriginal Corporation, Batchelor Institute of Indigenous Tertiary Education, N.T. Department of Infrastructure, Planning and Environment.

Raymond, E., Blutja, J., Gin.gina, L., Raymond, M., Raymond, O., Raymond, L., Brown, J., Morgan, Q., Jackson, D., Smith, N. and Wightman, G. 1999. *Wardaman Ethnobiology.* Centre for Indigenous Natural and Cultural Resource Management Occasional Paper No. 2, Charles Darwin University; NT Botanical Bulletin No. 25, Parks and Wildlife Commission of the NT, Palmerston..

Smyth, D.M. 2002. *Indicating Culture – development of cultural indicators for the management of the Wet Tropics World Heritage Area.* Final Report to the Rainforest CRC Project 1.5, James Cook University, Cairns.

Thamarrurr Rangers 2003. *Thamarrurr Region Land and Sea Management Plan, Parts 1&2.* Thamarrurr Regional Council, Wadeye.

Ward, T. 1983. *The Peoples and Their Land Around Wadeye.* Wadeye Press, Port Keats.

Appendix M

Social Impact Assessment of the Proposed Blacktip Project, Wadeye, Northern Territory prepared by IMpaxSIA Consulting






This page has been left intentionally blank

IMPAXSIA

SPECIALISTS IN ECONOMIC, SOCIAL AND COMMUNITY IMPACT STUDIES

REPORT:
Social Impact Assessment
Blacktip Project, Wadeye, Northern Territory



Report prepared for
The Blacktip Joint Venture

Prepared by
ImpaxSIA Consulting
Brisbane, Queensland.

October 2004

Front cover painting from the Wadeye Community Homepage www.indiginet.com.au/wadeye.

Table of Contents

EXECUTIVE SUMMARY ..... **IV**

1 INTRODUCTION **1**

1.1 ROLE OF THE NORTHERN LAND COUNCIL 1
1.2 BLACKTIP PROJECT OVERVIEW 2
1.3 LAND TENURE AND MAPS 5
1.4 LEGISLATIVE FRAMEWORK 5
1.5 SIA BACKGROUND 6
1.6 METHODOLOGY 7
1.7 ACKNOWLEDGEMENTS 9

2 DESCRIPTION OF AFFECTED PEOPLE **10**

2.1 GOVERNANCE 10
2.2 DEMOGRAPHIC PROFILE 11
2.3 LANGUAGE 12
2.4 INCOME 13
2.5 HEALTH STATUS 14
2.6 EDUCATION 15
2.7 EMPLOYMENT 16
2.8 RECREATION AND CULTURE 17
2.9 ENVIRONMENTAL PROTECTION AND MANAGEMENT 18
2.10 TRANSPORT AND COMMUNICATIONS 19
2.11 ECONOMIC BASE AND ENTERPRISES 19
2.12 HOUSING, INFRASTRUCTURE AND FACILITIES 21
2.13 SOCIAL AND HEALTH SERVICES 22
2.14 LAW AND ORDER 22
2.15 OUTSTATION DEVELOPMENT 23

3 PREVIOUS EXTERNAL IMPACTS **24**

3.1 IMPACTS OF CONTACT TO DATE 24

4 ASPIRATIONS AND CONCERNS **26**

4.1 UNDERSTANDING OF THE PROJECT 26
4.2 ATTITUDES TO THE PROJECT 27
4.3 ASPIRATIONS 27
4.4 CONCERNS 27

5 POTENTIAL SOCIO-ECONOMIC IMPACTS OF THE BLACKTIP PROJECT **29**

5.1 INTRODUCTION 29
5.2 HERITAGE PROTECTION AND CULTURAL IMPACTS 29
5.3 ENGAGING WITH THE COMMUNITY 29
5.4 NEED FOR SAFEGUARD POLICIES 30
5.5 COMMUNITY INTERACTIONS WITH NON-INDIGENOUS WORKFORCES 30
5.6 SECURITY 32
5.7 FEMALE EMPLOYMENT 33
5.8 ACCESS OF WORKERS TO HUNTING AND FISHING AREAS 33
5.9 GRANTING OF FAVOURS 33
5.10 ALCOHOL 34
5.11 COMMUNICATION AND RELATIONSHIP-BUILDING 34
5.12 ECONOMIC IMPACTS 35
5.12.1 Diseconomies 35
5.12.2 Access to hunting and fishing 35

5.12.3 Employment, training and recruitment 35
5.12.4 Business development opportunities 36
5.12.5 Environmental management 39
5.13 FREE GAS AND/OR IMPROVED ENERGY INFRASTRUCTURE 39
5.14 COMPENSATION AND CONSIDERATION FOR LAND USE 41
5.15 POTENTIAL SOCIAL IMPACTS OF UPGRADES TO ROADS AND INCREASED TRAFFIC 42
5.16 COMMUNITY HEALTH AND SAFETY IMPACTS 42
5.17 CUMULATIVE IMPACTS 43
5.18 IMPACTS OF THE SIA PROCESS ITSELF 43

6 CAPACITY TO RESPOND TO CHANGE 44

7 MONITORING 45

8 CONCLUSION 47

9 APPENDICES 48

9.1 LIST OF PEOPLE INTERVIEWED 48
9.2 TERMS OF REFERENCE 50
9.3 REFERENCES AND BIBLIOGRAPHY 53

List of Figures

Figure 1: Map showing general location of the Blacktip Gas Field and Proposed Onshore Processing Plant.

Figure 2: Map showing proposed land tenure of Blacktip Project Area.

Figure 3: Population by Age – Wadeye (and Outstations) compared with Northern Territory Indigenous and Northern Territory Total Populations.

Figure 4: Comparison of Individual Weekly Incomes 15 years and Over, Wadeye and Total Northern Territory Population.

Figure 5: Comparison of Weekly Incomes Indigenous Persons at Wadeye and Indigenous Persons Northern Territory as a Whole.

Figure 6: Highest Levels of Schooling Wadeye (and Outstations) and Total Northern Territory Population as a Whole.

Figure 7: Map of settlement distribution in the Thamarrurr Region, 2003.

List of Tables

Table 1: Blacktip Project Proposed Schedule

Table 2: Internet usage at Wadeye

Executive summary

The proposed Blacktip Project involves bringing gas, and possibly condensate, onshore from the Blacktip field via a 120 kilometre export pipeline which would connect to an onshore gas infrastructure located close to the Aboriginal community, Wadeye, in the Thamarrurr Region, west of the Daly River. The Blacktip Project would connect with the proposed Trans Territory Pipeline (TTP), which would deliver the gas to the Alcan alumina refinery at Gove. The TTP, although integral to the proposed Blacktip Project, is also the subject of a social impact assessment undertaken by ImpaxSIA Consulting, the findings of which are contained in a separate report.

Wadeye is the largest Aboriginal community in the Northern Territory, with more than 2,000 residents. This is the first major project west of the Daly River and is generally welcomed by many Traditional Owners and Aboriginal community members as holding the promise of assisting to establish an economic base for the region. At present the region is heavily reliant on state transfers. Description of the existing services, infrastructure and facilities at Wadeye reveal serious under-funding and inadequacy.

Information and communication

Consultations in relation to the potential social impacts of the Blacktip Project were limited in part because representatives of service organisations and residents feel that they do not have enough specific information about the Project. Some Aboriginal people in the affected community were not even aware that a Project is being proposed.

Aspirations

In the absence of any other source of employment, many people expressed high hopes for contracting, employment and training opportunities being derived from the Blacktip Project, if it is approved.

Local indigenous service and enterprise organisations demonstrated interest in, and capacity to, provide environmental services, translation and liaison services, catering services to the construction camp, cultural sensitivity and awareness training to workers and supervisors, transport services, air flights and charters, and cultural tourism services to workers. They are also keen to supply bread and meat to the construction camp and sell take away foods, art and artifacts and alcohol to workers, and sand and gravel to the

Project. Representatives from these local organisations expressed frustration regarding the lack of detail about the specific opportunities.

There is also a widespread belief that the Project will lead to the provision of natural gas for the generation of the community and regional power needs. Some individuals expressed the hope that they would receive free gas to fill up their gas bottles. Our consultations with the Northern Territory Power and Water Corporation indicate that these hopes are misplaced.

A number of Traditional Owners expressed the aspiration that royalty monies (their words) would provide income to purchase vehicles, to build up homelands and, through investment, provide ongoing income streams. Some hopes were expressed that the Project would lead to improved infrastructure and that housing and infrastructure would be left behind that could be used by community members.

Overall, our view is that expectations are high, possibly too high, and there may be a need to improve the management of expectations in relation to the opportunities that the Project might genuinely provide. There is concern that realisation of the benefits that the Project might deliver will require greater lead times than are currently being allowed for, if it is intended that the commencement date currently being proposed of the dry of 2005 is to be met.

Concerns

Issues raised by informants included concerns about negative impacts on the environment and whether the Proponent had the ability to prevent or repair these; damage to roads and road safety issues; vandalism and theft of company property and fuel by local Aboriginal people, particularly youths; the impacts of a non-local workforce on community relations, particularly in regard to workers liaising with local women and unauthorised accessing of country; two way trafficking of drugs and alcohol between construction workers and local community members; fighting and increased domestic violence associated with distribution of cash from compensation; that compensation payments to Traditional Owners directly affected by the Project would result in “the haves and the have-nots” in the community; and concerns about gas explosions, among others.

In our view the Wadeye community, because of its isolation and inexperience of major infrastructure projects such as the proposed Blacktip Project, is highly vulnerable to potential negative impacts. Accordingly, the adoption of a strict Safeguard Policy regime will be vital. Harm prevention is considered to be essential since management of issues after the fact will likely not be possible.

Part of preventing negative social impacts could be the adoption of strategies which insulate the community and isolate the construction workforce. Maximising female employment in the construction workforce could contribute significantly to minimising potential negative impacts.

It is likely that the Proponent will find that engaging with the community is difficult because of language barriers and because traditional authority structures are still strong and their logic not always transparent to outsiders. Therefore, it will be critical that local organisations, (such as the Thamarrurr Regional Council, Police and the Language Centre), as well as senior Traditional Owners and others, are involved in planning various facets of the Project, including Traffic Management Plans, Communication Strategies, Insulation and Isolation Strategies, Alcohol Policies, Cross-Cultural training for supervisors, and other interventions and strategies intended to minimise negative impacts and maximise opportunities that might be associated with the Project.

A major research study is currently being undertaken at Wadeye by the Centre for Aboriginal Economic Policy Research, ANU, Canberra, to monitor the socio-economic impacts of the Indigenous Communities Coordination Pilots. Monitoring and evaluation of the planning and implementation of the Blacktip Project would be best undertaken in collaboration with local stakeholder representatives.

Consideration should be given to developing strategies in relation to the following:

- further communications with the Wadeye community about the Project generally,

- communicating information about training, employment and business development opportunities,

- the development and implementation of training and employment programs for Indigenous people in Wadeye,

- safeguarding members of the Wadeye community from potential negative social impacts relating to the presence of a large construction camp,

- maximisation of female recruitment into the construction workforce,

- reduction of theft and vandalism of company property and the adoption of culturally appropriate responses by the Proponent's security staff,

- sustainable and appropriate responses to informal requests to the construction camp for favours or assistance by local community members,

- the development of positive community relations between the construction camp and the local community,

- a Traffic Management Plan to reduce road accidents and hazards,

- control of alcohol and drugs at construction camps,

- maximisation of contracting opportunities to benefit local communities, including supply of consumables such as alcohol, bread and meat to construction camps,

- communication of accurate information about the future availability of regional gas supply (other than to Alcan),

- support to Traditional Owners and communities to manage any monetary benefits arising from the Project,

- support to local Rangers to engage in environmental monitoring and management activities associated with construction and operation of the roads, sea impacts and gas processing plant, and

- engagement with relevant local and regional stakeholder organisations (e.g., Thamarrurr Regional Council, senior Traditional Owners, Northern Territory Police, Kardu Dari Kardu Family Centre, Wadeye Language Centre, Thamarrurr Rangers and the Northern Land Council), in the design, planning, implementation and monitoring of the above strategies.

Abbreviations

AQIS	Australian Quarantine and Inspection Service
BRACS	Broadcasting for Remote Aboriginal Communities
CDEP	Community Development Employment Projects Scheme
CFCU	NLC's Caring for Country Unit
ICCP	Indigenous Communities Coordination Pilots
IHANT	indigenous Housing Authority of the Northern Territory
NLC	Northern Land Council
NT	Northern Territory
NTG	Northern Territory Government
PAWC	Power and Water Corporation
SIA	Social Impact Assessment
STIs	Sexually Transmitted Infections
TTP	Trans Territory Pipeline
TCA	Territory Construction Association
WALC	Wadeye Aboriginal Language Centre

1 Introduction

Woodside Energy Ltd, in partnership with ENI Australia, proposes to develop the Blacktip Gas Field located in the Joseph Bonaparte Gulf. The Blacktip development involves bringing gas, and possibly condensate, onshore from the Blacktip field via a 120km export pipeline which would connect to onshore gas infrastructure located close to Wadeye, (formerly known as Port Keats), which lies within the Thamarrurr Aboriginal region (Woodside 2004).

Wadeye is the largest Aboriginal community in the Northern Territory and is situated on the western edge of the Daly River Reserve in the Northern Territory. It is approximately 50 minutes flying time from the capital of the Northern Territory, Darwin, and is not accessible by road for five months of the year, December to May, during the wet season. It is accessible by sea and operates a weekly barge.

Should the Aboriginal Traditional Owners give their consent to the Project, (and subject also to the Proponent's commercial decision to proceed), this will be the first major development in the region. It would be expected that roads would be upgraded as part of the Project, which may also result in a range of impacts in their own right. The Social Impact Assessment (SIA) aims to assess if and how the Wadeye community and wider Thamarrurr Region might be impacted, and how to maximize the potential opportunities offered by the Project and minimise or mitigate any potential negative impacts.

This Report represents the findings of a consultation program conducted at Wadeye with Traditional Owner groups and the wider Aboriginal community likely to be affected. The preparation of the SIA has been undertaken in order to enable the Proponent to meet its requirements to assess and manage social impacts associated with the Project and to provide information to the statutory regulators responsible for undertaking the Project's approvals processes. It is also expected that the findings of the SIA would feed into the Agreement-making process with the Northern Land Council (NLC) on behalf of Traditional Owners.

The proposed Blacktip Project is also linked to the proposed Trans Territory Pipeline Project (the TTP) which would export the gas from Blacktip to Alcan mining facilities at Gove. The TTP and the expansion at Alcan's operations at Gove are subject to separate approval processes. ImpaxSIA Consulting was engaged to conduct the Social Impact Assessment for both the Blacktip and TTP Projects. This Report addresses the potential social impacts associated with the proposed Blacktip gas processing plant. The potential social impacts associated with the proposed TTP are the subject of a separate report, prepared also by the authors of this Report.

The Report has been prepared for Woodside Energy Ltd Petroleum and the Northern Land Council (NLC), with the assistance of Woodside in the provision of information materials used in the consults, and assistance from the NLC in the organisation and conduct of fieldwork.

1.1 Role of the Northern Land Council

The Northern Land Council (the NLC) provided the Consultants with detailed information on the identity and location of traditional Aboriginal Owners, and Native Title claimants

and Indigenous people with strong historical associations who have affiliations with the affected country. The NLC also provided the Consultants with maps of the Project area that identified the location of communities and groups of people associated with the Project area. The maps and identity of titleholders remain confidential and are not included in this Report. The NLC was also responsible for arranging interpreter services as required, and provided competent field officers who took responsibility for logistics and for assisting in setting up interviews with Councils, organisations and individuals. Those field officers, who had ties to the affected country themselves, also attended some consultations.

1.2 Blacktip Project overview[1]

The Blacktip gas development comprises the Blacktip gas reserves located in the Joseph Bonaparte Gulf, approximately 245km south-west of Darwin and is operated by Woodside Energy Ltd on behalf of the Blacktip Joint Venture Partner, Eni Australia Ltd.

The Blacktip reserves were found in 2001 and in June 2003, Alcan Gove Pty Limited and the Blacktip Joint Venture signed a Heads of Agreement to supply Alcan's alumina refinery and bauxite mine at Gove, 40 petajoules of natural gas over a 20 year period from 2007.

Once onshore, and after treatment at the proposed gas processing plant to be constructed near Wadeye, the gas will be piped to Gove (Nhulunbuy) in the Northern Territory (NT) for power generation at Alcan's alumina processing plant. A subsea condensate export pipeline to a swamp mooring, approximately 3-4 kilometres from Yelcherr Beach will also be included alongside the gas export pipeline to export condensate to markets located east of Wadeye. The gas pipeline may also supply other potential customers that have yet to be identified.

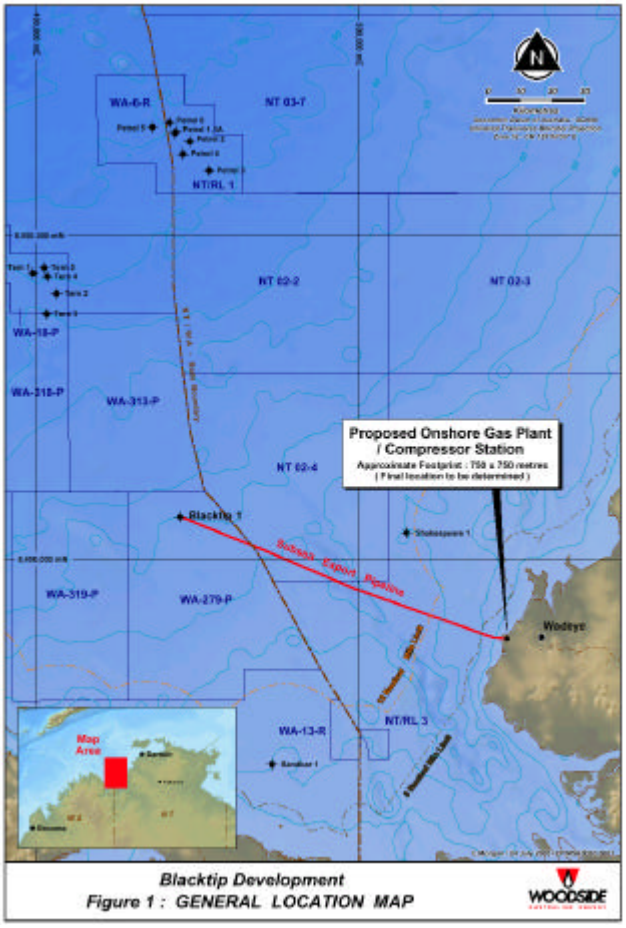
The development of the Blacktip Field is intrinsically linked to the proposed gasification plans for Alcan's Aluminum plant at Gove. This development will also provide an alternative gas supply to other potential gas customers in the Northern Territory (Woodside 2004).

The location of the notional development area is presented in Figure 1, overleaf.

The anticipated capital expenditure for the Blacktip Gas Project is approximately $450 million over the peak construction period of 2004 to 2006. Expenditure over the 30 year life of the Project will potentially be significantly more than this (ACIL 6:2004).

[1] *Note that the information contained in this section (and in the ACIL report) rely on Proponent information provided in December 2003, however, since that time, the development concept for Blacktip has evolved and some details may have changed.*

Figure 1: Map showing general location of the Blacktip gas field and proposed onshore processing plant.



The key project milestones, as set out in the Notice of Intent, are as follows:

Table 1: Blacktip Project Proposed Schedule

Concept Selection Dec 2003
Start Basis of Design Jan 2004
Final Investment Decision Oct 2004
Offshore Well Head Platform Installation & well construction commences 2006
Offshore pipeline installation commences 2006
Onshore plant construction commences 2005
Onshore pipeline installation commences 2006
First gas 2007

The activities associated with the facilities include:

- Construction of an onshore workers' camp
- Construction of maintenance and operational accommodation
- Installation and hook-up of the WHP
- Construction of wells, pipelines/flowlines
- Construction of onshore facilities including access and haul routes
- Construction of onshore pipeline and associated systems
- Commissioning and testing of installed facilities
- Production operations
- Decommissioning of facilities at the end of field life (NOI 2003)

The Blacktip project will generate around 430 direct full-time and part-time

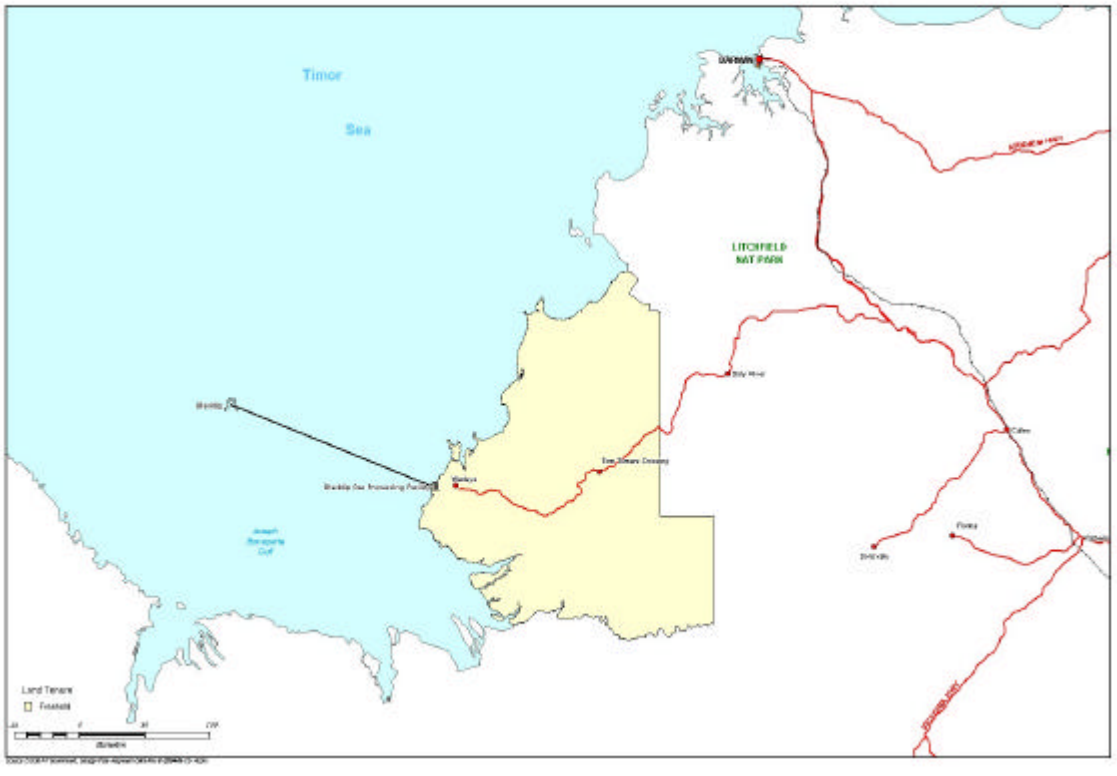
jobs during the initial construction period of 2004 to 2006. Approximately 158 of these workers will be located on-site and the remainder will be Perth-based project staff. It is expected that 75 per cent of the on-site jobs will be sourced from the Northern Territory and the remainder from the rest of Australia. During operation, it is anticipated that the Blacktip Project will employ up to 19 workers a year on a fly in–fly out basis from Northern Territory locations (ACIL 7:2004).

1.3 Land tenure and maps

The underlying existing land tenure of the site of the proposed Blacktip Project is inalienable Aboriginal freehold (Commonwealth), vested in the Daly River/Port Keats Aboriginal Land Trust.

There are also granted exploration licences (diamonds) in the Land Trust area (held by Rio Tinto Exploration) and a pending application for an onshore petroleum exploration permit. Onshore petroleum exploration has occurred in the area historically.

Figure 2: Map showing land tenure of the Proposed Blacktip Project Area



1.4 Legislative framework

The signing of a Heads of Agreement (HOA) between the Blacktip Joint Venture and Alcan has enabled development plans to be put in place for Permit WA-279-P in the Joseph Bonaparte Gulf. The eventual development of this field will act as catalyst for

other potential hydrocarbon developments in the Joseph Bonaparte Gulf which would utilise the Blacktip infrastructure and which may potentially provide long term gas supplies to the Northern Territory (Notice of Intent 2003).

The proposed development will be undertaken in accordance with a range of Territory, State and Commonwealth legislation pertaining to planning, environmental management and Aboriginal Affairs. The primary State, Territory and Commonwealth legislations governing project approvals are:

- Environmental Protection and Biodiversity Conservation Act 1999.
- Northern Environmental Assessment Act 1994 (Northern Territory).
- Petroleum Submerged Lands Act 1967.
- Petroleum Submerged Lands (Management of Environment) Regulations 1999.
- Aboriginal Land Rights (Northern Territory) Act 1976 - negotiation pursuant to s19 (4A). - (ALRA).
- Native Title Act (Commonwealth) 1993 - compulsory acquisition of, consultations about, or negotiation over impacts on native title rights.
- Lands Acquisition Act (NT) - access for surveys and compulsory acquisition of all privately held interests in land - (LAANT).
- Energy Pipelines Act (NT) - access for surveys and pipeline license - (EPA).
- Sacred Sites Act (NT) 1978 - Authority Certificate to ensure indemnity against inadvertent disturbance of sacred sites - (SSA).
- Heritage Conservation Act (NT) - Ministerial permission to disturb sites of Aboriginal, Macassan or European heritage - (HCA). (Woodside 2004).

1.5 SIA background

ImpaxSIA Consulting was approached by Woodside Energy Limited, with the support of the NLC, to undertake a Social Impact Assessment of the Trans Territory Pipeline and Blacktip Projects in order to assist it to meet its corporate requirements in addition to obligations under the Northern Territory's Environmental Assessment Act 1994 Environmental Protection and Biodiversity Conservation Act 1999 (Cwlth). It is highly unusual for an SIA Consultant to be contracted directly to the Proponent when the SIA involves an Aboriginal community within the jurisdiction of a land council. ImpaxSIA agreed to the arrangement with the proviso that the NLC supported it.

A separate Social Impact Assessment has been undertaken by ImpaxSIA in relation to the Trans Territory Pipeline.

It should be noted that a Social Impact Assessment, conducted by Environmental and Engineering Consultants URS Australia, has been undertaken to assess the potential social impacts of the expansion of Alcan's alumina plant at Gove. At the time of writing, the draft Alcan Expansion Social Impact Assessment was already in the public comment phase. Although the Principal of ImpaxSIA Consulting met with the SIA Consultants for the Alcan Expansion Project, the time frames were such that the latter's field work had finished prior to the commencement of ImpaxSIA's work commencing. Therefore, there was no opportunity to liaise in relation to the two impact assessments.

Blacktip Project SIA terms of reference
Draft terms of reference were prepared in consultation with the Proponent and with the Northern Land Council. Both organisations signed off on the terms of reference in February 2004. The purpose of the Blacktip Project Social Impact Assessment (SIA) is to:

- Identify the nature and magnitude of any potential social impacts, both positive and negative,
- Contribute to a better understanding of the Projects by those potentially affected and those with responsibilities toward potentially affected groups and individuals,
- Facilitate the expression of views, concerns and aspirations about the Projects by those potentially affected,
- Assist the Proponent and potentially affected people, communities and organisations, to plan activities associated with the Projects in such a way as to optimise the potential positive impacts and mitigate any potential adverse impacts on affected communities, and
- Provide the basis for compiling a Social Impact Management Plan for the Projects.

The full text of the terms of reference is provided in the Appendix.

1.6 Methodology

The SIA Team was comprised of Dr Annie Holden, economic anthropologist and team leader, anthropologist Justin Beal, and a social researcher with anthropological training, Gay English. Sensitivity to gender was reflected in the use of male and female consultants on the SIA Team. The NLC advised on the identity of affected Aboriginal people and provided field support in the form of field officers who assisted the SIA Team with setting up meetings, introductions and arranging translation services.

The Social Impact Assessment Team completed two one-week visits to the Wadeye community in the weeks commencing 29 March and 10 May, 2004. In addition interviews were conducted in Darwin with Wadeye Indigenous organisation employees, and other researchers who had conducted field work or spent time in Wadeye who could provide some contextual background or assist us with our project planning. Consultations in relation to the Blacktip Gas Project and the Trans Territory Pipeline (TTP) were conducted at Wadeye simultaneously. The results of the consultations in relation to the TTP are presented in a separate report.

The SIA Consultants were accompanied at all times in Wadeye by Aboriginal field officers from the NLC and, where possible, a local Aboriginal interpreter.

The methodology included:

- Conducting formal interviews and informal discussions with each of the five clan groups resident in Wadeye whose Country is directly affected by the proposed Blacktip and TTP Projects. The team ensured that senior representatives from each of the clan groups were present at each meeting. In total 55 people Traditional Owners attended SIA consultations.

- House to house visits were conducted primarily to disseminate information to Aboriginal community members about the proposed Blacktip and TTP projects.

- Conducting interviews with Aboriginal staff and senior representatives and/or employees of the following local service and enterprise organisations:

    - Thamarrurr Regional Council
    - Thamarrurr Rangers
    - Thamarrurr Housing Authority
    - Mi Patha Takeaway/Bakery
    - Murrinhpatha Nimmipa Store
    - Palumpa Station/Butcher
    - Murin Association (Murin Air & Murin Outstation Resource Centre)
    - Northern Territory Health, Wadeye Health Clinic
    - Northern Territory Police, Wadeye
    - Northern Territory Correctional Services, Wadeye
    - Our Lady of Sacred Heart School, Wadeye
    - Kanamkek-Yile-Ngala Museum
    - Wadeye Aboriginal Language Centre
    - Library/Knowledge Centre
    - Kardu Dari Kardu Family Centre
    - Dirrmu Ngakumarl Art Gallery
    - Top End Women's Legal Service
    - Northern Territory Power and Water Corporation

A number of recent and current studies and reports provided to the SIA Team contain comprehensive and current descriptive information and socio-economic data for the region. The SIA Team, therefore, did not duplicate this research, but instead has relied on secondary sources for the compilation of historical and base line data for this Report. The SIA team focused its research on qualitative consultations with Traditional Owners and other affected Aboriginal people, and service and enterprise organisation employees resident at Wadeye.

The SIA consultations and feedback from respondents were limited by the following circumstances:

- Traditional Owners and Aboriginal community members have no previous experience of, and therefore no point of reference for, a major infrastructure project.

- During the second visit to Wadeye, a follow up consultation was not held, as planned, with a group of senior women who were unavailable due to their cultural and ceremonial commitments for the preparation of a senior woman's funeral.

- People who are not members of Thamarrurr Council or part of the Traditional Owner groups, with few exceptions, told us that they had received no previous information about the Project. Some told us that they were not even aware that a project was being proposed.

- Traditional Owners and community members do not appear to be accustomed to being consulted and engaging in abstract debate.

- Traditional Owners of affected estate groups stated that they did not really want to discuss possible impacts of the proposed Blacktip and TTP Projects until they have been presented with a financial offer by the Proponent and have had time to assess their position and make a decision, and until they have had more information about what other Traditional Owners along the proposed pipeline route are thinking.

- It appeared that some Traditional Owners felt that if they were to enter into discussion about the possible impacts of the Projects, were they to proceed, that this might be construed as agreement in principle to the Projects. Thus some were reluctant to discuss the Projects at all until Traditional Owners had made their decision.

- Aboriginal community members were reluctant to engage in discussions about the proposed Projects unless they were members of directly affected estate groups.

- A number of people told us that the issues were too complex to discuss and needed a lot of thought and consideration before they could provide comment.

- There were a limited number of local interpreters available to support the SIA team.

1.7 Acknowledgements

The SIA Team would like to thank the Northern Land Council field officers and NLC pipeline consultants for their assistance in planning, coordinating and conducting interviews for the SIA, including Patrick Briston, Keith Taylor, John Daly, William Parmbuk, Josephine Hart, Daniel Maher, Terry Piper, Bobby Munurrung Wunumgmurra, Victor Sandy, David Ross and Lyndsay Goodwin. The NLC anthropologists, Robert Graham, Anna Nolan and John Cook also provided invaluable assistance. We would also like to thank Nicole Turner, Emma White, Emily Beresford-Cane, Des Stones and James Kernaghan from Woodside Energy Ltd.

2 Description of affected people

The social region likely to be affected by the Blacktip Project is the Thamarrurr Region, which is governed by the recently established Thamarrurr Regional Council. The Thamarrurr Community Government area covers 3,450 square kilometers and reaches from New Moon Inlet in the south to just south of Cape Scott in the north. The western border is the coastline, including Docherty Island, and Nemarluk to the east, excluding Palumpa which is a community government area in its own right (DCDSCA 2003).

The Thamarrurr Region consists of 20 land-owning groups. The township of Wadeye is located on Yek[2] Diminhin land. The proposed gas processing plant is expected to be located on Yek Maning land. Yek Diminhin land is potentially affected by the proposed construction of a new access road from the Wadeye airstrip to the Gas processing plant.

Wadeye is the main community in the Thamarrurr Region with a total resident population of 2,147 (Taylor 14:2003). People in the Thamarrurr Region have socio-cultural links that extend in the north to Belyuen, Darwin and the Tiwi Islands, east to Palumpa, Peppimenarti and Daly River, and south to Timber Creek, Kununurra and Wyndham. There is considerable short-term population movement occurring within the Thamarrurr Region between Wadeye and surrounding outstations. There are 20 clan-based outstations, where 260 people live permanently or seasonally (DCDSCA 2003). In addition there is an estimated 226 persons who are not considered to be usual residents but who use Thamarrurr services, notably housing, and a further 113 non-Aboriginal residents (Taylor 15:2003).

2.1 Governance

The Thamarrurr Regional Council was approved by the Northern Territory Government as a Local Community Government Area on 19 March 2003. The 20 clan groups are represented and all pre-existing organisations, such as the Kardu Numida Council, now come under its authority. Thamarrurr Regional Council has over 200 employees, including CDEP, and an annual budget of $11 million.

The Thamarrurr Regional Council structure is unique in the Northern Territory, (and therefore Australia), in that it is based on a traditional form of governance and cooperation. The structure is the outcome of seven years of community discussions and planning. It has a constitution which blends customary decision-making and governance with the principles that guide the western democratic system.

Thamarrurr is currently involved in the Indigenous Communities Coordination Pilots (ICCP), which is a component of the Council of Australian Governments (COAG) Reconciliation Framework. There is one pilot in each State or Territory, and Wadeye is the Northern Territory's nominated community. The ICCP Project is consistent with the NT Government's partnership approach and will trial more effective ways of service delivery by establishing improved coordination across and between levels of government. A Sharing Responsibility Agreement was signed in March 2003 by the Thamarrurr Council and the NT and Commonwealth governments, formalising the partnership arrangements. Wadeye action groups made up of government and

[2] Sometimes written as "Yak".

community members have been established to address three key priority areas as identified by the Wadeye community. These are

- youth,
- women and family, and
- housing and construction (www.nt.gov.au/dcm/Indigenous_policy/Indigenous_policy).

In addition, men have recently been identified as a fourth priority (pers comm. Ivory 2004).

The importance of the establishment of the Thamarrurr Regional Government is considered to be pivotal to the re-vitalisation of the region:

> "For the Aboriginal people of Wadeye, the past sixty years has seen a growing dislocation between the old and the young, between family groups and landowning groups, between a traditional lifestyle shaped by contemporary technological advances, between an economic system grounded within mutual familial obligations and one commensurate with a common rate of exchange, between traditional political structures that are hereditary and autocratic in nature and contemporary political structures that are, in principle , democratic and egalitarian. This dislocation has resulted in the Aboriginal people growing less responsible for their lives as they are no longer able to express valid cultural, political, economic and spiritual relationships to family and to land … Addressing this imbalance is paramount to achieving social harmony and justice. The re-emergence of Thamarrurr is the vehicle through which such a balance can be achieved" (Thamarrurr 7:2000)

2.2 Demographic profile

As part of the ICCP Project, a major demographic study has recently been undertaken by the Centre for Aboriginal Economic Policy Research, ANU, Canberra, (Taylor 2003), in order to provide baseline data by which to monitor the outcomes of the ICCP Project. Rather than duplicate that research, our Report makes reference to this study and its findings.

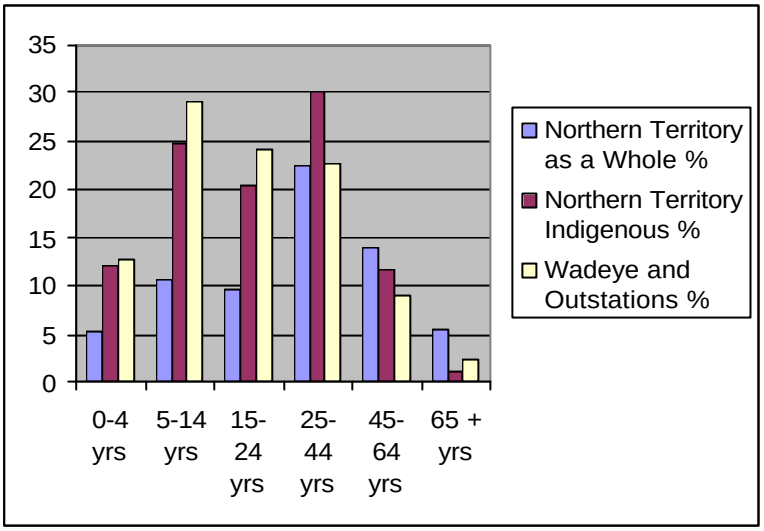
In addition, we have used Australian Bureau of Statistics data to explore some socio-economic indexes not considered in the CAPER Study, which are not relevant to the ICCP Project but which are relevant for our study, namely comparative data in order to establish socio-economic and health status as compared with other Aboriginal communities and the Northern Territory as a whole.

Even by Aboriginal standards, the Wadeye population is comparatively young, Figure 3 below demonstrating proportionally more persons in the 0-4, 5-14 and15 -24 year age groups at Wadeye and outstations, compared to the Indigenous population across the Northern Territory[3].

[3] The ABS data sources used here are not completely accurate, as discussed by Taylor 2003. However, for the current purposes of broad comparison with other, larger populations they suffice.

In contrast to the Northern Territory as a whole, where the most populous age group is the 25-44 year age group, at Wadeye, the most populous age group in the charts below is the 5-14 year age group.

Figure 3: Population by Age – Wadeye (and Outstations) compared with Northern Territory Indigenous and Northern Territory Total Populations.



Source: ABS 2001 Census Community Profile Series, Indigenous Profile Wadeye and Outstations. Cat No 2002.0, Indigenous Profile Northern Territory Cat No 2002.0 and Northern Territory Cat No 2001.0

Taylor has calculated a death rate of 24 deaths per thousand which he writes is 18% higher than the equivalent rate of 20 deaths per thousand calculated for Aboriginal people in the Northern Territory as a whole (58:2003). The Figure above demonstrates a higher percentage of people in the 65+ age group at Wadeye and outstations than for the Indigenous people in the Northern Territory as a whole, suggesting that mortality rates in the younger age groups is even higher again, although the small sample size does require that some caution be applied in the interpretation of results.

Taylor's analysis of age profiles notes that "relatively large numbers of women in the child-bearing ages, and even larger cohorts beneath them, indicates high potential for future growth in numbers, even if the actual fertility rate were to decline" (17:2003). His projections provide for an expected population in the order of 4,045 by the year 2023.

2.3 Language

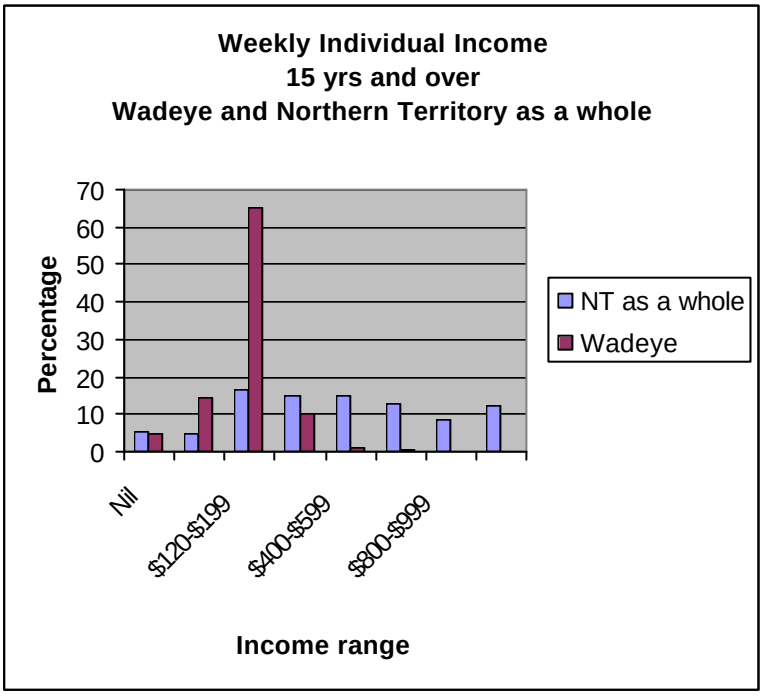
There are seven different languages spoken by the different clans in the Thamarrurr Region: Kardu Diminin people speak Murrinh-Patha, Kardu Piru Panguy speak Murrinh-Nuwanh, Kardu Yek Naninh speak Marti-Ke, Kardu Yek Thinti speak Amor, Kardu Darrinpirr speak Marringarr, Kardu Papa Ngala speak Murrinh Kura, and Kardu Thang Kural people speak Marri Jabin. Most people are fluent in Murrinh-Patha and use this language to communicate with each other at Wadeye; however, most people speak their own language in their homes (www.indiginet.com.au/wadeye).

Few people in the Thamarrurr Region are fluent in English. ABS data tend to over-state English language proficiency since some Aboriginal people tend to over-estimate their own English language proficiency. ABS 2001 Census data (Cat No 2002.0) report that 474 of 1,295 people who answered the question on proficiency in spoken English stated that they speak English very well or well, 528 not well, and 227 not at all.

2.4 Income

As Figure 4 below demonstrates, at Wadeye the individual weekly income of persons 15 years and over, balloons at the $199 income barrier. In contrast, income levels in the Northern Territory are relatively even across the income range sets. This reflects the absence of employment opportunities in the Thamarrurr Region, other than CDEP, and demonstrates the relative poverty of Aboriginal people in the region.

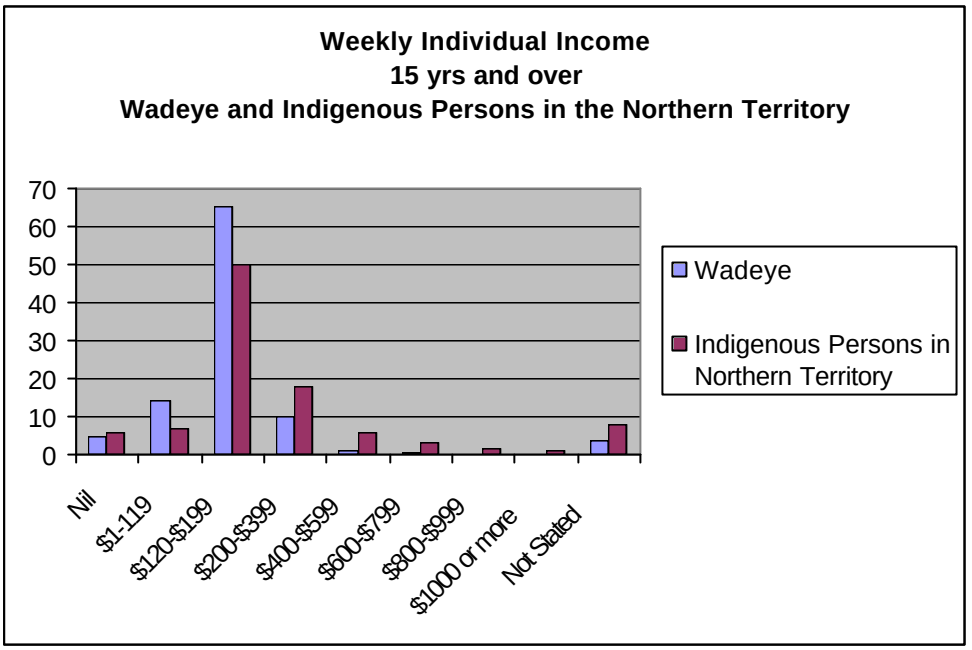
Figure 4: Comparison of Individual Weekly Incomes 15 years and Over, Wadeye and Total Northern Territory Population



Source: ABS 2001 Census Community Profile Series, Indigenous Profile Wadeye and Outstations. Cat No 2002.0 and Northern Territory Cat No 2001.0

As Figure 5 overleaf demonstrates, even by Indigenous standards, Aboriginal people at Wadeye are comparatively poor. The almost exclusive reliance on CDEP for employment means that few individuals are able to move beyond the $399 income barrier.

Figure 5: Comparison of Weekly Incomes Indigenous Persons at Wadeye and Indigenous Persons Northern Territory as a Whole.



Source: ABS 2001 Census Community Profile Series, Indigenous Profile Wadeye and Outstations. Cat No 2002.0, Indigenous Profile Northern Territory Cat No 2002.0 and Northern Territory Cat No 2001.0

Taylor calculates that the total gross annual personal income accruing to adult residents of the Thamarrurr Region in 2001 amounted to $10 million but that only two-thirds of this ($6.6 million) went to Aboriginal residents despite the fact that they accounted for 92% of the adult population. He also notes that only 16% of the total regional income of $4 million generated by mainstream employment was earned by Aboriginal people.

Taylor (39:2003) reports that there are no data on expenditure patterns at Wadeye, but that a common pattern reported from similar communities is one of cash feast and famine against a background of high costs for essentials such as food and transport, which accords with our own anecdotal evidence gathered during consultations at Wadeye.

2.5 Health status

People in Wadeye suffer from the usual diseases of Aboriginal people in Australia – circulatory system, respiratory diseases, endocrine disorders (especially diabetes), neoplasms and external causes (Taylor 58:2003).

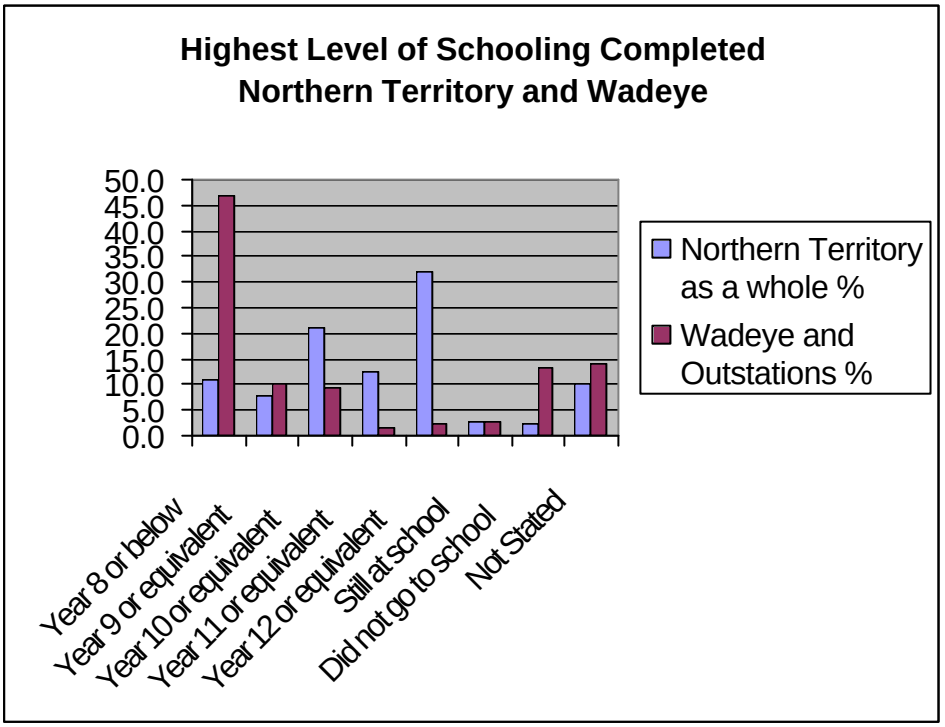
A growth assessment of children aged less than five years undertaken by Wadeye Clinic in 2002 showed an estimated 20% of children stunted in growth, 21% underweight and 10% wasted (Taylor 66:2003).

The community has been unsuccessful in procuring the services of a long-term doctor. Dog control and Environmental Health Services are not funded and morgue, cemetery and funeral expenses are not funded.

2.6 Education

Aboriginal people in Wadeye have a comparatively low level of schooling, with over 50% of persons 15 years and over not completing basic secondary education. While this may in part reflect a view by Aboriginal people at Wadeye that formal schooling has little relevance to them, it is also the case that Wadeye does not have a secondary school. As Taylor writes, "given the current size of the school age population (626) and its expected growth over the next 20 years to 1,140 … this lack of full secondary education facilities at Wadeye is difficult to explain when set against other Northern Territory towns with similar school age numbers" (43:2003).

Figure 6: Highest Levels of Schooling Wadeye (and Outstations) and Total Northern Territory Population as a Whole.



Source: ABS 2001 Census Community Profile Series, Indigenous Profile Wadeye and Outstations. Cat No 2002.0 and Northern Territory Cat No 2001.0

School attendance is very poor, with an estimated 82% of enrolled students being absent for cumulative periods amounting to more than 50 days in the year. The recent construction of a swimming pool and adoption of a "no school, no pool" rule, appears to have an initial impact of improving attendance. Taylor notes that boys are least likely to be enrolled at school and even less likely to attend classes, with this gap widening with age (Taylor 44:2003).

An anticipated benefit of the TTP Project, if it proceeds, is the potential for fibre optic cable to be laid in the pipeline corridor which, it is assumed by community members and administrators, will lead to improved access to the Internet and better telecommunications in the community. In 2001, the Census recorded 12.4% of non-Indigenous residents, and no Indigenous residents accessing the Internet in their homes. Seven percent of non-Indigenous residents stated that they used the Internet at work, in contrast to 0.8% of Indigenous residents. Three percent of Indigenous residents indicated that they accessed the Internet elsewhere (most likely the school or library). Overall 83.6 percent of Indigenous residents and 70.8 of non-Indigenous residents did not access the Internet. At Wadeye twice as many males (n=32) as females (n=16) used the Internet.

Table 2: Internet usage at Wadeye

	Indigenous %	Non-Indigenous %
Used the Internet at home	0	12.4
Used the Internet at work	0.8	6.7
Used the Internet elsewhere	2.7	6.7
Used the Internet at work and at home	0	3.4
Did not use the Internet	83.6	70.8
Not stated	12.9	0

Source: ABS 2001 Census Community Profile Series, Indigenous Profile Wadeye and Outstations. Cat No 2002.0.

2.7 Employment

Because of wide discrepancies between ABS Census data and ATSIC and Centrelink records, the CAPER study undertook a survey of regional employment at Wadeye in November 2003. The survey identified 178 Aboriginal people in the Thamarrurr Region had jobs, of which 133 were funded by the Community Development Employment Projects scheme (CDEP) and 45 were funded from other sources.

According to Taylor,

> *"While the regional labour market has grown in both size and complexity in recent decades, as the mission influence has receded and government and market forces have encroached, it can be argued that Aboriginal labour force participation has declined. In effect, the past 30 years in this region have witnessed a shift in Aboriginal employment from an historical association with the private sector, as represented by the pastoral industry, to an almost total reliance on the government sector in the form of CDEP. Beyond the latter, there is very limited Aboriginal engagement with mainstream work with the bulk of the adult population dependent on welfare payment for their incomes." (25:2003).*

Most CDEP participants are employed in service provision, including the delivery of municipal services, aged care, health work and teacher's aides, with a further 12 involved in housing construction. Some people are also employed as language workers

at the Wadeye Language Centre. The Dirrmu Ngakumarl art gallery is currently supporting the activities of ten local artists, (four women and six men), and has dealt with as many as 126 artists, weavers and carvers since 1997 (Taylor 27 and 28:2003).

Taylor also speculates that the ABS datum of an available labour force of 630 persons is likely to also be under-numerated. He points out that barely 2% of 15-24 year olds is engaged in non-CDEP work, and only 15% in CDEP. The vast majority (80%) of these young adults are not currently in the labour force (Taylor 28:2003). Presumably they are deriving their income from welfare payments, most particularly Family Income Support.

One consequence of such a young age profile is Wadeye's high childhood dependency ratio (i.e. the ratio of the number of children in the population aged 0-14 years to working age adults). In this case, in the Thamarrurr Region, the childhood dependency ratio is 0.95. This contrasts with that of the Northern Territory as a whole which is only 0.66. Taylor also contrasts the "economic burden" (i.e. the ratio of the number of children and economically inactive persons to employed persons), which is 44 dependents for each working person in the Thamarrurr population, with that of the Aboriginal population of the Northern Territory generally, which is only nine to one. The economic burden at Wadeye is almost five times as great as for the Northern Territory Aboriginal community as a whole.

2.8 Recreation and culture

The Kanamkek Yile-Ngala Museum has been operating since 1994. The Museum takes its name from Kanamkek, who is an ancestral creation being, and Yile-Ngala, the name by which Aboriginal people knew Father Docherty, the Catholic priest who established the mission at Port Keats. The Wadeye Aboriginal Languages Centre (WALC) and the Museum are housed in a building that was constructed by local Aboriginal people in the 1960s. The Museum and WALC are highly valued by community members.

While the Museum is registered with Museums Australia as an archive and small regional museum, it does not receive any funding and relies upon community donations, a volunteer Coordinator and CDEP staff. The WALC is also unfunded and relies on generating some revenue by subcontracting from Batchelor Institute to pay a part-time Coordinator. Aboriginal language workers are employed through CDEP and the Thamarrurr Council assists by maintaining the building.

The Museum is open to the public (tourists and visitors) and used by the local school on culture days. It is a keeping place for artefacts, slides and photographs which date back to the 1930s.

The WALC aims to preserve language and records Indigenous knowledge relating to:

- traditional knowledge about country
- mapping of country and place naming
- bush tucker (in each language)
- traditional stories for different language groups
- educational materials generated for use in the local school
- oral histories

The WALC is working in conjunction with Batchelor Institute to develop a database beginning with a dictionary of each of the languages in the region.

The major obstacle to the operation of the Museum and the WALC is the lack of recurrent funding for:

- Wages for a Coordinator
- Administration and logistical support
- A community mini bus to transport local people involved in language projects
- A dedicated work vehicle that is suitable for bush trips
- Resources used for recording stories from old people

In addition, Wadeye operates a Broadcasting for Remote Aboriginal Communities (BRACS) service which provides two television stations, and is also not funded.

The newly established Knowledge Centre (library) is well used by community members but is not fully funded for operational support. A Northern Territory Libraries Grant was received but cleaning, repairs and maintenance are not funded.

Recreation facilities at Wadeye are limited and inadequate to cater for the recreational and sporting needs of the regional population and particularly the large numbers of youth. Facilities include:

- A recently-built swimming pool. The swimming pool was funded by the Thamarrurr Regional Council, Murrinhpatha Nimmipa Store, Murin Association Incorporated and the local school,. Our Lady of the Sacred Heart. Contributions were also made by the Northern Territory Department of Transport and Regional Services and ATSIC. The Thamarrurr Regional Council provides ongoing maintenance and operational funding.
- A poorly equipped recreation hall that is rarely used.
- A grassed football field that is also used for softball. Softball equipment is stored at the school.
- A basketball court with lighting.

A Recreation Officer is jointly funded by the Thamarrurr Regional Council and the local school, Our Lady of the Sacred Heart. Australian Rules football and softball competitions are organised locally and include matches against teams from Palumpa. The Youth Coordinator of the recently established Youth Development Unit, in conjunction with the Juvenile Diversion Program, also aims to provide some recreational programs to Aboriginal youth in the region.

2.9 Environmental protection and management

Protection of natural and cultural resources is paramount to Aboriginal people. Up until three years ago there was little natural resource management activity in the Thamarrurr Region as Aboriginal landowners in the region have limited or no capacity to conduct traditional natural resource management practices and limited understanding of contemporary natural resource management issues.

The Thamarrurr Ranger Program was established, with the assistance of the Northern Land Council's Caring for Country Unit in 2001 (refer to Appendix), to support the involvement of Aboriginal Traditional Owners in natural and cultural resource management activities on their Country with the view to maintaining traditional country in good condition and providing land management conservation and development opportunities to future generations. The Program also aims to support the maintenance of Indigenous natural resource management knowledge in the region.

The Thamarrurr Rangers operate a functional community-owned land and sea management regional program that has the support of senior Aboriginal landowners. The Program currently employs 15 local Aboriginal men and women in land and sea management activities such as mimosa and feral animal eradication, marine species survey, sacred site protection and in ensuring continuity in local environmental knowledge (Taylor 28:2003).

The Thamarrurr Ranger Program has achieved significant environmental, social and economic outcomes (Thamarrurr Regional Council 2:2004). In recognition of the success of the Ranger Program, the Thamarrurr Regional Council is currently proposing to develop a Thamarrurr Natural Resource Management Department within its structure to address the growing natural resource management issues in the region. It also aims to capitalise on possible enterprise opportunities for Aboriginal landowners in the Thamarrurr Region such as eco tourism, provide further employment and mentoring opportunities for young people and become a family based "land and sea management drop in centre".

2.10 Transport and communications

Wadeye is accessed from the Daly River crossing by the Port Keats Road. The Port Keats road is a public road that is maintained by the Northern Territory Government. According to a report prepared by Matchplay Engineering in July 2003, the Thamarrurr Region has a road network of approximately 234 km accessing outstations, 70% of which is in the flat-bladed-track category, and in average to poor condition. The Report estimates that a blanket-upgrade of the network to an acceptable standard of well drained, formed road would cost $14 million.

The Wadeye community is serviced by a sealed air strip.

2.11 Economic base and enterprises

The Thamarrurr Regional Council's primary objective is to create an economic base in the region so as to develop long-term employment opportunities for local Aboriginal people. Currently, there is no economic base in the Thamarrurr Region, other than service provision, a fledgling Council construction industry being developed by the Council and a small- scale cattle industry based at Palumpa Station. Employment opportunities for local Aboriginal people are extremely limited. Thamarrurr Regional Council, local Indigenous enterprises and the Northern Territory Government provide some employment for local people in the delivery of a range of municipal and social services and in the provision of other goods and services.

Profits generated by the locally-owned Indigenous organisations are channeled back into the Wadeye community and regional homelands for community benefit. The Thamarrurr

Regional Council plays a critical role in providing financial and other support to a range of community infrastructure, training, employment and development projects.

The Mi Patha Takeaway & Bakery was built and is owned by the Wadeye Palngun Wurnangat Association Incorporation and is a financially secure enterprise. The profits generated by the Takeaway and Bakery are controlled by local Aboriginal women and all profits go back into Wadeye projects for community benefit.

The Murrinhpatha Tribal Development owns and operates the Murrinhpatha Nimmipa Store, Remote Area Purchasing Services (i.e. Courier service based in Darwin), the Vegetable shop and the local Dirrmu Ngakumarl Art Gallery. It is owned by Aboriginal community members and is chaired by Boniface Perdjert, a senior Yak Diminhin man, in recognition by local Aboriginal people that Wadeye is built on Yak Diminhin land.

Profits from the Murrinhpatha Tribal Development are used for community benefits. For example, over the last 12 months the Murrinhpatha Nimmipa Store contributed $560,000 to the building of the new swimming pool at Wadeye. On an annual basis the store distributes an estimated $200,000 to community members for funerals, ceremonies and other community expenses. Profits from the Murrinhpatha Tribal Development were also used to build the Wadeye Dirrmu Ngakumarl Art Gallery and establish a retail outlet in Darwin. The Art Gallery is not yet profitable and relies on ongoing funding from the store. The retail outlet in Darwin was unsuccessful and is in the process of closing. Failure of the business is attributed to competition in didgeridoos from imported copies from Asia.

Murin Travel and Freight Services provides daily passenger and freight air services between Darwin and Wadeye and provides passenger terminal facilities at Wadeye and Darwin. Murin Travel and Freight Service is owned by Aboriginal people living in the Thamarrurr Region and employs a number of Aboriginal people. Profits are used to support community development and housing projects at the Wadeye community and homelands. For example, the Association contributed $20,000 to the new swimming pool at Wadeye, sponsors local sporting teams and has built 15 houses in the region over the last 25 years.

The Thamarrurr Regional Council provides a range of subsidised services, most of which are not profitable. For example, the mechanical shop is unable to generate profits due to high demand by Council vehicles during the dry season, while the metal fabrication workshop experiences high rates of vandalism and break and enters, resulting in high costs in repairs that impact heavily on its profitability. The Council also operates a Post Office Agency and Centrelink Agency, neither of which generates sufficient income through fees and sales to cover expenditure.

The Council operates a local motel which has high maintenance costs and is not commercially viable. It is used primarily by staff, consultants and sub-contractors. In 2003 the new Rural Transaction Centre was built by Council to provide new offices for Centrelink, the Post Office, the Library/Knowledge Centre (library), Traditional Credit Union, and an Employment and Training office. The Council provides ongoing funding for the repairs, maintenance and cleaning costs of the Rural Transaction Centre.

2.12 Housing, infrastructure and facilities

The Thamarrurr Housing Authority comes under the Thamarrurr Regional Council and currently operates a housing administrative system and housing repair and maintenance program. The Authority is funded by the Indigenous Housing Authority of the Northern Territory (IHANT) annually for emergency repairs and maintenance. The Authority employs a number of local Aboriginal people and non-Aboriginal tradesmen and contractors including:

- Aboriginal Trainee Manager
- Aboriginal Housing Administration Officer
- 12 local Aboriginal people who are progressing into Stage 2 of general construction training, funded through CDEP and top up funding from Thamarrurr Regional Council
- Non-Aboriginal staff including three carpenters, two electricians and two plumbers

The overall goal of the Thamarrurr Housing Authority is to support people to live at homelands, satellite communities and subdivision arrangements on a permanent basis. The Manager noted the need for homelands to also establish some economic base as well as be provided with a normal level of health, education, power, water, housing and telecommunication services.

At the present time the Thamarrurr Housing Authority manages 217 dwellings in the region, which are in addition to the 39 government-owned dwellings at Wadeye. According to Taylor, these 217 dwellings accommodate on average 11.0 persons each; however, the Manager of Thamarrurr Regional Housing Authority believes that Taylor has seriously under-estimated overcrowding and that their estimates are that on average there are 17 persons per dwelling in the wet season and 14 persons per dwelling in the dry season. In addition, 17 of the existing dwellings are slated for major repairs and 54 have been condemned. Taylor calculates that the average number of persons per bedroom is five (Taylor 53:2003). On this basis, he estimates that the number of extra dwellings needed to adequately meet housing needs by the year 2023 is 465. If the Manager of the Thamarrurr Housing Authority is correct, then Taylor's estimate of an additional requirement of 465 is probably more like 600-700 new dwellings required.

Major limitations to the delivery of healthy housing services by the Housing Authority include

- Lack of funding for new housing
- Lack of serviced land
- Lack of services to homeland communities
- Poor condition of roads which are a major barrier to homeland development
- Inadequate water supply
- Extremely high repairs and maintenance costs of community housing due to wilful damage (Kardu Numida Inc Financial Statements 2003).

Taylor writes that temporary shifts of population contribute to the service population and add substantially to pressure on selected local services (16:2003). His assessment of the services and infrastructure in the Thamarrurr Region is that they are seriously inadequate:

> *"Thus within a generation, Wadeye and its associated outstations will have a population greater in size than present day Nhulunbuy… unless a major upgrading occurs, this trajectory means that Wadeye (along with many of predominantly Aboriginal towns across the Top End) will be*

> *increasingly anomalous in the Australia settlement hierarchy for being a vibrant and growing medium-sized country town yet with almost none of the basic infrastructure and services normally association with such places." (22:2003).*

2.13 Social and health services

Taylor reports that Wadeye was ranked 33rd out of 49 Aboriginal communities by Bartlett and Duncan (2000) in terms of the adequacy of its health staff resources (70:2003). At present there are 11 personnel employed at the Wadeye Clinic. Attempts to employ the services of a General Practitioner on a long-term basis have failed despite there being good quality family housing available for a permanent doctor and adequate accommodation for a visiting or second doctor.

A women and family project has been funded by the Family and Community Services (Northern Territory Government) but there have been cost overruns in the establishment, accommodation and operational areas, which the Thamarrurr Regional Council has borne.

In late 1997 health services were withdrawn from Wadeye after damage to the Ambulance and when nursing staff vacated the community for personal safety reasons.

A Respite Centre for the aged and infirmed has been established with no external funding. The Clinic was renovated by the Council with no external funding to accommodate the services of a doctor. A staff Daycare Centre was opened in April 2003, with costs borne by Council. A Meals on Wheels service is in operation at Wadeye.

2.14 Law and order

Discussions with Police at Wadeye confirmed reports of volatility in social relations among community members. The community no longer operates a club and residents travel to Peppimenarti during the dry season to drink alcohol at the Club there. Drinkers return to Wadeye after drinking at Peppimenarti and difficulties arise.

The community does not have a serious petrol sniffing problem, as it uses Avgas as a way of controlling petrol sniffing. Police estimate that there is currently a core group of up to 10 youths who still sniff petrol but consider the issue to be generally under control. Breaking and entering and theft of vehicles, food and equipment by youth are major and ongoing issues at Wadeye.

The statistics demonstrate that law and order is a major issue at Wadeye. Wadeye has the highest per capita juvenile offending rate in the Northern Territory (Taylor 71:2003). In the year 2002, there were 329 reported offences. Of these 17.3% were for unlawful entry of a dwelling or business, 18% were for theft and 35.2% were for property damage or other property offences (Taylor 72:2003).

In 2002 ATSIC provided some funds to operate a night patrol service, which operated for a short time. A Juvenile Diversion Unit has been established but its establishment and operational costs are not fully funded. A women's shelter building is operated by local women.

2.15 Outstation development

Homelands development is very important to Aboriginal people residing at the Wadeye community and in the Thamarrurr region as they continue to maintain strong connections to their traditional lands. In many cases, people reside at Wadeye only in order to access services. Many people we interviewed described improving access and services to their homelands, and wanting to build these up, as their primary goals.

The Murin Resource Centre currently provides services to 20 outstations located in the Thamarrurr Region and is looking to take two more on in the near future.

Figure 7: Map of settlement distribution in the Thamarrurr Region, 2003.



3 Previous external impacts

The present day community of Wadeye grew from a Catholic mission established at Port Keats in 1935. Prior to this, contact with other non-Aboriginal groups had been restricted to only limited engagements with Europeans, Malays, Javanese and Japanese. In 1938 the mission relocated to its current site, due to water shortages, and established a church, a head of cattle and food crops. In 1947 a dormitory and convent were built. The impact of placing children in the dormitory was to undermine their engagement in ceremonial life.

The Catholic Church managed the community until the early 1970s when the Northern Territory Government introduced self-management with the establishment of an elected local Council. The Aboriginal Council, Kardu Numida Inc, was established and provided services until the 1994 when it encountered financial difficulties. The Catholic Church continues to have a small presence at Wadeye.

Other than this contact with the Catholic Church and, obviously, contact with Australian and Northern Territory Governments, Aboriginal people living at Wadeye and in the Thamarrurr Region have only had some engagement with the cattle industry and have not had any previous experience with mining or major infrastructure projects

3.1 Impacts of contact to date

Despite missionisation, the relative isolation of people living in the Thamarrurr Region has enabled them to maintain strong continuity with traditional cultural practices and beliefs. Reasons for this continuity include:

- Continued access to traditional hunting and fishing grounds.
- Relative abundance of traditional food sources.
- Continued access to sacred sites and sites of significance.
- Only very limited destruction/modification of the physical environment so that the cultural landscape is relatively intact.
- Limited economic development and so limited engagement with the mainstream economy.
- No previous major projects on Aboriginal land which might provide a cash income stream.
- Maintenance of exchange relations based on reciprocity.
- The development of an economic base founded on community ownership and not on private ownership.
- Relative continuity of place of residence within the region.
- Wadeye people have not been marginalised in their own lands and remain the dominant peoples.
- At the family and language group level, they have largely been able to ensure that their cultural and social values prevail in the region.

Nevertheless, the effects of colonisation are still evident. In particular,

- Introduction of substances and substance abuse, most notably alcohol and marijuana.

- Undermining of cultural values and practices through reduced participation in cultural maintenance activities and breakdown in traditional marriages.
- Some breakdown in cultural transmission between generations.
- Adoption of a more sedentary lifestyle, and corresponding increase in the physical and mental health problems associated with this.
- Some loss of social capital[4].

[4] Social capital refers to the immaterial skills and knowledges which facilitate effective participation in social life and contribute to social vitality, political efficacy and economic self sufficiency.

4 Aspirations and Concerns

4.1 Understanding of the Project

A small number of Traditional Owners indicated that they felt they had a strong and thorough understanding of the Project. These individuals had clearly been the attention of a number of information events designed to ensure that they fully understood what was being proposed. Some senior people from Yek Maning had little understanding of the Project. Some Traditional Owners who did have a good understanding of the Project, expressed frustration at a lack of detail enabling them to assess for themselves whether the Project was a good project or not. Many senior people from Yek Diminhin, while they clearly had a keen awareness of the Project, did not appear to have a thorough understanding of the Project, nor of its potential social and environmental impacts. Those few Traditional Owners and community organisation representatives who had had the benefit of one-on-one discussions with company representatives and the NLC were the best informed.

Generally there was very little understanding of the Project among community members, in deed, among some households there was little awareness that a Project of any sort was even being proposed. There was a view that the Project was not only the concern of Traditional Owners, and that information needs to be disseminated more widely. As one Aboriginal informant put it "people need to get the right information, no good rushing it … tell them the good things and the bad things… everyone needs to hear about what is going on, everyone living in the Region needs to know, the Project affects everyone." (May 2004)

The low level of knowledge and understanding of the Project among Aboriginal community members is a reflection, in part, of the severe language barriers in the community that any outside organisation experiences when attempting to engage with people at Wadeye. It also provides an indication of the high level of effort and resources required to engage effectively with a community of people such as this. A video which had only become available the week prior to our second round of field work and which includes translations in English and Murrin-patha will go some way to redress this problem. It is proposed that this video be shown regularly on BRACs; however, not all households in the community have TVs or VCRs. Copies of the video would no doubt be left at the Knowledge Centre where a VCR is available. A video alone, however, will not adequately engage the community members in developing an informed awareness of the Project and its likely impacts. A number of Aboriginal informants told us that the SIA process, which relied on intense small group and one on one information exchange and interviews was a good process because people "need to have it face to face, so that we have the chance to ask questions and hear the story first hand" (May 2004).

A number of representatives of organisations expressed frustration at a lack of specific information about the Project. They said they needed this information in order to start their planning processes if they are to be ready in time to take up promised potential opportunities and mitigate effectively anticipated negative impacts. Local enterprises sought specific information on commercial opportunities. The NLC Training and Employment Unit requested more specific information on job opportunities and training requirements. In addition, Police at Wadeye said that they were seeking specific information about the location of the construction camp, its security arrangements and policies, particularly in relation to alcohol.

The Thamarrurr Ranger Group expressed disappointment and concern that neither the NLC pipeline consultants nor the Company had provided them with detailed and ongoing information about the proposed Project. The Ranger Coordinator and senior Aboriginal Ranger stated in interviews that rangers and other local people are asking them questions about the Project. They would be happy to assist people with gaining an understanding of the project over time, at a slower pace and in language, but have not been consulted or engaged in discussions with NLC Consultants or Company staff.

The Ranger Group view themselves as a principle community organisation in the region with interests in land and sea management issues. Therefore, any proposed infrastructure projects such as the Blacktip Project, that affect land and sea country, are the concern of the Ranger Group. They believe it is appropriate that they are kept informed by the NLC and the Proponents about the projects and consulted as a lead agency.

Management staff at the Thamarrurr Council and a number of other informants from community organisations who were interviewed also requested that information materials, used by the SIA Consultants, be left with them, since they had no other materials on hand and a number of Aboriginal community members were asking them questions about the Project which they could not answer.

4.2 Attitudes to the Project

The consultations did not reveal any animosity towards the Proponents or their agents. Generally the people within the Wadeye community are well disposed towards the proposed Blacktip project. There was some frustration expressed over there not yet being a proposal for compensation on the table for Traditional Owners to consider, however, generally speaking, the Traditional Owners, wider community members and community employees and representatives expressed very positive views towards, and high expectations of benefits from, the Project.

4.3 Aspirations

In the absence of any other source of employment, many people expressed high hopes for contracting, employment and training opportunities being derived from the Blacktip Project, if it is approved. There is also a widespread belief that the Project is capable of and likely to lead to, the provision of natural gas for the generation of the community and regional power needs. Some individuals expressed the hope that they would receive free gas to fill up their gas bottles.

A number of Traditional Owners expressed the aspiration that royalty monies (their words) would provide income to purchase vehicles and develop and “build up” homelands. Some hopes were expressed that the Project Company would leave behind housing and infrastructure associated with the construction of the proposed Project at Wadeye for use by community members.

4.4 Concerns

Concerns raised by informants included the following:

- Pollution caused by condensate spilling into the sea while it is being pumped to tankers
- Pollution caused by ballast water being emptied into the ocean and polluting local waters
- The Company not taking responsibility for gas, condensate and pollution leaking into the sea
- The effect of Category 4 and 5 cyclones on the gas processing plant and the wellhead platform in the ocean
- The Company not having procedures in place to ensure the gas processing plant is safe at all times, particularly during cyclones and that explosions do not occur
- The effects of traditional burning in the vicinity of the proposed plant
- Construction, operational and maintenance workers using firearms
- Damage to roads by heavy equipment and other company vehicles,
- Theft of company property by local Aboriginal people, particularly youths
- Theft of company fuel by petrol sniffers
- Vandalism by local community members of company property
- The impact of a non-local workforce on community relations, particularly in regard to workers liaising with local women
- The two way trafficking of drugs and alcohol between construction workers and local community members
- The TTP route leading to unauthorised access to Aboriginal land by tourists, pig hunters and other outsiders
- Workers wandering away from the construction camp without permission from Traditional Owners
- Fighting and increased domestic violence associated with distribution of cash from compensation
- Increased road accidents resulting from an increased number of Company vehicles and equipment using local roads and from increased alcohol consumption by local community members associated with cash distributions of compensation monies
- Deaths on the road to Peppimenarti because people walk along the roads at night and often set up camps alongside the road at night and might not be seen by heavy vehicles using the roads at night.
- Concerns that compensation payments to Traditional Owners directly affected by the Project would result in “the haves and the have-nots” in the community.

5 Potential socio-economic impacts of the Blacktip Project

5.1 Introduction

The Project has the potential to create contracting and employment opportunities, and through a compensation arrangement, possibly contribute to the creation of an economic base in the region. In the absence of other real economic development opportunities, beyond service provision and state transfers, the Project is considered by those interviewed to be important for this reason. Supply of goods and services to the construction camp and possible service contracts post construction are highly sought after. The key concern at this stage is whether such opportunities can be realized given the short lead-times currently being proposed.

The potential social impacts of the Project are high risk, high impact during the construction phase and likely to be negligible during the operational phase. Road accidents are another possible concern.

The small area of land that the Project will occupy, and the ability to continue to use Yelcherr Beach, mean that it is not expected that traditional hunting, gathering and fishing activities will be significantly curtailed.

5.2 Heritage protection and cultural impacts

The NLC is particularly sensitive to the protection of sacred and other significant sites located on Aboriginal land and sea country and have consulted, and continue to consult extensively, with affected Traditional Owners to identify new and existing land and marine-based sites to ensure their protection.

5.3 Engaging with the community

Local organisations are well positioned to assist the Proponent to achieve its project aims and to manage impacts. Language barriers, combined with the community's lack of experience in engaging with major projects, are highly likely to create misunderstandings, on both sides. Unusual for a project such as this, neither the company nor the NLC has engaged a local liaison officer, other than on a casual basis, to act as a channel for information into the local community and to assist the company and the NLC to plan their engagements with the community.

The local Wadeye Aboriginal Language Centre has expressed its concern and disappointment that the Proponent had not sought its assistance in developing communication materials for the Project. The Language Centre plays an important role in documenting and preserving local languages and has access to senior Aboriginal people who are experts in translation. The Language Centre does not have recurrent funding and relies solely on income generated from contract work. Hence, contract work associated with the Blacktip and TTP Projects provide a rare and welcome opportunity to supplement the Centre's precarious income base.

Dealing through existing community organisations will reduce the possibility of the Proponent engaging with the community ineffectively, and/or its workers being accused of unfair dealings. For instance, workers who wish to purchase local art should be

instructed to ensure that they purchase art through the Dirrmu Ngakumarl Art Gallery. A number of people expressed concern that local artists may sell paintings to local workers at below market prices in exchange for "quick drinking money".

5.4 Need for safeguard policies

Despite, or perhaps because of this positive disposition towards the Project currently being exhibited by the affected community, the Proponent is advised that, from the outset, it should adopt strict safeguard policies as a general principle in all planning associated with the Project. Any mistakes, or insensitive, or culturally uninformed actions may erode positive sentiment.

The use of safeguard policies would have the primary objective of **prevention** of negative social impacts. Prevention, rather than mitigation, is considered essential in this instance, for the following reasons:

1. The Wadeye community members are considered to be highly vulnerable because of their physical and social remoteness and total lack of previous experience with major infrastructure and mining projects.

2. The community is by its nature highly volatile, as evidenced by ongoing and recent violent incidences between its Aboriginal residents. Such incidences appear to stem from historical tensions amongst Aboriginal family groups. They may also be the result of an ongoing reliance on traditional methods of dispute resolution to maintain social relations.

3. Any mistakes which the Proponent might make which may create negative impacts could prove difficult, if not impossible, to manage or mitigate after the fact. Prevention is the key to managing the potential social impacts associated in particular with the Blacktip Project, and thus interactions with the community need to be carefully planned and supervised.

5.5 Community interactions with non-Indigenous workforces

There were varied opinions amongst those interviewed about whether workers at the construction camp should stay in the camp, or be permitted to visit the community. Some people interviewed were of the view that the construction workers should not be permitted to leave the camp unless accompanied by a Traditional Owner, including visiting the community stores. Others took the view that workers should be encouraged to visit the community, in particular to make purchases at the stores. Strategies which comprehensively insulate community members and isolate the workforce will be critical for the following reasons:

- Aboriginal community members have never been exposed to the range of social impacts that a major infrastructure project with a large construction force can potentially produce.

- Aboriginal community members have no points of reference by which they might anticipate possible impacts. All those interviewed were asked their views on whether they expected there to be any problems with a construction force of around 200 being camped within five kilometers of the community. Amongst

those Aboriginal people interviewed, some responded that they could not foresee any problem with this while others appeared unsure. A smaller number of Aboriginal informants expressed concerns about the potential problems associated with a construction workforce. Generally, the Aboriginal informants responses, or lack of, are cause for concern, as it suggests that community members have no experience of the types of problems that might arise in such a situation, (examples are provided below), and therefore, will be unlikely to take preventative action. They may also be less forgiving of any such problems if they do occur, because these were not anticipated.

- The Proponent may lose its community mandate to operate if only a single incident occurs which the community considers unforgivable and for which the community chooses to hold the Proponent accountable. Wadeye is a community which might be characterised as very trusting but which "does not forgive". In a worst case scenario, a single incident involving a non-local worker may potentially jeopardise irrevocably the Proponent's ability to continue to operate in the area. While Bougainville is an extreme example, it nevertheless exemplifies the extent to which loss of local community support can undermine a company's ability to continue operations in a remote and volatile location.

- Aboriginal women in the community are, in the main, not using contraceptives and would be most unlikely to seek to use contraceptives in the event of choosing to have consensual sex with a non-local construction worker.

- Sexual relations are a "shame" subject and therefore potential problems are unlikely to be discussed openly or be dealt with effectively.

- The incidence of sexually transmitted infections (STIs) is reportedly already high, although no data were available to substantiate this.

- The Peppimenarti Club is only approximately one hour's drive away. It is understood (and recommended) that workers will not have private vehicles, and so there is the potential for workers to seek to pay Aboriginal people to procure alcohol on their behalf.

- The use of the only road into the community by construction vehicles will create hazards for both local residents using the roads, and for drivers of construction vehicles who may share the roads with drunk drivers returning from the Peppimenarti Club.

- Wadeye is not regarded as a community of people who would be likely to take offence passively. Rather the community members can be expected to react aggressively and swiftly in response to any offence, (intended or unintended), by the Proponent and/or its workers. In some cases community members are not likely to hold back in expressing their anger through violence and/or vandalism.

- For most local Aboriginal people living at Wadeye and surrounding homelands, English is their last language. Language difficulties, combined with local people's inexperience with major infrastructure projects, may create misunderstandings that may not be easily resolved.

Examples of the sorts of incidents which might lead to violence against the Proponent and/or its workers and property include:

- Non-local workers socialising with Aboriginal women, regardless of whether such encounters are initiated by the Aboriginal women themselves.

- Non-local workers appearing to socialise with Aboriginal women, again regardless of who initiates such interactions or even whether they actually occur. Sexual jealousy can be very strong among people living in remote communities and can arise even when there is no evidence of an actual encounter. The sometimes violent consequences for women, perpetrated by their own men, can also cause serious injury (and death) as well as severely disrupt social relations among local families.

- Non-local workers sharing their alcohol allocation with Aboriginal women or men, or trading their alcohol allocations for sexual favours from Aboriginal women.

- Road incidents involving local community members and company vehicles, regardless of who is at fault. In particular if there is injury to Aboriginal community members.

- Non-local workers travelling away from the construction site or work-site (e.g. sight-seeing) without the express permission of Traditional Owners and/or not in the company of Traditional Owners.

- A perception of unfair treatment of Aboriginal workers by supervisors, or perception of unfair dismissal.

5.6 Security

The Wadeye community is currently experiencing high rates of damage to, and theft of, property and vehicles. There will be a very high and ongoing risk of damage and theft to the company's property and vehicles. Local Police advised that the property of builders brought in to build the new subdivision in recent years had been targeted by youths, which had resulted in the local Police having to spend considerable time attending to petty crime. The Police also advised that construction workers should not be allowed to have firearms or drugs and this would need to be policed carefully. They also stated that only lite beer should be kept on premises to discourage local youth from damaging property in attempts to steal alcohol.

Police stated that local Aboriginal people may potentially beg for food, fuel and other goods. It was suggested that private security guards would be needed to protect property and deal with "humbug". However, security staff would need to be inducted and carefully managed. The local Police and some Traditional Owners suggested that a local planning committee consisting of the Police, Traditional Owners, Council representatives and Woodside representatives should meet to establish a set of rules, policies and procedures for Company security workers to follow in the event of offences involving local community members. All security guards would need to be properly inducted and briefings should include information relating to:

- Living on Aboriginal land
- Specific socio-cultural issues

- Procedures for dealing with particular problems including the maintenance of radio contact with local police
- The benefits of maintaining a close relationship with the local police who have a good understanding of the local politics and social relations

Some Traditional Owners stated that community elders should be involved in resolving any difficulties with youth, particularly if disciplinary action was to be taken. It is critical that mechanisms for dealing with offences by local Aboriginal youth, involving Company property and personnel, are developed by senior community representatives with experienced Company representatives before construction begins.

Both the Police and a number of Traditional Owners said that they felt that if there were any problems at the Blacktip workers construction camp (for instance, involving theft or trafficking), that the Company should involve always involve local police and identified community elders to deal with such matters.

The Police also advised that their resources at Wadeye are already stretched and that they would need a minimum of three to six months lead time prior to construction work beginning to obtain additional police staff to cope with the expected increase in crime, problems and issues associated with the presence of a large contingent of construction workers near Wadeye.

5.7 Female employment

Gender balance within the construction workforce will likely improve the ability to implement insulation/isolation strategies. The presence of a significant number of female workers will provide a more normal social situation within the work camp.

5.8 Access of workers to hunting and fishing areas

Local Police took the view that there was a need to reduce issues of access and movement of construction workers on Aboriginal land and it was suggested that construction workers should not be able to gain verbal permission from Traditional Owners to access areas for fishing, hunting and sightseeing. Police proposed that designated areas should be identified by Traditional Owners and permits issued through the NLC. It is understood that the NLC is considering establishing an NLC office at Wadeye. Should this occur the NLC's capacity to adequately administer and enforce an appropriate permit arrangement for access by construction workers would be significantly increased.

5.9 Granting of favours

It is advised that the Proponent not grant any small "favours" to local families or individuals, unless it intends to continue to grant these favours indefinitely and to all those individuals and families who might consider themselves to be entitled to such favours, since "drawing a line" will likely meet with anger and resentment. For instance, an exploration camp located near an Aboriginal community further south initially offered assistance to stranded families in vehicles by providing them with fuel when they had run out and spare tyres when they had flats. This, however, set up an expectation that the company would continue to provide such favours. When the demands for such favours increased to an unsustainable level, the company refused. From the company's point of

view its generosity was being abused. From the Aboriginal perspective, the company was now refusing to pay its rent. While the company had initially provided these favours in order to strengthen positive feelings with the community it instead set itself up to create bad feelings down the line.

Granting of favours to the families of Traditional Owners is also not advisable, as it not only sets up expectations but, because the nature and identity of Traditional Ownership is often more complex than it appears, companies have frequently granted favours to families they believe to be members of a Traditional Owner group to the annoyance of other Traditional Owner groups who are not as well recognised by the proponents. Benefits should be delivered at the community level or via representative organisations which can protect the Proponent from accusations of favouritism or bribery.

5.10 Alcohol

Those interviewed were asked their views on whether workers should be allowed to consume alcohol at the construction camp. A common view was that, providing they had a permit, construction workers should be allowed to consume alcohol. Although many also took the view that while it was alright for non-local workers to be provided with alcohol, local Aboriginal co-workers should not be allowed to have alcohol. There is a need to explore, with senior community members, the difficulties and inconsistencies associated with the issue of alcohol being provided to non-local workers and not to local Aboriginal co-workers, in more depth. However, providing limited access to alcohol for workers may have some slight effect in lessening the likelihood of workers seeking to procure illicit alcohol, or bringing unauthorised alcohol into the camp.

The local Police at Wadeye expressed concerns in relation to construction workers and alcohol and advised that there had been incidences of alcohol and drugs being brought in to the community by builders who were building houses at the new subdivision over the last two years.

At Peppimenarti, interviews with the licensee and Council indicated that there was hope that the construction camp would provide business for the Club at Peppimenarti, and so additional revenue, and that they expected the company to take responsibility for the behaviour of workers at the Club and outside the Club after closing hours.

5.11 Communication and relationship-building

Isolating the construction workforce and insulating the community, does not, however, prevent the Proponent from initiating carefully managed interactions between the construction workforce and local community in such a way as to build positive community relations. Some examples of the sorts of managed interactions which might be undertaken with positive effect include:

- Social football and other team games, alcohol free, between workers and community members.

- Managed and regulated visits to the community stores and art centre for purchases by workers.

- o "Open Days" at the construction camp where local community members are invited to a barbeque or other event at the construction camp and invited to view the construction progress. Such "Open Days" are especially beneficial for informing the community of progress on the Project and enabling community members to see that there are no "secrets".

- o A comprehensive and carefully planned communication strategy, which might include regular visits (e.g. fortnightly) by the project manager to the community to inform community leaders and interested members on progress of the Project, and regular presentations on the BRACs and posting of photos of the Project progress on a community notice board.

- o Sponsoring of community events e.g. art prize, or provision of a community benefit such as a community bus.

5.12 Economic impacts

5.12.1 Diseconomies

It is not expected that there will be any significant diseconomies resulting from the Project with the exception of some limitations on fishing and use of Yelcherr Beach during construction of the pipeline coming from the ocean across Yelcherr Beach to the gas processing plant.

There is a reasonable prospect that "creaming" of the workforce may occur, whereby competent and qualified personnel, which the Thamarrurr Regional Council and other Wadeye organisations rely on for essential work, may be attracted to more lucrative paid positions with the construction workforce.

5.12.2 Access to hunting and fishing

The area affected by the gas processing plant is not significant in contrast to the available lands for hunting and gathering, and it is not anticipated that hunting, gathering or fishing activities will be curtailed as a result of the Projects.

5.12.3 Employment, training and recruitment

Other than the CDEP, there is no existing agency at Wadeye coordinating and facilitating training and employment for local Aboriginal people in the Thamarrurr Region. Training is high on the Thamarrurr Regional Council's priorities and the Council is currently in the process of negotiating with Group Training Northern Territory for some general training to occur at Wadeye. An Employment and Training Centre has recently been constructed at Wadeye at Council's expense, and it is hoped that ultimately training costs will be funded.

The NLC's Indigenous Training and Employment Unit has demonstrated its ability to coordinate and facilitate significant Indigenous training and employment outcomes for a range of major infrastructure projects, including the ADRail Project, in the Top End of the Northern Territory (English 2002). The Unit has taken some initial actions and worked closely with the Territory Construction Association (TCA) as part of taking a proactive role in coordinating the planning for the training and employment of Indigenous people in the Blacktip (and TTP and ALCAN expansion) Projects. The Unit advises that it has already facilitated the involvement of some Indigenous people in relevant training programs such as plant operation, hospitality services,

welding and general construction in Darwin. However, due to staff constraints, the Unit has not engaged with organisations or individuals at Wadeye at all.

The Unit advised that it is acutely aware of the compressed timeframes associated with the planning for, and construction of the Blacktip project, particularly in terms of the lead-time required to identify, train and mentor Aboriginal people. The Unit's project planning and training processes continue to be limited by the lack of information provided by Woodside, and the other Proponents, about the employment opportunities on each of these projects (preconstruction, construction, commissioning and maintenance). To date, the Unit has relied on information generated by the Territory Construction Association and the NLC, neither of which say they have been able to check or confirm their estimates with the Proponents.

The NLC Indigenous Training and Employment Unit, in partnership with the TCA, have the experience, knowledge, networks and methodologies to effectively engage Traditional Owners and other local Aboriginal people in the Thamarrurr Region, in training and employment. However, to successfully facilitate the training and employment of Traditional Owners and local Aboriginal people in the Blacktip Project in the current time-frame (i.e. Oct 2004, preconstruction dry season 2005 & construction during dry season in 2006) the Unit will require additional human and capital resources. The Unit estimates that this would include a Coordinator and two Indigenous Training and Employment Project Officers based at Wadeye. The proposed Coordinator would be responsible for:

- Liaising and coordinating with Job Network providers, Group Training organisations, Centrelink and CDEPs,
- Liaising with the Proponents, subcontractors, supervisors and managers as part of ongoing planning, monitoring, evaluation, problem solving/prevention and mitigation,
- Managing and supporting Project staff, and
- Reporting to the NLC and Proponents.

The NLCTE Unit proposes that the Training and Employment Project Officers would:

- visit communities and outstations to provide information about the training and employment opportunities for the Blacktip and TTP Projects to Traditional Owners and Aboriginal community members living at Wadeye, outstations and other communities in the west TTP region,
- register interested people on the NLC database,
- assist people with their applications for training and employment,
- ascertain individual training needs,
- support people to participate in the appropriate training in accordance with the Unit's culturally appropriate 5 Step Assessment and Referral Process,
- assist people with job applications and their preparations for interviews;, and
- provide ongoing support and mentoring to people employed.

The Unit would also require one to two vehicles over the two to three year period that includes planning, preconstruction and construction phases of the Blacktip and TTP Projects. The NLC Training and Employment Unit suggested that its staff based at Wadeye might potentially share office space and equipment with Group Training NT.

5.12.4 Business development opportunities

There are high hopes and expectations by Traditional Owners, community members, the Thamarrurr Regional Council and local Indigenous organisations that the Blacktip

Project will contribute to the development of an economic base in the immediate region and create training and employment opportunities, particularly through contracts, for local Aboriginal people during the pre-construction, construction and operational phases of the Projects. As discussed above in relation to employment and training, there was frustration expressed by those interviewed in relation to commercial contracting opportunities about the lack of information available to organisations to assist them to initiate training programs and to plan for increased capacity.

The Economic Impact Assessment, prepared by ACIL Economics, writes in relation to Indigenous impacts:

> *"The regional location of the Projects provides employment and business development opportunities for local Indigenous people during both construction and operation. Opportunities during construction could include preliminary earth works, road works and site revegetation. During operation they could include site maintenance, security provision and general repairs. During operation, there is also the possibility of flow on opportunities such as tourism ventures that take advantage of improved access to remote areas." (ACIL 22:2004).*

Our consultations revealed interest in taking up those opportunities identified by ACIL, but also in taking up other opportunities further to those identified. These include:

- supply of bread and meat to the construction camp,
- catering services to the construction camp,
- provision of cultural sensitivity and awareness training to workers and supervisors, cultural tourism services to workers,
- sale of take away foods and sale of art and artifacts to workers,
- provision of translation and liaison services,
- sale of alcohol,
- sale of sand and gravel, and
- provision of transport services, including air flights and charters.

All of the Indigenous enterprises, some community organisations and the Thamarrurr Regional Council have expressed a strong interest in carrying out contracts associated with the Blacktip Project that are commensurate with their capacity. As discussed above, profits generated by the locally-owned Indigenous organisations are channeled back into the Wadeye community and regional homelands for community benefit, thus there are important local multiplier effects of economic benefits capable of being achieved through local supply and service contracts.

Traditional Owners also expressed a keen interest in providing cultural education and cultural tourism services to workers, and artists at the Dirrmu Ngakumarl Art Gallery hope that the Project will provide more clients for art work.

The following is a summary of the interest and capacity of local organisations in the Thamarrurr Region to complete supply and service contracts associated with the Blacktip project.

- The Mi Patha Takeaway & Bakery has a fully equipped and operational bakery that makes fresh bread and rolls every day. The bakery has a capacity to make 1000 loaves of bread per day. Currently, Monday is the peak day with an average of 600 loaves sold. The

Bakery has the capacity to supply bread to the Blacktip construction camp and to operational and maintenance workers over the next 25 years.

- The Mi Patha Takeaway is also interested in taking on the entire catering contract for the Blacktip construction workforce. The Takeaway has a large full equipped kitchen with a qualified chef and ample local staff as well as substantial storage room, freezers and chillers.

- The Murrinpatha Nimmipa Store is particularly interested in becoming a major supplier of food and other goods to the Blacktip Construction camp and operational and maintenance crews over the next 25 years. The store has substantial capacity in terms of its access to Darwin Independent Grocers, courier and transport services from Darwin to Wadeye, local storage facilities for dry, chilled and frozen goods.

- Murin Travel and Freight Services are particularly interested in becoming the primary approved airline carrier of Woodside (and its subcontractors) so they can provide passenger and freight air services for the construction and maintenance workforces associated with the preconstruction, construction and operation of the Blacktip project over the next 25 years. Murin Travel and Freight Services have quality passenger and storage services and facilities at Darwin and are prepared to finance and build a new air conditioned and serviced passenger and freight facility at Wadeye as part of its commitment to providing first class passenger facilities to Blacktip employees.

- The Thamarrurr Regional Council plays a critical role in the provision of a municipal and community development services in the region. In addition to its core responsibilities the Council provides financial and other support to a range of community infrastructure, training, employment and development projects that would otherwise not be viable. The Thamarrurr Regional Council is in the process of increasing its capacity so it can position itself to carry out minor and major contracts associated with all phases of the Blacktip project. It has indicated a willingness to invest in equipment and machinery in order to be able to take up roadwork and earthmoving contracts, as well as construction activities.

- The local Wadeye Aboriginal Languages Centre plays an important role in documenting and preserving local languages and has access to senior Aboriginal people who are experts in translation. The Language Centre has the interest, expertise, technology and capacity to complete contracts involving the development of communication materials related to the Blacktip project.

- The Wadeye Knowledge Centre has the capacity, through BRACS and the Library, to also disseminate information about the Project in a range of mediums.

- The Palumpa Station is a community-owned enterprise that generates local employment at both Palumpa and Wadeye. The Station operates a fully equipped butchers shop at Wadeye and has the capacity to provide locally grown and butchered beef to the Blacktip construction camp and ongoing operational and maintenance crews.

- The Peppimenarti Club sells alcohol and light meals and consultations with the licensee and Council representatives indicated that they were hopeful that workers from the Blacktip (and TTP) Projects would be using Club facilities.

5.12.5 Environmental management

The Thamarrurr Rangers have particular interest in gaining economic and employment benefits through contract work associated with the preconstruction, construction and operational phases of the Blacktip project. They are able to carry out weed control contracts, participate in fauna and marine survey work and manage and monitor fauna during periods when the TTP trench is open.

The Thamarrurr Rangers are the principle agency in the Thamarrurr Region to assist Aboriginal landowners to understand any minor or major projects affecting land and sea country. They have the network and capacity to disseminate information about the Blacktip project to Aboriginal landowners and their families and other interested community members as well as provide feedback to the NLC and Woodside.

The Thamarrurr Rangers stated, however, that they need timely and specific information about the training & employment and contract opportunities associated with all phases of the Blacktip Project as soon as possible so they can increase their organisational and human resource capacity. The Rangers were particularly keen to understand the Project timeline as they are conscious of the long lead times needed, for organisations such as theirs, to gear themselves up to fully take advantage of any employment and contract opportunities associated with all phases of the Project. They stated that a lot of time is needed to facilitate an understanding by local people of the Project training, employment and contract opportunities.

Funding and additional resources are needed to increase the capacity of the Thamarrurr Rangers, through the development of a Natural Resource Management department within the Council. Such developments would include:

- Developing a ranger base that includes office space, outdoor meeting/planning area and lockup storage space for vehicles and equipment is urgently needed. Currently, the Rangers work from a small room next to the Recreation Hall that is inadequate in terms of size and facilities.
- Upgrading the existing ranger vehicle to a reliable vehicle for transporting rangers and equipment.
- Employing a Ranger Mentor/Supervisor.
- Acquiring equipment for weed control.

The Rangers have made submissions to the ICCP, the Aboriginal Benefits Association, Indigenous Land Corporation and Rio Tinto who have exploration interests in the region, and will be making further submissions to other agencies. However, given that the Project will create work for the Rangers who will have a role in environmental monitoring and communication about impacts of the Project, it would be appropriate that the Proponent give consideration to supporting the Rangers as part of the legitimate project costs, over the life of the project.

5.13 Free gas and/or improved energy infrastructure

There are high expectations in the community and within the Thamarrurr Regional Council that the Project will result in an upgrading of electricity generation equipment and the provision of

free gas. Council advised that the current generators are located close to community housing and are hopeful that the Project will result in the relocation of these facilities, with an upgrade to equipment using gas supplies. Our interviews with the Northern Territory Power and Water Corporation (PAWC) indicate to us that these expectations are misinformed.

Currently 97% of the electricity generated by PAWC is sourced from natural gas. Since 1986 PAWC has purchased gas from the Amadeus Basin, via the Alice Springs to Darwin pipeline, south west of Alice Springs, to supply gas-fired power to the major Northern Territory centres, including Alice Springs, Tennant Creek, Katherine, Pine Creek (because of the mine) and Darwin. The current contract will cease in 2009 and PAWC expect that the Amadeus gas fields will be unable to deliver the gas requirements of the Northern Territory after 2009.

It is understood that PAWC is currently negotiating with the Proponent of the Blacktip Project, and other gas suppliers, to purchase a supply of gas so the Corporation can continue to generate power by natural gas to the major centres, including Alice Springs, Tennant Creek, Katherine, Pine Creek and Darwin, over the next 15-20 years.

PAWC advised that it is <u>not</u> considering supplying gas-fired generators to communities, including those Aboriginal communities located in the vicinity of the Blacktip Project for the following reasons:

- The supply of gas-fired generators to smaller communities, including Wadeye, is not economically viable as their power needs fall "a long way short of the threshold load to justify such gas plants". At this point in time there are no communities, outside of the major centres, that have a sufficient power load to achieve the economy of scale required. This situation is likely to remain into the foreseeable future. While the anticipated population growth over the next 25 years at Wadeye is substantial, PAWC states that the estimated increased use of power by residents at Wadeye would still fall short of the required threshold. The development of industry would be needed to substantially increase power needs at Wadeye as population increases do not principally grow electricity demand.

- Diesel generators are a currently an appropriate and flexible source of power for communities. Diesel generators are available in a wide range of sizes to meet the varying power needs of different sized communities. In addition, the purchase of backup diesel generators is considerably cheaper than that of backup gas fired technology.

- Local Indigenous employees of PAWC, who live on remote communities, are familiar with the operation and maintenance of diesel generators and would have to make a "quantum leap" to operate and maintain gas technology.

PAWC currently provides electricity to all of the major centres and 78 major communities in the Northern Territory. The Corporation does not supply power to homelands and outstations which are generally serviced by community organisations. A Community Standard Tariff Equalisation Policy requires the NT Government to ensure, through a Community Service Obligation arrangement, that every resident in the Northern Territory, who is supplied electricity by the PAWC, pays a standard electricity tariff irrespective of where they reside. Thus, irrespective of the cost of the generation of electricity, all consumers pay the same rates. What this means is that, even if cheaper energy were procured, this would not result in any change to the cost of electricity in communities.

Organisations servicing outstations and homelands do pay the real costs of diesel-generated power to remote locations but they would certainly not provide the economy of scale to justify the infrastructure investment to provide them with cheaper gas or electricity supplies.

5.14 Compensation and consideration for land use

The Traditional Owner Group whose land is directly affected by the gas processing plant is a small group by Aboriginal standards but has extensive and complex obligations to many others in the community and surrounding regions. It is likely therefore, that any compensation payments made to this Traditional Owner Group will be widely distributed as there will be many demands made upon members of this Group by those who consider themselves to have an entitlement to sharing in any benefits.

Concerns were expressed to the SIA Team that the Traditional Owner Group needed to ensure that other Groups along the TTP route also supported the Project before it could give its consent since "when people see us all with four, five new Toyotas and generators for our outstations, and everything, they will come for us with a spear if they don't want that pipeline". There is a clear expectation on the part of this Group that any direct benefits likely to come from the Blacktip Project will be considerable to the point where they will make a measurable difference to the disposable income of this extended family group. The potential positive impacts of a compensation payment such as the main affected Traditional Owner Group is anticipating are significant. Informants spoke of achieving greater access to country and to meeting ceremonial obligations through ownership of vehicles, as well as the purchase of furniture and appliances for their new homes recently built in the new subdivision and occupied by this extended family group. Clearly if the Group approves the Project and such benefits are delivered, these types of impacts will be very positive.

The Traditional Owners, wider community and community employees and representatives expressed very positive views towards, and high expectations of direct benefits from, the Project. The two Traditional Owner Groups, whose country is primarily affected by the Blacktip Project, said that they would be looking for independent advisory support to assist the clans to set up a mechanism to receive compensation and to provide ideas about how to plan and invest monies received. They are keen to manage compensation in a clear and straight way so as to stop arguments.

Local Police expressed concerns that compensation payments are likely to contribute to increased alcohol-related accidents, crimes and violence including domestic violence. According to the local Officer in Charge, every available car at Wadeye is currently used to transport people to Peppimenarti on Thursday and Fridays so they can access alcohol from the Club. He expressed concern that compensation in the form of royalties is likely to increase the number of vehicles purchased by community members, and subsequently increase people's access to and consumption of alcohol and other drugs as well as increase the number of car accidents and injuries.

Healthcare professionals echoed these concerns stating that additional cash circulating in the community may lead to greater consumption of alcohol, with the attendant increases in community violence and injury as a result.

5.15 Potential social impacts of upgrades to roads and increased traffic

There was divided opinion among informants on the benefits of upgrading the road to Daly River. Some people were "worried" that an improved road would increase access to Peppimenarti and result in an increase in alcohol consumption and associated social problems. A small number of community members interviewed stated they did not want a bridge built over the Daly River as "it will bring problems". Others saw benefits in an upgraded road in terms of improved transport and infrastructure that would enable safer and faster movement of local traffic as well as supporting the development of an economic base in the region.

A number of Traditional Owners and Aboriginal community members expressed concerns about the increased risk of road accidents involving local people travelling to and from Wadeye, Palumpa and Peppimenarti during the Blacktip and TTP construction periods and consider it "to be a very serious matter". They talked about local Aboriginal people, including those affected by alcohol, commonly sleeping and walking on the road at night time after becoming tired or their cars breaking down.

A number of informants suggested the following ways to reduce the risk of road accidents.

- Address sharp bends and improve sight lines during an upgrade of the Port Keats road
- Ensure that all TTP and Woodside drivers and workers complete orientation courses so they understand the different ways in which local Aboriginal people use roads, particularly the main Port Keats road
- The NT Road Traffic Safety Council, in conjunction with the Wadeye Language Centre could develop and implement a bilingual road safety awareness campaign targeting local Aboriginal road users to warn them about the increased risks during the construction phase of the TTP and Blacktip projects. It was suggested the campaign could include a road safety video in Murrin-patha language shown through BRACS and at the Library/Knowledge Centre to raise awareness among local people.

Police suggested that a Traffic Management Plan would need to be developed and requested that they be involved in the development of same.

5.16 Community health and safety impacts

A number of people interviewed asked about safety risks associated with the gas processing plant and gas pipeline and expressed concerns about the environmental affects of gas leaks and whether they could still carry out traditional burning.

Risks to the health and safety of community members arise most directly in association with extra traffic on the Port Keats Road, as discussed elsewhere in this Report.

A number of people also raised concerns about workers trafficking drugs and about community members selling drugs (in particular marijuana), to non-local workers. The risks associated would be addressed by the implementation of insulation and isolation strategies.

5.17 Cumulative impacts

The proposed Blacktip gas processing plant is not expected to trigger additional projects or developments in the immediate region beyond the TTP. Although it has been speculated that the construction of the plant and attendant pipeline might make viable otherwise marginal mining or processing projects, the authors are not aware of any such proposals in the immediate region of the Blacktip gas processing plant. The SIA Consultants are not aware of any other projects or events likely to occur in the near future which would combine with the impacts of the Blacktip Project to aggravate impacts.

5.18 Impacts of the SIA process itself

The methodology used by the SIA Program focused on consulting with Traditional Owners and Aboriginal community members in small clan and family based settings, either at their homes or at their preferred place. This process allowed the SIA Consultants to spend considerable time providing information, where possible with the assistance of local interpreters, about the Blacktip and TTP projects at an appropriate level and pace. The process allowed Aboriginal informants to ask a range of questions, particularly in relation to safety and environmental aspects (e.g. gas leaks) and for the Consultants to provide information and reassurance.

The SIA process also focused on consulting with Aboriginal and non-Aboriginal representatives of local and regional enterprises and service organizations. There was consistent feedback from these informants that the SIA team was the first group to provide information to their organisations

In our view the SIA consultations generally provided Aboriginal and organisational respondents with an opportunity to state a position about the Project and express concerns and aspirations without the pressure of being asked whether or not they agree with the Project. Overall the response to our presence was positive, although our consultations were limited by the factors cited in our discussion of methodology.

6 Capacity to respond to change

As discussed above, the Wadeye community members are considered to be highly vulnerable because of their physical and social remoteness and lack of previous experience with major infrastructure and mining projects. The Wadeye community is reliant on non-Aboriginal administrators and the Thamarrurr Region's governance arrangements are still being consolidated.

These circumstances suggest that the community's ability to respond to change would be considerably less than that of another Aboriginal community which is accustomed to engaging with projects such as this and where its governance arrangements were firmly established and proven resilient. Wadeye's flexibility and responsiveness is likely to be further compromised by language barriers and poor communication networks for transmitting efficiently the sort of project-related information likely to be generated by the Project.

High expectations in relation to the Project need to be carefully and sensitively managed and it would seem that greater information and resources need to be injected into the community to equip it to:

- Disseminate better information about the Project and its possible impacts to the wider community members
- Allow organisations to respond appropriately and in a timely fashion
- Develop realistic understanding and aspirations about the opportunities the Project is likely or unlikely to provide
- Enable affected Traditional Owners and community members to have a voice in relation to aspirations, concerns and impacts

Clearly the organisations in the community have given a great deal of thought to the types of opportunities which they believe are likely to arrive with the Project, and have commenced intense internal informal planning for how they might position themselves to benefit. There is some concern as to whether their planning is realistic or timely and whether they will be able to effectively engage with the Proponent to ensure their aspirations are met.

Of concern is the relative inexperience of the Aboriginal community members with projects such as this, in particular of the sorts of tensions and problems that can arise with the presence of a construction workforce, in particular in relation to sexual jealousies. The capacity of the community members to respond will be predicated upon the openness with which the Company, community organisations and Traditional Owners and the Council can engage in discussion and strategic planning for the prevention of problems.

Strategies will be required to strengthen the community's capacity to respond positively to change and proactively pre-empt potential negative impacts.

7 Monitoring

A major monitoring study is currently underway at Wadeye, being undertaken by the Centre for Aboriginal Economic Policy Research, Australian National University, Canberra. The Study is compiling a baseline data set of social indicators for the Thamarrurr Region and providing ongoing monitoring of those indicators, in order to assist in the monitoring and evaluation of the Indigenous Communities Coordination Pilots (ICCP) protocol. The ICCP is a pilot project currently being implemented between the Thamarrurr Regional Council, the Northern Territory Government and the Commonwealth Government, which has as its first objective "the establishment of partnerships for achieving measurable and sustainable improvements for people living in the region" (Taylor 7:2003).

The purpose and role of the ANU monitoring study is to

> *"…identify mutually determined social, economic and service delivery outcomes, together with the means to achieve them and assumed responsibilities… these will be codified in a negotiated regional development plan, and then subject to a regular process of evaluation and monitoring against measurable outcomes." (1:2003).*

The data to be collected include "demographic structure and residence patterns of the regional population, its labour force status, education and training status, income, welfare, housing and health status, as well as indicators of interaction with the criminal justice system" (Taylor 7:2003). Since these are precisely the indicators which would be included in the selected indicators to monitor impacts of the Blacktip Project, it would be pointless to collect the same data twice.

The ANU study will need to interpret the data to determine the extent to which changes to the indicators it collects are the result of outcomes of intervention and interest by the ICCP or some other factor, or indeed, if such changes can be attributed to the social and economic impacts of the Blacktip Project.

Rather than duplicate the ANU study, consideration should be given as to how the ANU Study can contribute to the monitoring and evaluation of the social and economic impacts of the Blacktip Project. Ideally, the ANU study should be expanded to incorporate monitoring and evaluation of changes to socio-economic indicators as outcomes of the Blacktip Project if it proceeds.

Data that would need to be collected for the purposes of monitoring and evaluating the social and economic impacts of the Blacktip and TTP Projects, additional to that proposed to be collected by the ANU study, include

- traffic accident data,
- qualitative reporting on community disturbances relating to sexual jealousies,
- qualitative reporting on drug and alcohol trafficking,
- expenditure at the local stores by the company and construction workers, and
- the value of contracts let to Council and other local organisations.

Close oversight and monitoring of the planning and implementation of the Blacktip Project would best be conducted by representatives of these relevant organisations.

8 Conclusion

Traditional Owners, members of the community and community organisations clearly have high expectations of benefits from the proposed Blacktip Project and it is not clear how realistic these expectations are. Certainly in relation to the provision of free gas and upgraded electricity generation infrastructure expectations appear unrealistic.

There is concern that realization of the benefits that the Project might deliver will require greater lead times than are currently being allowed for, if it is intended that the commencement date currently being proposed of the dry of 2005 is to be met.

Resources and information clearly need to be injected urgently into the community if this is the case.

As the demographic profiles and other social indicators suggest, the Wadeye community is a highly vulnerable community and engaging with this community will require sensitivity and sophistication on the part of the Proponent. Using existing organisations and involving them in participatory planning to the extent possible will be essential to preventing the potentially serious negative impacts such a vulnerable community might experience, and to maximising the benefits which the community clearly believes it will receive. For the Project to retain its mandate to operate it will need to proceed with caution and with a recognition of the volatility of the community and that there will likely be frequent opportunity for misunderstandings to arise.

9 Appendices

9.1 List of people interviewed

The names of Traditional Owners and Aboriginal community members interviewed have been provided to the NLC and are not included in this Report for confidentiality reasons. The following people were interviewed in their capacities representing local organisations:

Terry Bullamore, CEO, Thamarrurr Regional Council

Dale Seaniger, Deputy Council Clerk, Thamarrurr Regional Council

Scott McIntyre, Coordinator, Thamarrurr Rangers

Arthur Karui, Senior Ranger, Thamarrurr Ranger

Rick Blyss, Housing Manager, Housing Authority

Geoff Barker, Housing Management Consultant & Project Manager for "Fixing Houses for Better Health"

Sergeant Dean McMaster, Officer in Charge, Wadeye Police Station

Mark Crocombe, Coordinator, Kanamkek-Yile-Ngala Museum

Aloyshus Kungle, CDEP worker, Kanamkek-Yile-Ngala Museum

Theodora Narndu, Coordinator, Kardu Dari Kardu Family Centre

Russell Dejonge, Manager, Murrinhpatha Tribal Development

Rob Baildon, Manager, Mi Patha Takeaway and Bakery

Bob Tedcastle, CEO Murin Travel and Freight Service

John Hardy, Managing Director Hardy Aviation

Robin Files, Manager Murin Resource Centre

Aboriginal members of Murin Resource Centre (monthly meeting)

Noeline Dungul, Coordinator, Ngepan Patha Women's Centre

Peter Bunduck, Correctional Services Officer at Wadeye, NTG Correctional Services

Paul Donald, Manager, Palumpa Station

Kevin Slavin, Butcher based at Wadeye

Julie Reece, Manager, Wadeye Healthy Centre, RNs, AHWs and other Aboriginal staff

Stacey Long, Self Help and Respite Centre

Tobias Nganbe, Deputy Principle Our Lady of the Sacred Heart School , Aboriginal Teachers and non-Aboriginal school staff.

John Tarca, General Manager Gas Business Unit, Power and Water Corporation

Bertrum Birk, General Manager Remote Operations, Power and Water Corporation

Sean Lange, Manager NLC Indigenous Training and Employment Unit

Paul Josif, Manager NLC Land and Sea Management Branch

Michael Storrs, NLC Caring for Country Coordinator

Kimberley Bott, Solicitor, Top End Women's Legal Service

Vicky Brogan, Aboriginal Community Development Worker, Top End Women's Legal Service

9.2 Terms of reference

Blacktip Project
Social Impact Assessment
Terms of Reference

28 January 2004

Objectives

The purpose of the proposed Social Impact Assessment (SIA) is to:

- Identify the nature and magnitude of any potential social impacts, both positive and negative,
- Contribute to a better understanding of the Projects by those potentially affected and those with responsibilities towards potentially affected groups and individuals,
- Facilitate the expression of views, concerns and aspirations about the Projects by those potentially affected,
- Assist the Proponent and potentially affected people, communities and organisations, to plan activities associated with the Projects in such a way as to optimise the potential positive impacts and mitigate any potential adverse impacts on affected communities, and
- Provide the basis for compiling a Social Impact Management Plan for the Projects.

The preparation of the SIA will meet the requirements of the proponent in managing social impacts and in addition, will provide valuable information to the statutory regulators responsible for undertaking the Projects' approvals processes.

Tasks associated with the Impact Assessment

Profile the affected communities.
Undertake a stakeholder analysis, identifying all relevant organisational stakeholders in the affected areas.
Describe affected communities in terms of:

a) Governance arrangements
b) Land tenure
c) Community and social relations overview
d) Economic base
e) Enterprises
f) Infrastructure, services and facilities
g) Law and order
h) Social and health services
i) Outstation development
j) Capacity of existing infrastructure, services and facilities to meet people's current needs and aspirations in relation to the future of their communities.

Prepare a base-line data set for the affected communities, Indigenous and non-Indigenous.

a) Demographic profiles including age, gender and language.
b) Overview of the residential arrangements, the location and nature of the communities and their socio-economic status.
c) Health, education and employment status, access to a motor vehicle, housing density, economic status and traditional hunting and gathering activities. (Data to be drawn from existing studies where available).

Historical and legislative context

a. Provide a brief overview of the settlement and development history of the Northern Territory to provide an historical context within which to understand this current Project.

b. Document the broad history of the affected Aboriginal communities and Aboriginal associations within the Project region, including past engagement with outside economic and social forces, and in particular experiences with linear projects and onshore gas processing facilities.

c. Provide an overview of relevant mining-related income and other benefits received by communities to date from development in the region, and evaluate the social and economic impact of those benefits and the effectiveness of their method of distribution.

d. Outline the relevant legislative regimes affecting both Projects.

Attitudes to the Project

Assess the attitudes of affected people to the Projects, including whether they approve/disapprove or are neutral to the Projects. This is to be achieved through direct consultations with potentially affected people and communities and key community representatives in the areas associated with the Projects. In addition, a broad telephone survey of residents of Darwin and the Katherine region will be undertaken, as discussed above.

Identify impacts

Identify potential impacts, if any, in relation to pre-construction, construction, operation and/or maintenance and decommissioning in relation to:

a) The impacts of the potential interaction of the workforces with the existing Indigenous and non-Indigenous communities in the region.
b) Demographic shifts likely to result.
c) Potential impacts on social relations.
d) Community development.
e) Diseconomies.
f) Possible dissipation of benefits through cash distributions.
g) Impacts on the use of, and access to, culturally important sites, landscapes and the traditional economic resources of the Project area.
h) Maintenance of cultural knowledge.
i) Possibilities of increased availability and consumption of alcohol and other substance abuse and means of mitigating existing and potential future substance abuse problems.

j) Potential for infrastructure enhancement (medical facilities, communications, etc).
k) Potential for access to enhanced services (including to information and consumer goods) and general economic activity in the region.
l) Increased employment and business opportunities.
m) Changes to lifestyle.
n) Employment, training and recruitment opportunities and capacities.
o) Business development opportunities.
p) Likely impacts of upgrades to roads and increased traffic.
q) Possible health impacts.
r) Impacts of compensation benefits that may be negotiated.
s) Cumulative impacts.
t) Likely impacts in the event of the Project not proceeding.
u) Concerns about and impacts arising from emergency events.
v) Impacts of the SIA process itself.

Identify any other impacts likely to result from the Projects.

Need for management strategies

After identification of the potential impacts, recommendations regarding which of these should require specific mitigation or optimisation, management strategies. These may include:

a) Impacts on the environment;
b) Impacts on sacred site and other places of cultural importance;
c) Opportunities for training, employment and business development.
d) Communication and management structures and policies to maximise information flows to and from the Projects.
e) Preferred policies regarding the availability of alcohol.
f) Insulation and isolation strategies to manage the presence and potential negative intrusion of large workforces in the vicinity of the Projects;
g) The provision of cultural awareness programs and behavioral guidelines for Project employees; and
h) The need, or otherwise, for a Social Impact Management Plan.

Capacity to respond

a) Assess the capacity of affected people to respond to the impacts of the Projects.
b) Recommend where capacity-building interventions are required.
c) Evaluate the capacity of contemporary structures of traditional Aboriginal owners and their communities to make the decisions necessary to manage future impacts and opportunities.
d) Summarise the benefits and disadvantages from an Indigenous and non-Indigenous community perspective for proceeding with the Project.

Monitoring and Evaluation

The following should be devised following the identification of any potential social impacts:

a) Suggest monitoring and evaluation strategies.
b) Identify appropriate indicators for monitoring.
c) Advise on issues pertaining to, and possibly suitable models, for governance of monitoring and mitigation management.

9.3 References and bibliography

ACIL Tasman Pty Ltd (2004) *Thamarrurr Region Economic impact assessment Summary assessment of the economic impact of the integrated Blacktip – Trans Territory Pipeline – Alcan Gove Gasification Project. Final Draft Report.* Prepared for Woodside Energy Ltd, Eni Australia B.V. and Alcan (Gove) Pty Ltd

Community Development, Sport and Cultural Affairs, Department of (2003) *Thamarrurr Brief,* Northern Territory: Unpublished.

English, Gay. (2002) *Three Year Strategy Framework for a Northern Land Council Capacity-Building Program*. Northern Land Council. Unpublished.

Kardu Numida Inc. (2003) *General Purpose Reports for the year ended 30 June 2003.* Unpublished.

Matchplay Engineering Services P/L (2003) *Road Condition Report*, Prepared for Thamarrurr Regional Council and NT Government Department of Infrastructure, Planning and Environment, Unpublished

Northern Land Council (2003) *Northern Land Council Caring for Country Strategy 2003-2006.* Casuarina: Northern Land Council (unpublished).

Northern Land Council (2004) *Capacity-building for Indigenous Economic Development: A briefing for the Indigenous Economic Development Taskforce.* Casuarina: Northern Land Council (unpublished).

Savvy Community Development Consultants (2002) *3 Year Strategy Framework for a Northern Land Council Capacity Building Program*. Unpublished.

Taylor, J (2003) *Baseline Profile of the Thamarrurr Population: A Report to Thamarrurr Regional Council and the Northern Territory Office of Indigenous Policy,* Canberra, ANU: Centre for Aboriginal Economic Policy Research, Unpublished

Thamarrurr Regional Council (2004) *Development of a formal natural resource management structure within the Regional Thamarrurr Regional Council.* Wadeye, Unpublished.

Thamarrurr Rangers Planning Books (A3 x 2 booklets)

Woodside Energy Ltd (2004) *Blacktip Development Phase 2B: Northern Territory Environmental Assessment Act 1982 and Administrative Procedures 1984. Notice of Intent.*

www.indiginet.com.au/wadeye

www.lgant.nt.gov.au/lgant/content/view/full/545

www.nt.gov.au/dcm/Indigenous_policy/Indigenous_policy

Appendix N

Blacktip Project – EIS Health Programme Project Health Review prepared by Worley






This page has been left intentionally blank

Worley

WOODSIDE ENERGY LTD

Blacktip Project - EIS Health Programme

Project Health Review

450/07245/0

23-Apr-04

Level 6, QV1
250 St Georges Terrace
Perth, Western Australia 6000
Tel: +61 8 9278 8111
Fax: +61 8 9278 8110
Web: http://www.worley.com.au
Worley Pty Ltd
ABN 61 001 279 812

© Copyright 2004 Worley Pty Ltd

Projects • Technologies • Services • Developments

SYNOPSIS

This report is a desktop study of Health related Hazards for the Blacktip Gas Project. It addresses typical Oil and Gas Industry Hazards for Design Office, the offshore Platform, contracted vessels and the drilling Rig, and the marine and onshore pipelines to, and from, the Onshore Gas Plant (but not the Trans Territory pipeline) and the Gas Plant itself. The report reflects the stage of development of the project with initial risk screening proposals for further studies and support identified where data is currently unavailable. Some cross references to existing Project documents and procedures has been included however population of the 'Procedures' column requires additional input to confirm all identified risks are addressed within the Project Safety Management System documentation.

Disclaimer

This report has been prepared on behalf of and for the exclusive use of Woodside Energy Ltd, and is subject to and issued in accordance with the agreement between Woodside Energy Ltd and Worley Pty Ltd. Worley Pty Ltd accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

Copying this report without the permission of Woodside Energy Ltd or Worley Pty Ltd is not permitted

PROJECT 450/07245/0 - BLACKTIP PROJECT - EIS HEALTH PROGRAMME

REV	DESCRIPTION	ORIG	REVIEW	WORLEY APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Issued for internal review	R J Shepherd	B Kahl	N/A	19-April-04	N/A	
B	Issued for Client Comment	R J Shepherd	B Kahl	C James	23-April-2004	C Morgan	

CONTENTS

1. Introduction 1
1.1 Abbreviations 3
2. Background 4
3. Discussion 6
4. Conclusions 7
5. References 9

Appendices

Appendix 1. – Design Office Health Risks
Appendix 2. – Offshore Platform Health Risks
Appendix 3. – Marine Vessels and Drilling Rig Health Risks
Appendix 4. – Onshore Gas Processing Plant Health Risks
Appendix 5. – Pipeline from Platform to Plant Health Risks
Appendix 6. – Outline Health Programme

1. INTRODUCTION

This preliminary desktop study addresses the Blacktip Gas Project Health related issues. These have been listed, project phase applicability assigned, whether the potential health exposure is to the project workforce or to the public assigned, and a statement of how the issue is normally addressed within the Oil and Gas Industry made.

The issues have then undergone an initial screening, with those of highest significance being identified for further study, work or control. In most instances application of Woodside's, or reputable, experienced contractors, existing procedures should be sufficient to control and mitigate potential health effects; the Woodside Energy Ltd. (WEL) procedures are cross referenced where appropriate.

An outline Health Plan for the Project has been derived from the assessment to ensure carry forward of the significant issues, identified during Front End Engineering Design (FEED) stage, which require further study or work during late FEED, Detailed Design and Operations. It is expected that the document will be revisited during these project development stages, and again prior to decommissioning.

The document is valid at the time of issue based on available data and information and is intended to form the basis for initiation of ongoing Blacktip Project Health Planning. The assessments will require review and update as more information, or changes in available data, become apparent through project development and operations.

The high level study is limited to the Design Office Work (assumed to be in Perth, Western Australia), Offshore Platform, typical Marine support vessels and drilling rig, pipelines to the Onshore Gas Processing plant and from the Gas Plant back offshore; it does not address the Trans Territory pipeline from the Onshore Gas Processing Plant to Gove.

Project Overview

At BOD it is envisaged that the Blacktip field will be developed with a unmanned Wellhead Platform (WHP), a 16" multiphase pipeline to shore and an onshore gas plant. Sales quality gas will be delivered at the fenceline of the onshore gas plant for onward transmission by others to Gove, in a pipeline measuring almost 960 km.

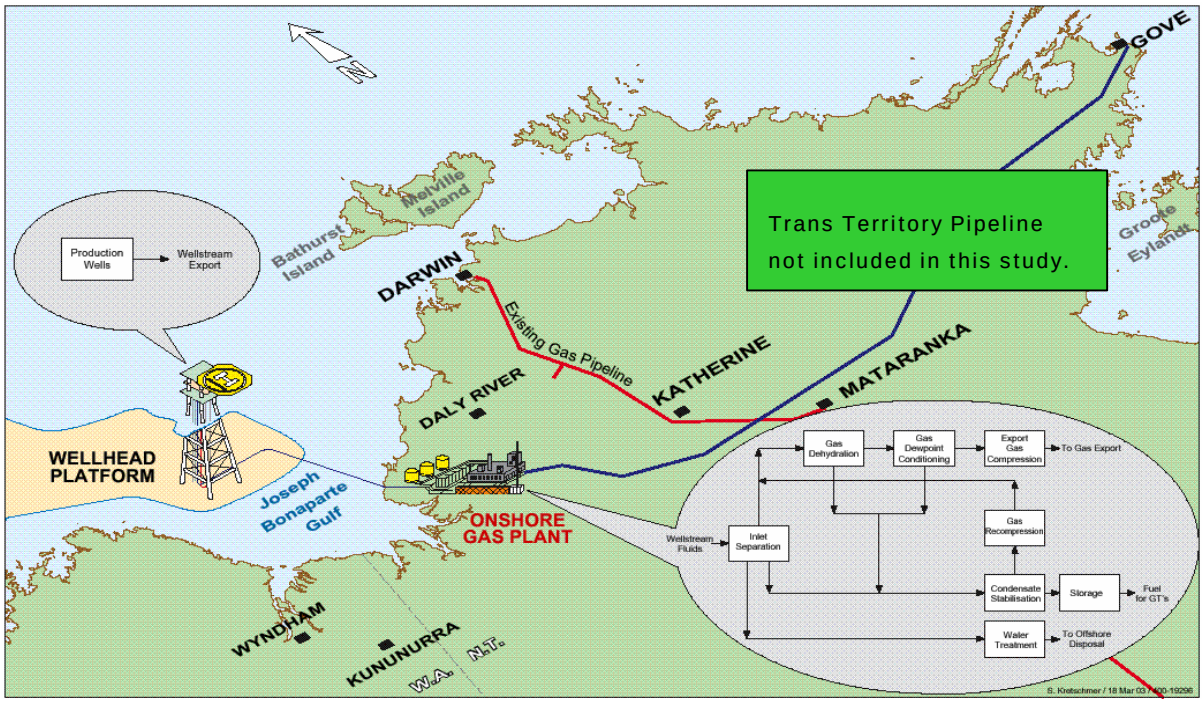
The Onshore Gas Plant facilities will consist of a single process train using Silica gel technology. The sales quality product gas will be exported via 2 x 100% gas turbine driven centrifugal compressors.

Condensate is stabilised in a flash stabilisation system. Stabilised condensate will be exported via a spread mooring situated some 3-4 km offshore.

Produced water is let down in pressure with dissolved gases removed in a degasser. Bulk oil is then removed in an air flotation unit before the water is polished in a settling pond. The effluent water will be disposed of to sea.

A graphic representation of this base case is presented in Figure 1.

Figure 1 Blacktip Base Case



1.1 Abbreviations

ALARP	As Low as Reasonably Practical
BOD	Basis of Design
BTEX	Benzene, Toluene, Ethyl Benzene, Xylene
EIS	Environmental Impact Statement
FEED	Front End Engineering Design
HAZID	Hazard Identification workshop-study
HAZOP	Hazard and Operability workshop-study
Hg	Mercury
HSE	Health Safety and Environment
HU&C	Hook Up and Commissioning
H_2S	Hydrogen Sulphide
IPIECA	International Petroleum Industry Environmental Conservation Association
LSA	Low Specific Activity scale (a form of NORM)
MSDS	Material Safety Data Sheet
NORM	Naturally Occurring Radioactive Material
PPE	Personnel Protective Equipment
WEL	Woodside Energy Limited

2. BACKGROUND

Potential Oil and Gas related Health issues are discussed in a variety of industry related documents. At the world level The World Bank Environment Department's Health Aspects of Environmental Assessment Environmental Assessment Sourcebook, Number 18, Update, July 1997 indicates that 'Exposure to chemicals' and 'Occupational Injuries' are oil and gas sector project related risks.

The International Association of Oil and Gas Producers reports on Strategic Health Management: Principles and Guidelines for the Oil and Gas Industry (Report No. 6.88/307, June 2000), Key Questions in Managing Social Issues in Oil and Gas projects (Report 332, October 2002, with IPIECA) and Managing Health for Field Operations in Oil and Gas Activities (Report No. 343, May 2003) provide more specific analysis of the industry's potential health related impacts.

Standards Australia provides a framework for Occupational Health and Safety management systems in standard AS/NZS 4801: 2001, to address the potential hazards, Oil and Gas proponents, operators and major contractors, generally develop sophisticated Safety Management Systems and specific HSE / Health Related procedures and guidance to control identified potential risks.

Woodside Energy Limited (WEL) has a management system, existing Corporate procedures, considerable practical experience and these are available to and being utilised as appropriate by, the Blacktip Gas Project team. WEL's contracting and HSE approach will ensure that appropriate standards are also in place with their subcontractors.

The intent of this document is to identify, address and provide a preliminary assessment of the health issues, with respect to WEL's Blacktip Gas Project in relation to the first dot point of Section 6 Health and Safety Programme of the EIS Guidelines- Part B, issued by the Northern Territory Government in March 2004. It is understood that the second two dot points will be addressed by WEL.

A number of health related WEL Blacktip Gas Project internal project documents were reviewed during preparation of this report, including eg Basis of Design Data Sheets 'HSE Management' (Ref Drims # 472620) and 'Health and Ergonomics Requirements' (Ref Drims # 476360), which provide the link (and reference to) Woodside's corporate HSE management system, policy (Codes and Standards) procedures and project documentation (References). The Blacktip Remote Area Access Guidelines (Ref Drims # 144703) also provides some specific health related guidance.

Part of the Projects developing documentation is the preparation of a Regulatory Register, designed to capture relevant regulations with which compliance must be achieved as a minimum; for the Blacktip project the prime regulatory influences are the Commonwealth Environment Protection and Biodiversity Conservation Act, 1989, Petroleum (Submerged Lands) Act 1967, and the Northern Territory Environmental Assessment Act, 1982, and relevant health regulations.

Additional background information has been gained from Building Healthier Communities, A Framework for Health and Community Services 2004-2009, and other internet available, publications, produced by the Northern Territory's Government's Department of Health and Community Services, and from Indigenous Health Matters, published by the Department of Health and Ageing of the Office for Aboriginal and Torres Strait Islander Health.

Other WEL Blacktip Gas Project internal project documents reviewed during preparation of this report are identified in section (5 References) below.

3. DISCUSSION

The attached Matricis (Appendicies 1-5) list potential health impacts in terms of Location, Physical, Chemical, Biological and Psyco-social hazards versus their Project Phase (ie Design, Construction, Operations (Maintenance and Shutdown) and potential impacts on the Public or Employees (ie Project Personnel), for Office work, the normally unmanned Platform, contracted Vessels and drilling Rig, the Pipeline from (Offshore) Platform to (Onshore) Gas plant , and the Gas Processing Plant itself.

The health hazards are not unique to the Blacktip Project and therefore existing management approaches, which recognise the (remote) location and local community issues, are expected to be adopted by the project with a minimum of alteration. Many of these are specifically addressed in WEL's Basis of Design Data Sheet 'Health and Ergonomics Requirements (Ref Drims # 476360), and the references, Codes and Standards identified within that document.

Areas where more study and or more control may be needed are identified. It should be noted that this report is a desktop study aimed at identifying likely potential impacts in a systematic manner. The preliminary screening results should be reassessed as the project develops and may change as further information or data becomes available, and as specific aspects of the project are subject to other risk assessment processes (eg HAZID and HAZOP).

The Matrices were developed in two stages;

Stage 1

- Risks were listed, potential exposures and typical (assumed) Oilfield controls noted.
- An initial screening was carried out to determine expected Low, Medium or High risks, in the opinion of the author.

Stage 2

Items assessed to have Medium or High risk were further considered and more specific existing controls sought. Where there was uncertainty about the potential for a health risk, due to lack of information at this stage of the project, the item has been noted as requiring

- further study,
- a new procedure (or project modification of an existing procedure) or
- external support requirement

To ensure appropriate mitigation of potential risks to employee or public health.

A number of the potential issues are addressed in the requirements of Guidelines for Preparation of a Draft Environmental Impact Statement for the Proposed Blacktip Gas Project, and, while the EIS and the Social Impact Assessment documents are still in preparation, cross reference is made, in the further study column of the matrix, to allow checking of information / consistency of approach with these documents when available.

4. CONCLUSIONS

No unusual Health related risks were identified for the offshore works provided WEL's normal sub contractor hire selection and contract process is followed, and Safety Case (and bridging document) development follows appropriate industry standards.

Onshore works hazards to the workforce are largely related to the remote location, very limited local medical support, potential interaction with wildlife (snakes, bighting insects etc) and subsequent bacterial or viral infection, heat-humidity and exposure to the sun, and occupational hazards (slips, trips, strains, and falls). These hazards may be compounded if effective communications are not available.

Potential impacts to the public from the facilities (eg noise, lighting, exhausts, etc) are unlikely, however if construction and operational sites are not secure, then there are risks to curious third party intruders. In this respect special security consideration should be given to rotating or mobile machinery (vehicles, cranes, motors etc) hazardous materials, chemicals and any medicines stored on site.

Social interaction with the local community may give rise to the potential for a variety of impacts, which should be addressed in the Social Impact Assessment; from a health perspective the most significant is the (two way) spread of diseases. Construction workforce interaction may be minimal, dependant on entertainment facilities provided in the construction camp and management policy for shift rotas and domestic issues, including use of local accommodation and facilities.

Physical and Chemical Issues are typically addressed in the Basis of Design and it is expected that once the Data sheets for that document for the Blacktip Project are completed, in accordance with the HSE Management sheet (Drims Ref 476360) these will be adequately addressed.

Chemical selection has not been finalised and therefore their mode of use and disposal route remain uncertain. However, development of a project specific operational chemical control procedures and a Waste Management Plan should address Health, safety and environmental concerns with respect to chemicals: this may be best addressed when actual chemicals are selected, design finalised and a Waste Disposal Contractor chosen.

The intended unmanned operation of both the offshore and onshore plant, in a remote area, present a number of health related concerns which will need to be addressed prior to adopting that mode of operation. Ad hoc visits to the field are currently controlled by the Blacktip Remote Area Access Guidelines (Ref Drims # 144703). It is expected that these will be developed and information included in pre visit induction and a re-occupation-leaving site training and information sheets/procedures eg a Site Visit checklist to address HSE related issues, including a preliminary site inspection to ensure that eg there are no dangerous animals present, water lines are flushed to 'spec' quality, safety and emergency gear and communications equipment are serviceable, First Aid kit is complete for the intended work, that there are no leaks or spills and stored inventories (eg chemicals, consumables etc) are present and secure; and on leaving the site that eg wastes are removed, materials are all securely stored, fridges clean and secure, and that consumable or perishable items requiring replacement for the next site visit are identified.

An outline Health Programme is given in Appendix 6.

5. REFERENCES

1) Health Aspects of Environmental Assessment Environmental Assessment Sourcebook, Number 18, Update, July 1997, World Bank, Environment Department

2) Strategic Health Management: Principles and Guidelines for the Oil and Gas Industry (Report No. 6.88/307, June 2000), International Association of Oil and Gas Producers

3) Key Questions in Managing Social issues in Oil and Gas projects (Report 332, October 2002) International Association of Oil and Gas Producers with IPIECA

4) Managing Health for Field Operations in Oil and Gas Activities (Report No. 343, May 2003) International Association of Oil and Gas Producers

5) Occupational Health and Safety Management Systems (AS/NZS 4801: 2001) Standards Australia

6) Guidelines for Preparation of a Draft Environmental Impact Statement for the Proposed Blacktip Gas Project, Part A & Part B, March 2004, Northern Territory Government.

7) Environment Protection and Biodiversity Conservation Act, 1989,

8) Petroleum (Submerged Lands) Act, 1967, Commonwealth Government.

9) Environmental Assessment Act, 1982, Northern Territory

10) Building Healthier Communities, A Framework for Health and Community Services 2004-2009, Northern Territory Government Department of Health and Community Services.

11) Blacktip Project Description (Drims # 277733, Ver 2) 2003, WEL

12) Blacktip Development Phase 2B- HSE Goals and Objectives (Drims # 402124, Ver 0) 2003, WEL

13) Blacktip Phase 2 & 3 Health, Safety and Environment Management Plan (Drims #381389, Ver 0) 2003, WEL

14) Blacktip Unmanned WHP Safety Philosophy (Drims # 251619, Rev 0) 2003, WEL

15) Blacktip Development Phase 2B – Onshore Gas Plant Safety Philosophy (Drims # 254669, Rev 0) 2003, WEL

16) BOD Data Sheet – Offshore Safety Requirements (Drims # 466709, Ver A) 2004, WEL

17) BOD Data Sheet – Onshore Safety Requirements (Drims # 466850, Ver A) 2004, WEL

18) BOD Data Sheet – HSE Management (Drims # 472620, Ver A) 2004, WEL

19) Blacktip Development Phase 3 Basis of Design Data Sheet Health and Ergonomics (Drims # 476360, Ver A) 2004, WEL

CONT

20) Blacktip Development Phase 3 Basis of Design Data Sheet Non-Flammable Hazard Requirements (Drims # 477556, Ver A) 2004, WEL

Appendix 1. – Design Office Health Risks

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Office Location													
Geographical Location													
Heat / Cold	*						*	Utilities Maintenance Program in Office	Typically low risk environment.	Low			
Humidity	*						*	Utilities Maintenance Program in Office	Typically low risk environment.	Low			
Daylight	*						*	Office blinds on windows / Lighting	Typically low risk environment.	Low			
Transport / Communications / Infrastructure	*						*	Town Supply	Perth facilities	Low			
Location of Health Facilities	*						*	Town Supply	Perth facilities	Low			
Standard of Facilities & staff Competency	*						*	Town Supply	Perth facilities	Low			
Security	*					*	*	Public do not normally have access to Project office locations, unless escorted	Typically low risk environment	Low			
Natural disasters	*						*	Perth is low risk location	Typically low risk environment. Public do not normally have access to office locations, unless escorted	Low			
Physical													
Noise	*						*	Typically low risk environment		Low			
Vibration	*							Not relevant		Low			
Pressure	*							Not relevant		Low			
Ionising Radiation	*							Not relevant		Low			
Non Ionising Radiations	*						*	Typically low risk environment	Recreational issue (out of working hours)	Low			
Thermal Work Environment	*						*	Air Conditioning / Heating		Low			
Ergonomic/manual Handling	*						*	Office Design & Furniture. Little Manual Handling. Lifting aids.		Low			
Machinery	*						*	Typically low risk environment		Low			
Sharp objects	*						*	Typically low risk environment		Low			
Display Screen equipment	*						*	Ergonomic assessment and information		Low			
Transport during work	*						*	Couriers used, Public Transport available.		Low			
Chemical													
Toxic Chemicals	*						*	Generally restricted to contract cleaners chemicals	Subcontracted specialist cleaners. Locked store. Periodic Audits	Low			
Dusts, mists & fumes	*						*	Hazardous materials, smoking etc,banned from workplace. Air Con/photocopier maintenance. Periodic HSE audits		Low			
Sensitisers	*						*	Not relevant		Low			
Carcinogens								Not revlevant	Smoking Banned within offices	Low			
Biological													
Wildlife (animals/reptiles/insects/plants)	*						*	Office Cleaning; periodic HES audits		Low			
Sexually Transmitted disease	*					*	*	Town available Medical Facilities	Pre Employment Medicals	Low			
Endemic/epidemic disease	*					*	*	Town available Medical Facilities	Pre Employment Medicals	Low			
Occupational Illness	*						*	Workplace ergonomic design/training	Pre Employment Medicals.	Low			
Food & Drink	*						*	Town Supply		Low			
Hygiene (catering/accommodation/toilet facilities/waste disposal)	*						*	Town Supply / Building Codes		Low			
Psyco-Social													
Isolation (access to social support)	*						*	Typically low risk environment.	Pre Employment Medicals	Low			
Communication problems (business & family)	*						*	Typically low risk environment.		Low			
Culture, local law, religion & language	*						*	Typically low risk environment.		Low			
Job design	*						*	Typically low risk environment. Office Ergonomics	Pre Employment Medicals	Low			
Job organisation	*						*	Design house management practice.		Low			
Leisure and recreational facilities	*						*	Typical Town Supply.	8 hour day (26 hr R&R)	Low			
Prostitution	*						*	Typical Town Supply		Low			
Stress factors	*						*	Typically a low risk environment	Pre Employment Medicals	Low			
Substance abuse	*						*	Drug & Alcohol Policy	Pre Employment Medicals	Low			
Smoking	*						*	Drug & Alcohol Policy	Pre Employment Medicals	Low			

Appendix 2. – Offshore Platform Health Risks

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Field Work: Offshore													
On Unmanned Facility: Platform													
Geographical Location													
Heat / Cold		*	*	*	*		*	Tropical environmental concerns, typical of work in the area. Work planning & rotas.	Personal Protective equipment (boilersuits etc). Adequate supply of potable water. Local shade where practical & safe.	Low	See Health Aspects of Work in Extreme Climates within the E&P Industry: The Heat. E&P Forum Report No 6.70/279 1998	Awareness training	
Humidity		*	*	*	*		*	Work planning and rotas. Refuge with Air Conditioning (HVAC) to be evaluated in design	Acclimatisation and awareness training.	Low		Awareness training	
Daylight		*	*	*	*		*	normally unmanned. Shift routines, Platform lights		Low			
Transport / Communications / Infrastructure		*	*	*	*		*	Platform will have communications & transport Helicopter/vessel) when required. Shore based infrastructure & office support.	Vessel will be nearby when platform is manned	Low			
Location of Health Facilities		*	*	*	*		*	Emergency Response Procedures for onshore support. First aider on board.	(Medivac)	Medium	Local (onshore) medical facilities adequacy to be reviewed.		WEL Medical adsviser
(Limited Medical Facilities in field)							*	Standby Vessel Facilities	First Aid/Ships facilities	Low			
			*				*	Accommodation Barge Facilities	Medical Suite & Medic	Low			
						*	*	Helicopter on location. Visitors accompanied	Unlikely visitors will travel by boat	Low			
Standard of Facilities & staff Competency		*	*	*	*		*	Designed to Australian / International Standards. Staff competencies part of HR hire and contracting procedures and staff training. O'night refuge & toilet arrangements, to be considered in design.		Low	Bod		Engineering and HR support
Security		*	*	*	*		*	Unmanned facilities far offshore. Fishing/Pirates/Boatpeople risk: Radar, CCTVand 'difficult' access arrangements to be considered in design.		Medium	Security v Access to be studied in Design		Security study
Natural disasters		*	*	*	*		*	Installations designed to appropriate earthquake, cyclone, etc standards. Personnel should not be onboard if there is a risk.		Low	Shutdown / Cyclone and evacualtion philosophy to be defined.	Evacuation Procedures	Operations input to Design.
Physical													
Noise		*	*	*	*		*	Limited by design (predictions & modelling), Insulation, Hearing Protection.		Low	Commissioning validation survey for noise predictions.	BoD Data Sheet Health & Ergonomics Drims # 476360	
Vibration		*	*	*	*		*	Limited by design. Task design (eg paint chipping using vibrating tool or nail gun)		Low			
Pressure		*	*	*	*		*	Contained. Vents / Flare in safe location	Pressure Tests (controlled condtions)	Low			
Ionising Radiation		*	*	*	*		*	Closed source design if required and operating procedures ; only open source may be NORM, for which procedural controls exist.		Medium	Assessment of formation water chemistry/potential for NORM formation	BoD Data Sheet Health & Ergonomics Drims # 476360	Scale formation potential study
Non Ionising Radiations		*	*	*	*		*	Design, operating & maintainance procedures addresses safe distances and barriers for non ionising radiations (eg electromagnetic, microwave, radio wave). UV (sunlight) sunscreen provided to workforce.		Low	Commissioning validation survey for stray radiation.	BoD Data Sheet Health & Ergonomics Drims # 476360	
Thermal Work Environment		*	*	*	*		*	Geographical location dominant: hot-cold plant insulated / shielded. Vessel entry procedures & forced air if required.		Low		BoD Data Sheet Health & Ergonomics Drims # 476360	
Ergonomic/manual Handling		*	*	*	*		*	Ergonomics considered during design. Provision of cranes and lifting devices.		Low			
Machinery		*	*	*	*		*	Rotating machinery is guarded, noise insulated & accessible for maintenance.		Low			
Sharp objects		*	*	*	*		*	Sharp objects eliminated in design. Little / no requirement for eg glass or syringes etc.		Low			
Display Screen equipment		*	*	*	*		*	Considered as part of ergonomic design		Low			
Transport during work		*	*	*	*		*	Flying (noise/vibration) or sea transport, normal part of oilfield work: typical safety systems in place	Marine approach to Platform- Basket transfers would require special consideration, including personnel fitness.	Medium	Platform access-security arrangement study in Design		Security Study
Chemical													
Toxic Chemicals		*	*	*	*		*	Highest risk during construction: use experienced contractors and appropriate procedures, including chemical selection. MSDS must be available at location of use. Potential exposures to Commissioning fluids should be minimised by job design. Other Hazardous materials (eg mineral fibres) to be identified. Operational chemical use to be considered in design to minimise handling and exposures	Australian Institute of Petroleum (AIP) Health Watch program. Produced fluid compositional analysis underway: for eg polonium, radium and mercury. Preliminary data shows H2S 10ppmv, mercaptans not detected and an estimated BTEX of 20,20,10,10 ppmv respectivly, Ref Drims # 277733	Medium	Specific listing of chemicals and hazardous materials to be developed and assessed. Antidote to be available if any poisons are required. Future eg workover hazards are not assesed: but may be 'typical' and should be assessed when proposed. Health Risk Assessments.		Engineering and drilling to detail chemicals & hazardous materials
Dusts, mists & fumes		*	*	*	*		*	Highest risk during construction: use experienced contractors eg coded welders, procedures (habitat & extraction/forced air ventilation). Ensure maintanence addresses leaks (& eg oil mists)		Low	Health Risk Assessments.		
Sensitisers		*	*	*	*		*	Highest risk during construction & operations: procedures to address, if health risk assessment indicates potential.		Low			
Carcinogens		*	*	*	*		*	Generally not permitted as 'chemicals': product not expected to contain aromatics, BTEX, etc; health risk assessment, use of PPE		Medium	Confirmation that no carcinogens are present required.		
Biological													
Wildlife (animals/reptiles/insects/plants)		*	*	*	*		*	Vessels & Platform subject to Quarantine inspection on arrival in Australian waters. Personnel hygiene. Marine species generally do not present significant risk and marine staff are generally aware of the dangers of stinging jellyfish, sharks and sea snakes.		Low		Awareness Training	
Sexually Transmitted disease		*	*	*	*		*	Pre employment medicals. Onshore and Offshore medical facilities		Low		Awareness Training	
Endemic/epidemic disease		*	*	*	*		*	Pre employment medicals. Onshore and Offshore medical facilities		Low		Awareness Training	

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Occupational Illness		*	*	*	*		*	Sprains & strains, potential chemical exposures; pre employment medicals, platform design, ergonomic guidance & procedures mitigate		Medium	Ongoing Safety awareness campaigns to minimise 'slips, trips and falls'.	Awareness Training	
Food & Drink		*	*	*	*		*	BYO Food & Water. Eski-Fridge facilities required for operational visits. Adequate water to be taken to platform on each visit.		Low			
Hygiene (catering/accommodation/toilet facilities/waste disposal)		*	*	*	*		*	Accommodation Barge- attendant vessel Facilities during periods of high manning. Platform fixed or temporary arrangement definition required. Use of professional catering company.	Galley, Water makers, ablutions	Low	Audit programme		
		*	*	*	*		*	Planned (Day) Work Program.	Accommodation Barge / Rig Facilities if onsite (24 hour work).	Low			
		*	*	*	*		*	Temporary Sanitary and waste arrangements (eg Chemical Toilets and all wastes removed each visit) to be defined (& approved). WEL Blacktip Project Waste Management Plan	On Platform / by helicopter (for eg day trippers). Correct Waste disposal (identification, labelling, manifesting etc) is important to minimising risks to onshore personnel.Use of IMDG trained logistics personnel mitigates risks.	Low - Medium		Waste Management Plan to address issues.	Engineering input and catering company input.
Psyco-Social													
Isolation (access to social support)		*	*	*	*		*	Available Communications. Normal offshore work practices & entertainments as available. Pre employment interview / medicals.		Low			
Communication problems (business & family)		*	*	*	*		*	Available Communications. Normal offshore management issues. Compassionate leave arrangements.		Low			
Culture, local law, religion & language		*	*	*	*	*	*	Normal offshore management issues. Pre employment interview. Catering facilities may need to consider dietary requirements		Low			
Job design		*	*	*	*		*	Planned Work Program. Ergonomics in Design. Lifting Aids	Pre Employment Medicals	Low			
Job organisation		*	*	*	*	*	*	Offshore job planning and experienced supervision / management.		Low			
Leisure and recreational facilities		*	*	*	*		*	Vessel and Rig facilities evaluated pre hire. Unmanned platform limited to comms & 'emergency' overnight accomodation.		Low	Pre Hire audit		
Prostitution								Not relevant offshore		Low			
Stress factors		*	*	*	*		*	Onshore Communications. Recreational Facilities. Emergency Response training	Pre Employment Medicals	Low			
Substance abuse		*	*	*	*	*	*	Pre employment medicals. Oilfield facilities are alcohol free. Heliport inspections and /or controls.	WEL Drug & Alcohol Policy	Low			
Smoking		*	*	*	*	*	*	Controlled (restricted) on offshore instalations and vessels for safety reasons	WEL Drug & Alcohol Policy	Low			

Appendix 3. – Marine Vessels and Drilling Rig Health Risks

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Field work on Subcontracted Vessels													
Pipelay Barge, Standby & Supply vessels, drilling rig													
Geographical Location													
Heat / Cold		*			*		*	Tropical environmental concerns, typical of work in the area. Work planning & rotas.	Personal Protective equipment (boilersuits etc). Adequate supply of potable water. Local shade where practical & safe.	Low		Awareness Training	
Humidity		*			*		*	Work planning and rotas. Accomodation with Air Conditioning (HVAC)	Acclimatisation	Low		Awareness Training	
Daylight		*			*		*	Standard (24 hour operation)rig shift & vessel watch routines, Onboard lighting		Low			
Transport / Communications / Infrastructure		*			*		*	Rig & Vessels have communications (& transport Helicopter/vessel) when required. Shore based infrastructure & office support.		Low			
Location of Health Facilities		*			*		*	Medic & First aider(s) on board. Emergency Response Procedures for onshore support.	(Medivac)	Medium	Local (onshore) medical facilities adequacy to be reviewed.		WEL Medical Adviser review
(Limited Medical Facilities in field)		*			*	*	*	First Aid, Rig and Ships facilities	Helicopter on location for rig visits. Visitors accompanied	Low			
Standard of Facilities & staff Competency		*			*		*	Designed to maritime etc Standards. Staff competencies part of HR hire and contracting procedures and appropriate (eg IADC/Maritime) training.		Low			
Security		*			*		*	24 hour operation and watch system, radar		Low			
Natural disasters		*			*		*	Seagoing design of vessels, mariner competency, meterological information, risk assesment (included in Safety Case) and emergency response procedures (including eg rig manning philosophy in Cyclones)		Low			
Physical													
Noise		*			*		*	Design, maintanance and insulation. Hearing protection . Flights at night to be avoided where practical; helicopter flight paths to avoid areas of habitation where practical.		Low			
Vibration		*			*		*	Limited by design. Task design (eg paint chipping using vibrating tool or nail gun)		Low			
Pressure		*			*		*	Contained: see Rig Safety Case which includes hazard assessments. Diving spread (if used) to have decompression facilities etc. Emergeny arrangements to be addressed in ERP / bridging documentation.		Low	Diving Emergency arrangements to be addressed in ERP / bridging documentation.		
Ionising Radiation		*			*		*	Closed source design, compliance with regulations and operating procedures. Pip tags and Well logging procedural controls exist. Prejob JHA to ensure awareness		Low		JHA procedure	
Non Ionising Radiations		*			*		*	Design, operating & maintainance procedures addresses safe distances and barriers for non ionising radiations (eg electromagnetic, microwave, radio wave). UV (sunlight) sunscreen provided to workforce.		Low			
Thermal Work Environment		*			*		*	Geographical location dominant: hot-cold plant insulated / shielded. Entry procedures & forced air if required.		Low			
Ergonomic/manual Handling		*			*		*	Ergonomics considered during design. Provision of cranes and lifting devices.		Low			
Machinery		*			*		*	Rotating machinery is guarded, noise insulated & accessible for maintenance.		Low			
Sharp objects		*			*		*	Sharp objects eliminated in design. Little / no requirement for eg glass or syringes etc.		Low			
Display Screen equipment		*			*		*	Considered as part of ergonomic design		Low			
Transport during work		*			*		*	Flying (noise/vibration) or sea transport, normal part of oilfield work: typical safety systems in place	Basket transfers require special consideration	Low	Crew change location and procedure to be defined.		Logistics support
Chemical													
Toxic Chemicals		*			*		*	Toxics avoided where possible. Any Poisons onboard registered and antidote locally available. Procedures devised for use. MSDS available (including emergency contact number). Secure storage of chemicals employed. Awareness presentation may be utilised where appropriate. Health Risk Assessment carried out and available to potential users.	Specialists (eg Mud and Cement Co) generally 'up to speed' on MSDS and Health Risks. Generic Health Risk assessments may be available from contractors.	Medium	Specific listing of chemicals and hazardous materials to be developed and assessed. Antidote to be available if any poisons are required.		Engineering and Drilling to detail chemicals & hazardous materials
Dusts, mists & fumes		*			*		*	Welding, soldering, mud, and cement handling carried out to procedure in controlled areas with forced air ventilation / extraction & shrouds/containment for dusts. Machinery oil mists minimised by good maintainance. Suitable PPE available as last resort.	Rig Health Risk Assessments for their operation may be available: issues to be addressed in the Rig Safety Case.	Medium	Specific listing of chemicals and hazardous materials to be developed and assessed, including mud formulation, cement and addatives, etc. Antidote to be available if any poisons are required.		Drilling and Engineering to detail chemicals and hazardous substances
Sensitisers		*			*		*	Sensitisers avoided where possible. Work practices designed to minimise exposures, barrier cream, PPE (respiratory and gloves) available. Awareness presentation may be utilised where appropriate. Health Risk Assessment carried out and available to potential users.	Medical surveliance: sensitised persons allocated alternative work where practical.	Low	May be dependant on mud type selected / drilling personnels previous sensitisation.		Drilling Contractor review
Carcinogens		*			*		*	Carcinogen use avoided where practical; procedural controls and PPE where use is unavoidable. Awareness presentation may be utilised where appropriate. Health Risk Assessment carried out and available to potential users.		Medium	Confirmation that no carcinogens are present required.		Engineering to detail chemicals & hazardous materials
Biological													
Wildlife (animals/reptiles/insects/plants)		*	*		*		*	Vessels Rig subject to Quarantine inspection on arrival in Australian waters. Personnel hygiene. Marine species generally do not present significant risk and marine staff are generally aware of the dangers of stinging jellyfish, sharks and sea snakes.		Medium - Low	Ensure dangers from Marine species to be addressed in awareness information and health related response actions detailed in emergency response procedures	Awareness training. Emergency Response training.	Contract HSE requirements
Sexually Transmitted disease		*			*		*	Pre employment medicals. Onshore and Offshore medical facilities		Low			
Endemic/epidemic disease		*			*		*	Pre employment medicals. Onshore and Offshore medical facilities		Low			
Occupational Illness		*			*		*	Sprains & strains, potential chemical exposures; pre employment medicals, rig / vessel design & procedures mitigate		Low			
Food & Drink		*			*		*	Vessel and Rig Watermakers approved. Routine water testing. Water may be bunkered from onshore.	Rig and vessel food supplies arrangements (eg ex Darwin) and transport/storage in refrigerated containers, to be assessed by Rig/Catering company.	Low			

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Hygiene (catering/accommodation/toilet facilities/waste disposal)		*			*		*	Use of professional catering company on Rig, normal ships cook/compliment.		Low	Pre Hire Audits		
		*			*		*	Vessels and Rig MARPOL certification. Garbage Management Plans and WEL Blacktip Project Waste Management Plan	Correct Waste disposal (identification, labelling, manifesting etc) is important to minimising risks to (onshore) personnel. Use of IMDG trained logistics personnel on Rig mitigates risks.	Low	Pre Hire Audits	Waste Management Plan to address issues.	
Psyco-Social													
Isolation (access to social support)		*			*		*	Available Communications. Normal offshore/marine work practices & entertainments as available. Pre employment interview / medicals.		Low			
Communication problems (business & family)		*			*		*	Available Communications. Normal offshore/marine management issues. Compassionate leave arrangements.		Low			
Culture, local law, religion & language		*			*		*	Normal offshore/marine management issues. Pre employment interview. Catering facilities may need to consider requirements		Low			
Job design		*			*		*	Planned Work Program. Ergonomics in Design. Lifting Aids. Vessel and Rig facilities evaluated pre hire.	Pre Employment Medicals	Low			
Job organisation		*			*		*	Offshore job planning and experienced supervision / management.		Low			
Leisure and recreational facilities		*			*		*	Onshore Communications. Rig & vessel Recreational Facilities.	Pre Employment Medicals	Low			
Prostitution		*			*		*	Not relevant offshore		Low			
Stress factors		*			*		*	Onshore Communications. Counselling, Recreational Facilities. Emergency Response	Pre Employment Medicals	Low			
Substance abuse		*			*		*	Pre employment medicals. Oilfield facilities are alcohol free. Heliport inspections and /or controls.	WEL Drug & Alcohol Policy	Low			
Smoking		*			*		*	Controlled (restricted) on offshore instalations and vessels for safety reasons	WEL Drug & Alcohol Policy	Low			

Appendix 4. – Onshore Gas Processing Plant Health Risks

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Field Work Onshore													
On Site: Gas Processing Plant													
Geographical Location													
Heat / Cold		*	*	*	*		*	Tropical environmental concerns, typical of work in the area. Work planning & rotas.	Geographical Location issues are not expected to impact the local (resident) population, except where indicated. Workers will have Personal Protective equipment (boilersuits etc). Adequate supply of potable water. Local shade where practical & safe.	Low	See Health Aspects of Work in Extreme Climates within the E&P Industry: The Heat. E&P Forum Report No 6.70/279 1998	Blacktip Remote Area Access Guidelines Drims# 144703	
Humidity		*	*	*	*		*	Work planning and rotas. Maintainance and Accomodation with Air Conditioning (HVAC)	Acclimatisation and awareness training.	Low		Awareness Training	
Daylight		*	*	*	*	*	*	Normally daywork for operations. Shift routines & nightwork would utilise lights	Overnight work illumination during construction may be disruptive to nearby residents. Operational lighting to be designed for site safety and security, with minimum stray light.	Low			
Transport / Communications / Infrastructure		*	*	*	*	*	*	Site will have communications & transport. Increased road and air traffic , phone /internet line use, may impact local services availability. Dust suppression may be required during dry season and care during wet season		Medium	Transportation and telecoms studies to evaluate need for local upgrade. Information may be available from the Social Impact Assessment.		Engineering and Logistics support to address
Location of Health Facilities		*	*	*	*	*	*	Emergency Response Procedures to be developed for Medical Emergency and home office support. Emergency Response Procedures will address transportation logistics (and eg aircraft availability), major and multiple injury arrangements (via eg Medivac) Local facilities will be utilised as facilities allow. First aid equipment on site.	'Local' Medical Support eg Aerial Medical Support (Royal Flying Doctor), Darwin, Katherine and Alice Springs Hospitals and Dental Services.	Medium	Medical Support requirements to be reviewed for construction and operational phases; evaluate the need for an onsite contract medic and of proximity and type of available medical resources. Information may be available from the Social Impact Assessment.		WEL Doctor/ Medical Adviser to evaluate requirements and available facilities and make recommendations on any further support / upgrade required.
Standard of Facilities & staff Competency		*	*	*	*		*	Designed to Australian / International Standards. Staff competencies part of HR hire and contracting procedures and staff training.	BOD	Low			
Security		*	*	*	*	*	*	Security of Construction and operational site to be addressed in Construction and Operational Planning. Potential risk to intruders and plant. CCTV, lighting and fencing arrangements to be considered in design to ensure operational security. Visitors to site will be accompanied.	Risk to curious public may be highest during construction: security patrols and temporary barriers warning of risk may be required.	Medium	Security study recommended. Information may be available from the Social Impact Assessment.		Site specific Security study
Natural disasters		*	*	*	*	*	*	Installations designed to appropriate earthquake, cyclone, etc standards. With shutdown option evaluated. Non Operational / non emergency response personnel should be kept clear if there is an incident. Security and local services may be utilised to assist.	BOD	Low	Shutdown / cyclone operating philosophy to be defined.		Operations input to design
Physical													
Noise		*	*	*	*	*	*	Operational noise limited by design (predictions & modelling), Insulation, Hearing Protection. Emergency Blowdown to be evaluated. Commissioning /operational noise survey to confirm compliance.	Overnight work noise during construction may be disruptive to nearby residents. Operational noise to be designed for worker health and is not expected to be a public issue.	Low	Commissioning noise survey to confirm predictions; Operational changes to be evaluated	BoD Data Sheet Health & Ergonomics Drims # 476360	
Vibration		*	*	*	*		*	Limited by design. Task design (eg paint chipping using vibrating tool or nail gun)		Low	Commissioning vibration survey to confirm predictions; Operational changes to be evaluated		
Pressure		*	*	*	*		*	Contained. Vents / Flare in safe location	Controlled Pressure Testing	Low			
Ionising Radiation		*	*	*	*	*	*	Construction and maintenance NDT testing procedural controls (including competency, distance, shielding and storage), Operational Closed source design and operating procedures ; only open source may be NORM, for which procedural controls exist.	Potential risk to public during transportation of sources: which is a controlled operation. Transportation and emergency procedures to address	Low	Register of Sources to be initiated should Inising radiation sources be required.	BoD Data Sheet Health & Ergonomics Drims # 476360	
Non Ionising Radiations		*	*	*	*		*	Design, operating & maintainance procedures addresses safe distances and barriers for non ionising radiations (eg electromagnetic, microwave, radio wave). UV (sunlight) sunscreen provided to workforce.		Low	Commissioning non ionising radiation survey to confirm predictions; Operational changes to be evaluated	BoD Data Sheet Health & Ergonomics Drims # 476360	
Thermal Work Environment		*	*	*	*		*	Geographical location dominant: hot-cold plant insulated / shielded. Vessel entry procedures & forced air if required.		Low		BoD Data Sheet Health & Ergonomics Drims # 476360	
Ergonomic/manual Handling		*	*	*	*		*	Ergonomics considered during design. Provision of cranes and lifting devices. Normal construction and operational issues.		Low		BoD Data Sheet Health & Ergonomics Drims # 476360	
Machinery		*	*	*	*	*	*	Rotating machinery is guarded, noise controlled & accessible for maintenance. Machinery to be located in secure compound. Potential risk to public during construction to be minimised by use of barriers and security patrols.		Low			Security Study
Sharp objects		*	*	*	*		*	Sharp objects eliminated in design. Little / no requirement for eg glass or syringes etc.		Low			
Display Screen equipment		*	*	*	*		*	Considered as part of ergonomic design		Low		BoD Data Sheet Health	
Transport during work		*	*	*	*	*	*	Road vehicle movements normal part of construction / oilfield work: typical safety systems in place. Construction traffic and large machinery may impact on local road system, dusts may require suppression.	Suitability of airstrip and roads for construction operational and maintenance to be studied for adequacy. Any additional requirements to be addressed via normal planning approvals process.	Medium - Low	Information may be available from the Social Impact Assessment.		Engineering and Logistics support to address.
Chemical													
Toxic Chemicals		*	*	*	*	*	*	Toxics avoided where possible. Any Poisons onboard registered and antidote locally available. Procedures devised for use. MSDS available (including emergency contact number)Highest risk during construction: use experienced contractors and appropriate procedures, including chemical selection. Secure chemical storage to be implemented. Potential exposures to Commissioning fluids should be minimised by job design. MSDS to be available at location of use. Pigging wastes to be evaluated once operational.	Australian Institute of Petroleum (AIP) Health Watch program. Awareness presentation may be utilised where appropriate. Health Risk Assessment carried out and available to potential users. Operational chemical use to be considered in design to minimise handling and exposures	Medium - Low	Produced fluid compositional analysis underway: for eg polonium, radium and mercury. Preliminary data shows H2S 10ppmv, mercaptans not detected and an estimated BTEX of 20,20,10,10 ppmv respectivly, Ref Drims # 277733	BoD Data Sheet Health & Ergonomics Drims # 476360	Engineering to detail chemicals & hazardous materials, and their storage
Dusts, mists & fumes		*	*	*	*	*	*	Construction dusts minimised by damping down if required. Operational exhausts, cold vent, blowdown and flare typical and not expected to impact local communities: survey to confirm once operational. Operational maintainance to minimise mists and maintain exhaust efficiency (plant and vehicles)	Dusts generated should be suppressed: chemical composition of dusts should be determined.	Medium - Low	Construction planning to address dusts and fumes.		Engineering and planning to address.
Sensitisers		*	*	*	*		*	Highest risk during construction & operations: procedures to address, if health risk assessment indicates potential.		Low			
Carcinogens		*	*	*	*		*	Generally not permitted as 'chemicals': product not expected to contain aromatics, etc; health risk assessment, use of PPE		Low	Confirmation that there are no carcinogens present required.		
Biological													
Wildlife (animals/reptiles/insects/plants)		*	*	*	*		*	Plant, Equipment and vehicles etc subject to Quarantine inspection on arrival in NT. Potential hazard to construction and operational workers to be addressed via awareness information and programme. Personnel hygiene. Local facilities to treat insect/snake bites, etc. Presence of stinging trees, Crocodiles, snakes, bighting insects, etc to be assessed prior to construction, and on a daily basis during construction and operations.		Medium	Ensure dangers from Marine species are addressed in awareness information and health related response actions detailed in emergency response procedures	BoD Data Sheet Health & Ergonomics Drims # 476360	
Sexually Transmitted disease		*	*	*	*	*	*	Potential hazard to construction and operational workers to be addressed via awareness information and programme.		Low		Awareness Training	

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Endemic/epidemic disease		*	*	*	*	*	*	Pre employment medicals. Onshore medical facilities		Medium - Low	WEL Medical adviser to review endemic diseases and advise any vaccination program for work in the area. Updates regarding further preventative measures to be provided with respect to epidemics. (see eg Centre for Disease Control) Information may be available from the Social Impact Assessment.		WEL Medical adviser review
Occupational Illness		*	*	*	*		*	Sprains & strains, potential chemical exposures; pre employment medicals, plant design & procedures mitigate		Medium	Ongoing Safety awareness campaigns to minimise 'slips, trips and falls'.	Awareness Training	
Food & Drink		*	*	*	*		*	Local Food & Water. Fridge-Eski facilities required for operational visits. Bottled water may be taken to site on each visit. Project produced potable water to appropriate standard. Refrigerated containers required for transport and storage of food: logistics to address accessibility and manning through periods of high activity (eg construction and maintenance).		Medium - Low	Catering facilities and arrangements to be resolved. Logistics and contingency planning to address potential issues.		Logistics and Catering Contractor input
Hygiene (catering/accommodation/toilet facilities/waste disposal)		*	*	*	*		*	Construction and Plant fixed or temporary arrangement definition (eg local hotels, construction camp, use of professional catering contractor, Chemical Toilets, etc) required for periods of high manning. Construction waste disposal requirements to be identified. Waste disposal arrangements (with wastes removed on each operational visit) to be defined (& approved).	Site drainage to consider potential of waste water impacting local water supply / freshwater sources.	Medium - Low	Audit programme. Engineering to address drainage.	WEL Blacktip Project Waste Management Plan to be developed.	Catering Contractor input. Engineering to address drainage. Waste Disposal Contractor input
Psyco-Social													
Isolation (access to social support)		*	*	*	*		*	Available Communications. Normal remote site work practices & entertainments in planning and design. Pre employment interview / medicals. Local entertainments. The wet may impose additional difficulties and stress.		Low			
Communication problems (business & family)		*	*	*	*	*	*	Available Communications. Normal site management issues. Compassionate leave arrangements.		Low			
Culture, local law, religion & language		*	*	*	*	*	*	Normal remote site management issues. Pre employment interview. Catering facilities may need to consider dietary requirements	Local issues to be identified and addressed via social impact study and consultation. Heritage and aboriginal affairs issues to be identified via EIS and Social Impact studies.	Medium	Community Liaison support requirements to de assessed and expected to include identification of responsible person on-site, availability of local interpreter and cultural and heritage adviser. Information may be available from the Social Impact Assessment.		Land and Community Adviser review
Job design		*	*	*	*	*	*	Planned Work Program. Ergonomics in Design. Lifting Aids. Commissioning procedures	Pre Employment Medicals	Low	Commissioning Procedures		
Job organisation		*	*	*	*	*	*	Construction and operational job planning and experienced supervision / management.	Existing NT Planning Controls and consultation process.	Low			
Leisure and recreational facilities		*	*	*	*	*	*	Construction Camp facilities/ local (Wadeye) facilities		Medium	Construction camp entertainment facilities to be provided and designed to minimise risks of adverse interaction with local communities. Information may be available from the Social Impact Assessment.		Land and Community Adviser review
Prostitution		*	*	*	*	*	*	Potential hazard to construction and operational workers to be addressed via awareness information.		Low	Information may be available from the Social Impact Assessment.	Awareness Training	
Stress factors		*	*	*	*	*	*	Onshore Communications. Recreational Facilities. Emergency Response training	Pre Employment Medicals	Low		Awareness Training	
Substance abuse		*	*	*	*	*	*	Pre employment medicals. Construction Camp management. Awareness information onsite.		Low	Information may be available from the Social Impact Assessment.	Awareness Training	
Smoking		*	*	*	*	*	*	Controlled (restricted) on onshore plant and instalations for safety reasons. Awareness information onsite		Low	Information may be available from the Social Impact Assessment.	Awareness Training	

Appendix 5. – Pipeline from Platform to Plant Health Risks

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Field Work Offshore and Onshore													
Pipeline to Plant (~<10 km) and to Offshore Produced Water discharge & Condensate Offload points.													
Geographical Location													
Heat / Cold		*	*	*	*		*	Tropical environmental concerns, typical of work in the area. For offshore work (eg Pipelay barge and attendant vessels) see Vessels & Rig matrix. Work planning & rotas.	Geographical Location issues are not expected to impact the local (resident) population, except where indicated. Workers will have Personal Protective equipment (boilersuits etc). Adequate supply of potable water. Local shade where practical & safe.	Low		Drims# 144730 Blacktip Remote Access Guidelines	
Humidity		*	*	*	*		*	Work planning and rotas. Refuge, with Air Conditioning (HVAC), to be evaluated in design	Acclimatisation and awareness training.	Low	Acclimatisation and awareness training.		
Daylight		*	*			*	*	Normally daywork for operations inspections. Shift routines & nightwork during construction / installation would utilise lights	Overnight work illumination during construction may be disruptive to nearby residents.	Low			
Transport / Communications / Infrastructure		*	*	*	*		*	Site will have temporary communications & transport. Increased road and vessel traffic during construction / installation. Dust suppression may be required during dry season and care during wet season		Medium	Transportation and telecoms studies to evaluate need for local upgrade. Information may be available from the Social Impact Assessment.	Drims# 144730 Blacktip Remote Access Guidelines	Engineering and Logistics support
Location of Health Facilities		*	*	*	*	*	*	Local support will be utilised as facilities allow. First aid equipment on site during construction / installation	'Local' Medical Support eg Aerial Medical Support (Royal Flying Doctor), Darwin, Katherine and Alice Springs Hospitals and Dental Services.	Medium	Medical Support requirements to be reviewed for construction and operational phases; evaluate the need for an onsite contract medic and of proximity and type of available medical resources. Information may be available from the Social Impact Assessment.	Drims# 144730 Blacktip Remote Access Guidelines	WEL Doctor/ Medical Adviser to evaluate requirements and available facilities and make recommendations on any further support / upgrade required. Information may be available from the Social Impact Assessment.
Standard of Facilities & staff Competency		*	*	*	*		*	Designed to Australian / International Standards. Staff competencies part of HR hire and contracting procedures and staff training.		Low			
Security		*	*	*	*	*	*	Security of construction and operational pipeline route to be addressed in Construction and Operational design and Planning: to ensure operational security. Visitors to site will be accompanied.	Risk to curious public may be highest during construction: security patrols and temporary barriers warning of risk may be required.	Medium	Security study recommended. Information may be available from the Social Impact Assessment.	Drims# 144730 Blacktip Remote Access Guidelines	Security adviser input
Natural disasters		*		*			*	Pipeline designed to appropriate earthquake, cyclone, etc standards. Emergency procedures to address any operational issues.		Low			
Physical													
Noise		*	*			*	*	Operational noise limited by design. Transient Construction noise eg Overnight work noise during construction may be disruptive to nearby residents. Local authorities should be notified of any planned noisy event (eg hydrotest/blowdown)	Overnight work noise during construction may be disruptive to nearby residents.Workplanning to minimise potential disruption	Low			
Vibration		*					*	Limited by design.		Low			
Pressure		*		*			*	Contained; any accessible pipeline valves secured.		Low			
Ionising Radiation		*			*		*	Construction and maintenance NDT testing procedural controls (including competency, distance, shielding and storage).		Low			
Non Ionising Radiations		*	*				*	UV (sunlight) sunscreen provided to workforce.		Low		Drims# 144730 Blacktip Remote Access Guidelines	
Thermal Work Environment		*					*	Geographical location dominant: hot cold pipe insulated / shielded.		Low			
Ergonomic/manual Handling		*	*				*	Ergonomics considered during design. Provision of cranes and lifting devices. Normal construction and operational issues.		Low			
Machinery		*	*			*	*	Potential risk to public during pipeline construction and installation to be minimised by use of barriers and security patrols.		Medium	Security study recommended. Information may be available from the Social Impact Assessment.		Security adviser input
Sharp objects		*					*	Sharp objects minimised in design.		Low			
Display Screen equipment							*	Considered as part of ergonomic design		Low			
Transport during work			*			*	*	Road vehicle movements normal part of construction / oilfield work (dusts may require suppression): typical safety systems in place. Construction traffic and large machinery may impact on local road system. Nearshore vessel movements controlled during shore crossing operations.		Medium - Low	Information may be available from the Social Impact Assessment. Contracted 'fly-in/fly out' aircraft to evaluate requirement to augment / carry bush survival emergency supplies	Drims# 144730 Blacktip Remote Access Guidelines	Potential Hydrocarbon exposures on 3rd Party offload tankers are not assessed here.
Chemical													
Toxic Chemicals		*					*	Highest risk during construction: use experienced contractors and appropriate procedures, including chemical selection. MSDS must be available at location of use, chemicals stored in secure area. Potential Hydrocarbon exposures on 3rd Party offload tankers are not assessed here.	Workers should be made aware of potential hazards.	Medium - Low	Exposure of any Acid Sulphate soils present may result in generation of Sulphuric acid causing water pH reduction (acidification), heavy metal mobilisation and potential fish kill/contamination.	Awareness training	Engineering to detail chemicals & hazardous materials
Dusts, mists & fumes		*					*	Operational spill risk response and potential health impacts to clean up workers to be addressed in Spill contingency plan. Authorities to be alerted to any associated blowdown or spill health hazards.	Dusts generated should be suppressed: chemical composition of dusts should be determined.	Medium - Low	Engineering studies	Emergency Response procedures to address	
Sensitisers		*					*	Highest risk during construction & operations: procedures to address, if health risk assessment indicates potential.		Low			
Carcinogens		*					*	Generally not permitted as 'chemicals'.		Low		Confirmation required that no carcinogens are specified.	

Key Issue	Design	Construction	Construction Transportation	Operations	Maintenance & Shutdowns	Public	Employees	How Addressed	Notes	Initial Risk Screening	Study	Procedure	Support
Biological													
Wildlife (animals/reptiles/insects/plants)		*	*	*	*		*	Plant, Equipment and vehicles etc subject to Quarantine inspection on arrival in NT. Potential hazard to construction and operational workers to be addressed via awareness information and programme. Personnel hygiene. Local facilities to treat insect/snake bites, etc. Presence of stinging trees, Crocodiles, snakes, bighting insectsetc to be assessed prior to construction, and on a daily basis during construction if required.		Medium	Ensure dangers from Coastal marine species are addressed in awareness information and health related response actions detailed in emergency response procedures	Drims# 144730 Blacktip Remote Access Guidelines	
Sexually Transmitted disease		*				*	*	Potential hazard to construction workers to be addressed via awareness information and programme.		Low		Awareness Training	
Endemic/epidemic disease		*	*			*	*	Pre employment medicals. Onshore medical facilities		Medium - Low	WEL Medical adviser to review endemic diseases and advise vaccination program for work in the area. Updates regarding further preventative measures to be provided with respect to epidemics. (see eg Centre for Disease Control) Information may be available from the Social Impact Assessment.		
Occupational Illness		*	*				*	Sprains & strains, potential chemical exposures; pre employment medicals, job design & procedures mitigate		Medium	Ongoing Safety awareness campaigns to minimise 'slips, trips and falls'.		
Food & Drink		*	*	*	*		*	Local Food & Water. Fridge-Eski facilities required for operational visits. Bottled water may be taken to site on each visit.		Medium - Low	Catering facilities and arrangements to be resolved. Logistics and contingency planning to address potential issues.		Catering Contractor input.
Hygiene (catering/accommodation/toilet facilities/waste disposal)		*	*	*	*		*	Construction temporary arrangement definition (eg local hotels, construction camp, use of professional catering contractor, Chemical Toilets, etc) required for construction and installation. Construction waste disposal requirements to be identified. Waste disposal arrangements (with wastes removed on each operational visit) to be defined (& approved).	Site drainage to consider potential of waste water impacting local water supply / freshwater sources.	Medium - Low	Audit programme.	WEL Blacktip Project Waste Management Plan to be developed.	Waste disposal Arrangements review. Engineering to address drainage. Catering Contractor input.Waste Disposal Contractor input
Psyco-Social													
Isolation (access to social support)		*	*					Available Communications. Normal remote site work practices & local entertainments as available. Pre employment interview / medicals. The wet may impose additional difficulties and stress.		Low			
Communication problems (business & family)		*	*					Available Communications. Normal site management issues. Compassionate leave arrangements.		Low			
Culture, local law, religion & language		*	*	*	*	*	*	Normal remote site management issues. Pre employment interview. Catering facilities may need to consider dietary requirements	Local issues to be identified and addressed via social impact study and consultation. Heritage and aboriginal affairs issues to be identified via EIS and Social Impact studies.	Medium	Community Liaison support requirements to de assessed and expected to include identification of responsible person on-site, availability of local interpreter and cultural and heritage adviser.		Land and Community Adviser review
Job design		*	*				*	Planned Work Program. Ergonomics in Design. Lifting Aids	Pre Employment Medicals	Low			
Job organisation		*	*				*	Construction and installation job planning and experienced supervision / management. Operational work largely inspections	Existing NT Planning Controls and consultation process. Realtime planning and notification of significant events.	Low			
Leisure and recreational facilities		*	*	*			*	Construction Camp facilities/ local (Wadeye) facilities		Medium	Construction camp entertainment facilities to be provided and designed to minimise risks of adverse interaction with local communities. Information may be available from the Social Impact Assessment.	Drimms# 144730 Blacktip Remote Access Guidelines	Land and Community Adviser review
Prostitution		*		*		*	*	Potential hazard to construction and operational workers to be addressed via awareness information.		Low	Information may be available from the Social Impact Assessment.		
Stress factors		*					*	Onshore Communications. Recreational Facilities. Emergency Response training	Pre Employment Medicals	Low			
Substance abuse		*	*				*	Pre employment medicals. Construction Camp management. Awareness information onsite.		Low	Information may be available from the Social Impact Assessment.	WEL Drug & Alcohol Policy	
Smoking		*	*				*	Controlled (restricted) on onshore plant and instalations for safety reasons. Awareness information onsite		Low	Information may be available from the Social Impact Assessment.	WEL Drug & Alcohol Policy	

Appendix 6. – Outline Health Programme

Outline Health Programme:

Specific issues identified during this preliminary study believed to require further work to ensure potential health impacts of the project are ALARP, are identified below; follow up of these specific issues, along with general project developing HSE studies during FEED, will contribute to the developing project HSE management system.

1) Develop a Medical Management Strategy and Plan.

   The Strategy and or Plan should include, but not be limited to, consideration of the following:

   Discussion with 'local' medical staff and facilities should be initiated directly from WEL's Medical Adviser (eg Company Doctor) to evaluate the adequacy of capability and the response time of local facilities.

   The need for, and standard of, additional (onshore) onsite medical support and supplies during construction and maintenance requires medical assessment and recommendation.

   Arrangements that may be required for local supply and storage of medicines (including through the operational phase) for eg prescription drugs, anti venoms and/or any chemical poison antidotes

   Advisory notes to be developed for site health hazards and any recommended vaccinations for employees (and contractors): notes to be updated (re eg new information or epidemics) throughout development life.

   Define training, refresher and competency of field First Aiders and Medics

   Recommended Field personnel fitness levels

   Provide input to, and/or participate in site HSE audits

2) Emergency Response: Medical, Medivac and Natural Disaster.

   Emergency Response Plans for the project should evaluate and address

   Transport and logistics considerations of Medical Emergency and Medivac and their inclusion in Emergency Response consultations, support contracts and procedures.

   Provision of support to the local emergency response organisations for project related issues, including potential multiple injury / fatality scenarios, of their, as well as project personnel.

   Worker wellbeing and support, including sustenance, for periods of isolation (flood, cyclone, etc.)

3) Develop an Health programme.

   Health Awareness and Health promotion: Determine medical (see 1 above) and Health advice to be included in eg Induction and Safety Awareness training, procedures or 'information sheets', to address local and site health concerns. Including, but not necessarily limited to, Health Procedural awareness (Ergonomics, Noise, Acclimatisation, etc) Exposure to sunlight,

Cont..

Ensure that the Regulatory Register contains all relevant Health Related Legislation and guidance. Review regulations and ensure appropriate guidance on health matters is disseminated to the project team.

Heat Exhaustion, Venomous creatures, stings and crocodiles, Diseases and their prevention, Food and water hygiene, Chemical Hazards, safe waste disposal.

Health Monitoring and Reporting: Determine and detail preliminary HSE audit schedule and content.

Onsite medic multiskilled work routines to be identified and evaluated.

Health (and First Aid) Procedures, to be developed or revised where needed, and maintained for the Project with location risks identified.

4) Design (Construction and Engineering) Health Inputs

Project HAZIDs and HAZOPs identify and evaluate Health Risks.

Construction camp food and water supply (and testing) storage, drains and sewage disposal arrangements to be defined (as should Operational site requirements , if different).

Early construction food and water supply and contingency (supply) arrangements to be identified.

Welfare and Entertainment facilities to be provided commensurate with management strategy for level of interaction with local community.

Chemical, and Hazardous material, selection to consider health aspects (including residue / container disposal) and maintenance/decommissioning.

Listing of hazardous materials (ie not limited to ‘chemicals’), and MSDS, to be compiled.

Project Waste Management Plan to be developed (addressing health issues as appropriate) to include safe storage and disposal.

Health Risk Assessments to be prepared.

Commissioning testing to confirm noise and radiation safe design criteria are met.

Formation water radioactivity, and construction site and onshore pipeline route inhalable ‘dust’ composition to be determined. Scaling predictions to address the likelihood of Low Specific Activity (LSA) scale (NORM) formation.

Process review to determine any concentration ‘hot’ spots for toxics (eg H_2S, Hg, BTEX), and project to assess the potential for worker, or 3rd party, exposures.

Determine the need and competencies for Community Liaison support personnel onsite during construction.

Design platform and site security for all operational scenarios (eg construction-unmanned, normal work and access – emergency escape).

Transportation and telecoms study to address normal operations, construction and emergency telecomm and transportation upgrade requirements (if any).

Cont..

Early identification of catering and waste disposal contractors to be considered to aid identification of logistical and storage requirement solutions.

5) Field Operations (Construction, Drilling, HU&C, Production Operations) to ensure

Project HSE Management System to be implemented both onshore and onsite.

Project Emergency Response Procedures and arrangements are appropriate to health risk management, and maintained as current documents.

Awareness of Health Regulations and maintenance of Regulatory Register as a current document

Adequate site security to be maintained.

Health Risk Assessments are carried out, when new information is available.

Health Risk Assessments are kept current and available to the workforce.

HSE Audits scheduled and include Health, hygiene and medical topics.

Job Hazard Analysis are utilised.

Operational (and Decommissioning) Plans, monitoring and procedures address health issues.

Health issues are included in induction training and Safety Meetings; procedures developed for Arrival and Departure from Normally unmanned sites address HSE issues.

Chemical Selection, transport, handling and disposal assesses Health risks.

Material Safety Data Sheets (MSDS) are available onsite, and antidotes to any specified poisons are available onsite.

A register of ionising radiation sources is available and current.

Adequate training in Personnel Protective Equipment (PPE), including sunscreen and shade, use is provided at site.

Programme of periodic atmospheric contaminant, noise and radiation monitoring when personnel are onsite.

Appendix O

Framework Offshore Environmental Management Plan prepared by Sinclair Knight Merz






This page has been left intentionally blank

Contents

1. Blacktip Project Framework Environment Plan 1

1.1 Overview 1

1.2 Purpose and Scope of the EP 1

1.3 Timing 3

This page has been intentionally left blank

1. Blacktip Project Framework Environment Plan

1.1 Overview

This document is a framework Environment Plan (EP), providing an outline for the final detailed document(s). This framework EP summarises the EP approval process for all offshore aspects and phases of the Blacktip Project. However, the detailed EP will be split into separate documents covering drilling, installation, production and decommissioning stages of the project.

EPs are typically undertaken by the Proponent. Woodside is the designated operator and proponent of Permit WA-279-P of the Blacktip Project.

Detailed EPs are required for petroleum activities in Commonwealth waters under the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999* [P*(SL)(MoE) Regulations*], where they are referred to as Environment Plans (EPs). The requirements of the *P(SL) (MoE) Regulations* will also be applied to Blacktip Project activities occurring in Northern Territory Territorial waters, which are also subject to the Northern Territory *Petroleum (Submerged Lands) Act 2003,* and shore crossing activities which are subjected to the Northern Territory *Petroleum Act 1984*.

This *framework* EP has been prepared to address the requirement of the 'Guidelines for Preparation of a Draft Environmental Impact Statement on the Proposed Blacktip Gas Project'.

1.2 Purpose and Scope of the EP

As specified in the 'Guidelines for the preparation of a draft Environmental Impact Statement for the proposed Blacktip Gas Project', a detailed EP should outline 'specific safeguards and controls, which would be employed to minimise or remedy environmental impacts'. The EP will also be prepared in accordance with the Commonwealth regulatory requirements, as per the *P(SL)(MoE) Regulations*, and will be structured as follows:

- ***A Description of the Proposed Activity:*** This section of the EP typically describes the technical detail pertaining to the proposed project. Details on the location of the project, description of the development during all phases of the development are provided.
- ***A Description of the Existing Environment:*** A summary of the existing environment of the project area will be provided which generally covers the following areas:
  - physical environment
  - biological environment
  - socio-economic environment
  - particular values and sensitivities.
- ***Identification & Assessment of Environmental Effects and Risks:*** The aspect, source, potential and predicted impact, management measures and residual risk are detailed covering the following activities:
  - drilling

  - installation and construction
  - operation
  - decommissioning of the facilities
- ***Environmental Objectives, Standards and Criteria***: Objectives and standards will be set to measure environmental effects and risks, to determine if an activity is meeting its environmental objectives and standards, and to assess the performance and implementation of the EP. The performance objectives and standards must be consistent with reducing environmental risks and effects to 'as low as reasonably practicable' (ALARP).
- ***Environmental Management Techniques***: This section provides a description of the proposed safeguards and mitigation measures to be put in place for all phases of the proposed development. Safeguards and mitigation measures will be implemented to ensure that all significant environmental effects associated with the proposed development are minimised or avoided.
- ***Implementation Strategy***: This section explains the strategy for implementing the EP. Details on the following are therefore included:
  - Roles and Responsibilities: Key roles and responsibilities of personnel with respect to meeting environmental management and performance objectives during the various stages of the project.
  - Training and Education: The operational systems and procedures designed to ensure that each employee or contractor working on or in connection with the project is aware of their responsibilities in relation to the environment and has the appropriate skills and training.
  - Monitoring, audit and reporting requirements: Arrangements for recording, monitoring and reporting information about the activity that will enable the relevant regulatory authority to determine whether the environmental performance objectives and standards in the EP have been met. A detailed audit and reporting schedule will be developed and implemented.
  - Environmental Monitoring: A detailed environmental monitoring programme will be developed to detect and monitor appropriate impacts resulting from the main environmental effects of the project.
  - Emergency Events and Contingency Planning: An up-to-date emergency response manual (including an oil spill contingency plan) that includes detailed response and investigative arrangements will be developed and maintained.
  - Consultations: Each EP will include a report on consultations between the operator and relevant authorities, organisations or other interested parties in the course of developing the EP. It will also include details of ongoing consultation arrangements to be adopted during the operational phase with other marine users and interest groups.
- ***Environmental Commitments:*** The development of the Blacktip Project will be undertaken in a manner that minimises impacts on the surrounding biophysical and social environments. Accordingly, Woodside will adopt the Environmental Commitments as outlined in **Section 15** of the Draft EIS.

1.3 Timing

The detailed EP will be split into separate documents covering drilling, installation, production and decommissioning stages of the project. Once the detailed design phase has been progressed to a stage at which technical detail is available to describe detailed management techniques, the EPs for each relevant phase will be drafted for approval by the relevant regulatory authorities.

Appendix P

Framework Marine and Intertidal Monitoring Programme prepared by Sinclair Knight Merz






This page has been left intentionally blank

Framework Marine and Intertidal Monitoring Programme for the Blacktip Project

The following is a framework monitoring programme for the marine and intertidal components of the Blacktip Project. This framework is intended for planning purposes only and the exact format of the monitoring programme will depend on the results of the baseline surveys and discussions with regulatory bodies.

The objectives of monitoring programmes is primarily to ensure that no adverse environmental impacts are occurring as a result of the Blacktip Project and determine the effectiveness of the environmental management measures put in place. Data collected in the monitoring programmes will:

- enable reporting to regulators on environmental performance and determination of whether environmental performance targets are met,
- allow differences between predicted and actual impacts to be quantified and the need for additional environmental management identified,
- determine rehabilitation success, and
- ultimately ensure that no adverse environmental impacts are occurring.

It is important to note that the Blacktip Project will operate over a long period of time during which time there may need to be changes to the focus of the monitoring programme. A change of focus of the monitoring programme may be a result of:

- advancements in monitoring techniques;
- advancements in the understanding of environmental issues causing changes in monitoring priorities;
- changes in legislation;
- advancements in the environmental performance of gas developments causing changes in monitoring priorities;
- changes to the scope of the Blacktip Project.

The final monitoring programme will be developed in consultation with regulatory authorities and will be reviewed and updated as the project progresses.

The framework monitoring programme design is based on the following:

- current best practice, including applicable standards and guidelines;
- results from baseline environmental surveys;

- expectations and requirements of regulatory authorities;
- commitments in the Draft EIS;
- experience gained on similar projects.

A number of baseline surveys have already been undertaken for the Blacktip Project including:

- geotechnical and seabed surveys;
- metocean measurements and hydrodynamic modelling;
- offshore environmental survey;
- intertidal environmental survey;
- near shore survey of turtle and dugong activity, including turtle nesting and hatching.

These baseline surveys covered sites in the immediate project area (wellhead platform, export pipeline, near shore facilities, beach crossing and gas plant), as well as reference locations.

The data gathered during these specific surveys has three main purposes:

- For use in the description of the project area for the Draft EIS (particularly the aspects which were poorly known prior to undertaking these baseline surveys) and to place project area into a regional, national and international context.
- To provide data which can be used to design ongoing monitoring programmes, including data for use in a pilot study and for statistical power analyses.

Baseline studies involved the collection of a broad range of parameters, based on a combination of 'best of practice', parameters used to assess impacts from other similar developments and parameters targeted at detecting the predicted impacts of the project. Monitoring parameters will be selected, with the assistants of further baseline surveys where necessary, before construction commences. The assessment parameters below are given as examples and not necessarily the ones that will be included in monitoring programs. Final selection of parameters to be monitored will be chosen after a review of the results of all baseline studies and advice and agreement of the relevant regulatory authorities.

Monitoring parameters

The assessment parameters may include but are not limited to the following:

- infauna and epifauna community diversity and abundance;
- plankton community diversity and abundance;
- turtle and dugong abundance and turtle nesting activity;

- sediment quality;
  - metals
  - particle size distribution
  - hydrocarbons and organics
  - radionuclides
  - ecotoxicological assessment
- water quality;
  - standard physio-chemical parameters (for example pH, salinity, DO, Turbidity, temperature);
  - hydrocarbons and organics;
  - metals;
  - ecotoxicological assessment.

Monitoring Locations

Drilling Site

The drill site monitoring programme will focus on the proposed location of the wellhead platform as this will be the site for drilling. The monitoring programme for drilling is intended to be sufficiently rigorous for impacts to be measured. The sampling parameters and number of sampling sites should be determined from power analysis of data collected during the baseline offshore survey. The timing and frequency of the monitoring programme will be agreed with the regulator and will be planned to provide a robust set of results to assist the environmental management process.

The monitoring programme may include:

- field sampling of sediment properties and infaunal communities post drilling to determine impacts and recovery;
- ecotoxicological investigations of the toxicity of drilling muds to assist with the selection of drilling muds and the interpretation of field observations.

The need for a drill site monitoring programme will be determined following advice and agreement of the relevant regulatory authorities.

PW Discharge

The PW monitoring programme may include but is not limited to the following:

- routine monitoring of oil in water and volume of discharge during operations;

- detail chemical analysis of PW;
- ecotoxicological investigation of PW.

Pipeline

The sub-sea pipeline will be regularly inspected to ensure pipeline integrity, stability and absence of leaks. If ROVs are used for monitoring of the condition of the sub-sea pipeline, the video data can be used to assess the colonisation of the pipeline by epifauna and the presence of introduced species (see below). However, the pipeline will be trenched for most of its length and high water turbidity and strong currents are expected to limit the effectiveness of ROVs, particularly in the near shore environment. An impact assessment of the presence of the pipeline during the operational phase of the project is not considered necessary and any monitoring is likely to be opportunistic.

Intertidal

The intertidal monitoring programme will focus on Northern Yelcher Beach where the pipeline crossing is proposed. The sampling parameters and numbers of samples will be determined from power analysis of data collected during the baseline intertidal survey. The baseline survey sampled sandy beach, mangrove and rocky substrates close to the proposed pipeline crossing. However, preliminary results indicate that only a subset of these parameters are useful for monitoring for example the beach samples contained little infauna. The timing and frequency of the monitoring programme will be agreed with the regulator and will be planned to provide a robust set of results to assist the environmental management process.

Turtle and Dugong

The turtle and dugong monitoring programme will concentrate on near shore waters and beaches between Cape Hay and Point Pearce during the construction phase. Particular attention will be focused on restoration of the pipeline crossing beach to its original profile to ensure turtle nesting activity on this beach is not affected.

Decommissioning

Decommissioning monitoring will involve an impact assessment based on the data gathered during baseline and ongoing monitoring programme, as well as any advances in monitoring techniques. The sampling locations will be re-established and the same parameters will be assessed with suitable replication to allow for the detection of decommissioning impacts and to monitor recovery to near pre-installation levels.

The duration and scope of decommissioning monitoring would be determined with the Regulatory Authority near the time of decommissioning.