APACHE ENERGY LIMITED

CHELONIA-1 & CHELONIA-2 EXPLORATION WELLS NORTHWEST SHELF

CONSULTATIVE ENVIRONMENTAL REVIEW

EPA ASSESSMENT 1170

June 1998

Chelonia-1 and Chelonia-2

Exploration Wells
EP342

Consultative Environmental Review

EPA Assessment Number 1170

Proponent:

Apache Northwest Pty Ltd
256 St Geroge's Terrace
Perth WA 6000

19 June 1998

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INVITATION TO MAKE A SUBMISSION

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

This Consultative Environmental Review (CER) proposes the drilling of two exploration wells, Chelonia-1 and Chelonia-2, in Permit Area EP342 at the head of Exmouth Gulf. In accordance with the *Environmental Protection Act* 1986, a CER has been prepared which describes this proposal and its likely effects on the environment. The CER is available for a public review period of four weeks from 22 June 1998 closing on 20 July 1998.

Comments from government agencies and from the public will help the EPA to prepare an assessment report in which it will make recommendations to government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part of each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the CER or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the CER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the CER;
- if you discuss different sections of the CER, keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name,
- address,
- date; and
- whether you want your submission to be confidential.

The closing date for submissions is: 20 July 1998
Submissions should be addressed to:

Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: Ms Rochelle Smith

TABLE OF CONTENTS
EXECUTIVE SUMMARY
SUMMARY TABLE OF ENVIRONMENTAL FACTORS

List of Tables

Section 1:

Section 2:

Section 3:

Section 4:

Section 5:

Section 6

List of Figures

List of Plates

Appendices

Executive Summary

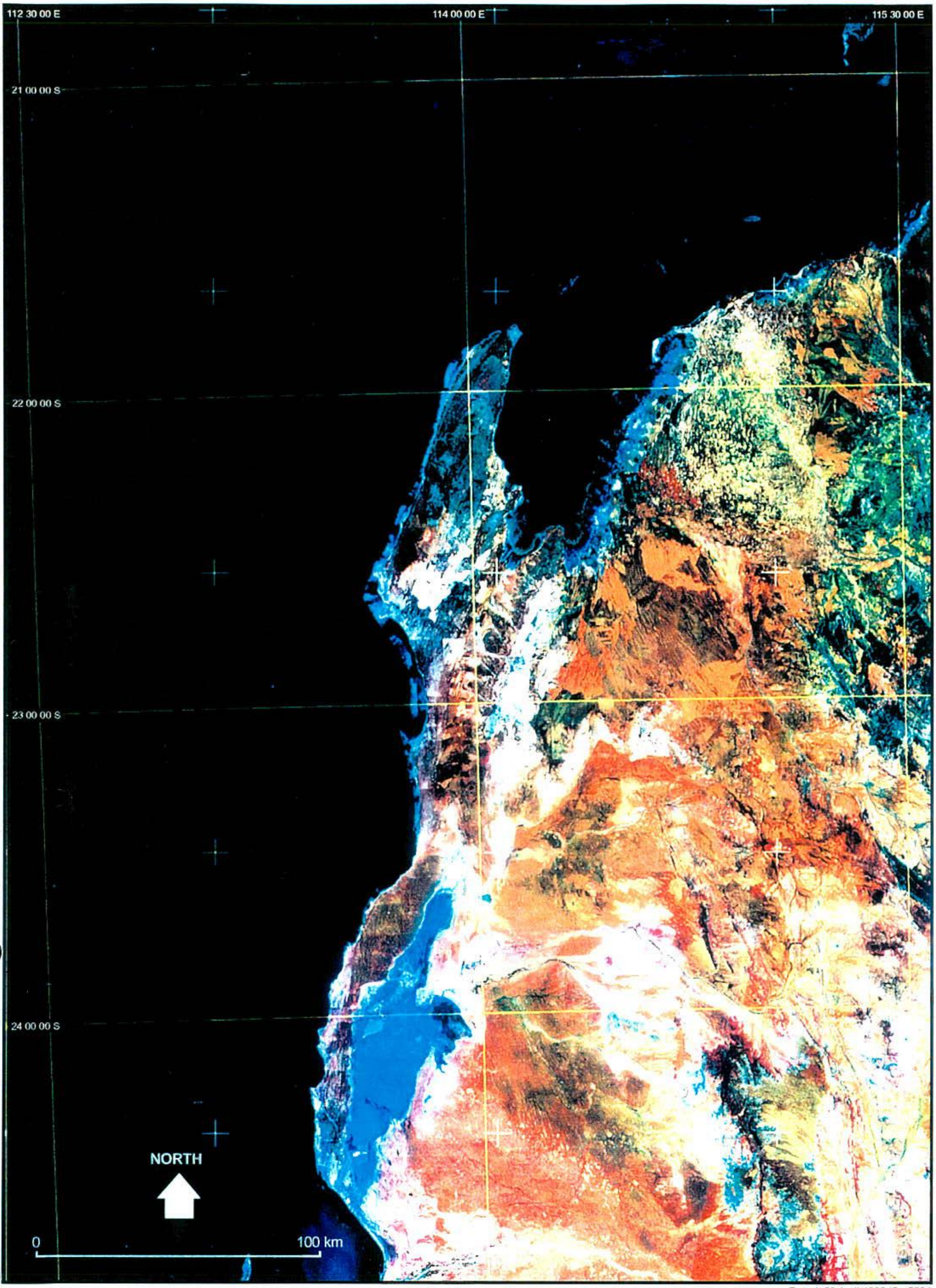
- This document is a Consultative Environmental Review (CER) submitted by Apache Energy and the Joint Venture Participants to seek environmental approval for an exploration drilling program location in Exploration Permit EP342.
- The proposal is to drill up to two exploration wells from a single location located offshore approximately 14 km to the northeast off the tip of North West Cape. Chelonia-1 will be drilled first and only if hydrocarbons are encountered will Chelonia-2 be drilled. The surface location will be situated about 111 m to the east of the Ningaloo Marine Park Boundary. The bottom hole location will be situated at a maximum measured depth of 4,089 m and will extend under the marine park. The maximum horizontal distance between the surface location and the bottom location will be 2.5 km.
- Drilling will be carried out using a jack-up rig. and will take either 26 days or 44 days to complete, depending on how many wells are drilled.
- A water based drilling fluid and Petrofree®, a synthetic ester-based drilling fluid, will be used for the two wells. Petrofree will be used for only the 12 ¼" sections only.
- The major ecological habitats of the area include benthic macroalgae, rocky shores, sandy beaches and fringing coral reefs. These habitats support fauna of both conservation and commercial significance. The seabed in the immediate vicinity of the Chelonia project location consists of unconsolidated sand supporting a sparse fauna of filter feeding macroinvertebrates.
- Social and commercial resources of the region include the town of Exmouth, the Exmouth prawn fisheries, recreational fishing, diving and tourist activities.
- The impacts from routine drilling activities will be minimal. All attempts will be made to dispose of drill cuttings and excess water based drilling fluid down the annulus into the lost circulation zone. Petrofree will be recycled and returned to shore.
- The overall probability of an incident occurring during drilling which would result in light crude oil reaching the adjacent shorelines of the Muiron Islands or North West Cape is extremely low. Safety and management plans have been developed which will further reduce the chances of an accident occurring.
- The risk of oil reaching the Ningaloo Reef and impacting the ecological and conservation value of the area is extremely low regardless of the time of year, although risks are higher in winter. In addition to operational and technical measures, to help reduce the risk, it is proposed that drilling will be carried out during the 1998/99 summer period.
- The Chelonia drilling program will not compromise the recreational, commercial or conservation values of the region due to its distance from shorelines, short project time and low risk of an incident occurring in the first instance.
- Apache will undertake the environmental actions, guidelines and management commitments given in the CER for the Chelonia drilling program and in all cases will fulfil these commitments to the satisfaction of the appropriate statutory authorities.

Summary of Environmental Factors and Management Objectives
Chelonia-1 and Chelonia-2 Exploration Wells
North West Shelf (Assessment No.1170)

Factor	EPA Management Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Outcomes
BIOPHYSICAL					
Coral reefs	Maintain the abundance, species diversity and geographic distribution of coral reefs.	Extensive coral reefs at Ningaloo Reef, Bundegi Reef, North and South Muiron Island, with less developed communities at Sunday Island. Refer to Section 3.	No potential impacts from routine drilling operations due to distance to reefs and weathering capability of oil. Impacts from accidental spills possible depending on size of spill and met/ocean conditions. The risk of oil from a 600,000 L spill reaching the closest fringing coral reefs at the Muiron and Sunday Island is ≈ 15%. Risk of impacts to Bundegi Reef and Ningaloo Reef is < 1%. The majority of the reefs are subtidal and less prone to impact by oil	Disposal of cuttings down annulus. Oil Spill Contingency Plan in place with response strategies. Strict refuelling procedures and valved hoses. Standby oil spill response vessel at all times. Ocean rated boom on location at all times.	No effect to adjacent fringing coral reefs. The EPA objective will be met.
Seafloor	Maintain the biodiversity of the sea floor and ensure that impacts on locally significant marine flora and fauna communities are avoided.	Extensive low profile pavement with coarse veneers. Highly variable cover of filter feeding organisms. Refer to Section 3.	Impacts of routine drilling restricted to physical impacts of the cement collar and initial drilling of 36" hole. Zone of primary mortality effects coverage <15m diameter around collar. Extended effects no more than 100 m diameter. Effects caused by accidental oil spill negligible.	The intent is to dispose of solids down annulus. Use of low toxicity fluids, including Petrofree. Strict control of operations to minimise the risks of oil spills. Oil spill contingency planning to rapidly respond to spilt oil.	Effects of smothering from drill cuttings will be localized and short terms due to small volume and high energy of region. The EPA objective can be met.
Island shorelines	Maintain the biodiversity, productivity and geographic distribution of the plants and animals of the island shorelines.	The islands within the possible range of effects from the Chelonia drilling program are North and South Muiron Islands, and Sunday Island. The Muiron Islands have rocky shores, cliffs, platforms and beaches. Sunday Island has sand beaches and a broad intertidal platform. Refer to Section 3.	No impacts from routine drilling activities. Impacts from accidental spills are possible, dependent upon the extent of spillage and met/ocean conditions. The risk of impact to island shorelines from a large (≈ 600,000 L) spill is about 15% to either South Muiron or Sunday Island. Oil would weather rapidly and is of low toxicity, and would form tar balls. Some impact could occur to shoreline platforms and rocky shore fauna by presence of tar balls.	Risk of oil spills minimised using over designed well control BOP devices. Good housekeeping procedures to minimise risk of small spills. Oil spill contingency planning to ensure rapid response to any spill.	No predicted impacts to island shorelines. The EPA objective can be met.

Mangroves	Maintain the biodiversity, productivity and geographic distribution of the plants and animals of the mangroves, saltmarshs and mudflats.	Mangrove systems are limited to sparse trees on the coast near Bundegi, and well developed mangals along the south and eastern coasts of Exmouth Gulf, from the Bay of Rest to Tubridgi.	No potential impact from routine drilling operations. Even in the unlikely event of a major oil spill the mangals are beyond the predicted range of effects.	No specific environmental management required for mangrove communities. Should a major spill occur and threaten mangroves, then all possible responses will be considered, including dispersant use, as these are the most important and susceptible of environments in the region.	No predicted impacts to mangrove communities. The EPA objective can be met.
Marine fauna	To avoid impacts on marine fauna and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	The area contains a sparse motile fauna, but migratory and pelagic fauna. The most environmentally significant fauna are whales, sea birds, whale sharks, turtles and pelagic fish species. Although the area lies within the Area A Exmouth Gulf Prawn Fishery, limited trawling operations are conducted in the immediate area.	The drilling program should cause minimal dislocation of existing fauna. The platform may act as a short term fish attractant. Spilt oil could cause impacts to air breathing marine fauna. No direct impact to prawn stocks, although negative market perceptions or tainting through fouled gear could occur following a spill.	Discharges to the marine environment will be minimal, and involve treated wastewater and cuttings during the initial drilling. Fishing will not be permitted. Oil Spill Contingency Plan with detailed response strategies.	Very minor and short term disturbance to marine fauna. The EPA objective can be met.
Seabirds	To avoid impacts on seabirds and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	The region contains important seabird nesting and feeding areas. Large shearwater rookeries occur on the Muiron Islands. Protected wading species utilise the island shorelines. Diving birds, particularly terns and shearwaters fish in the adjacent waters.	Some seabirds may be attracted to the rig due to the lights and may use the rig for perching. Should a spill occur, the impact will be dependent on size and bird numbers. Effects will be greatest for open water feeding birds and if shoreline roosting areas are impacted.	Impacts to seabirds would be limited to accidental oil spills. The risk of these would be minimised by best practice management strategies. In the event of an oil spill, protection of seabird habitat and fouled seabird clean up would be instigated.	No significant impacts to seabirds as a result of the drilling program. The EPA objective can be met.
POLLUTION MANAGEMENT					
Hydrocarbons (from spills)	Ensure that the risk of hydrocarbon spills is extremely low, that actions are taken to reduce identified risks, and that drilling operations and equipment are at the level of international best practice for drilling in environmentally sensitive areas.	Refer to Section 5.0 and Appendix 6.	The risk of an oil spill incident occurring from drilling operations is very low. A major hydrocarbon spill associated with a loss of well control is highly unlikely. Should a large spill occur, the coral reefs, platforms and shorelines of the Muiron and Sunday Islands and northern section of North West Cape could be impacted. If oil is encountered, it may be well weathered containing very little concentration of toxic light ends.	Potential sources of risk have been identified. Risk reduction actions put into place. Engineering of well design, well in excess of conditions encountered in the region. Four blowout preventors (BOP) used. Drilling fluids of correct weight for reservoir pressures. Routine pressure testing of BOP's and casing. Use of trained personnel on the rig floor. Design of an Oil Spill Contingency Plan (OSCP) approved by DME. Oil spill equipment on standby at the rig at all times. Good housekeeping on the rig - drip trays and sumps under all machinery, no open drains to the environment.	The risk of an oil spill can be reduced through various management actions. Company has experience in drilling in environmentally sensitive regions. The EPA objective can be met.

POLLUTION MANAGEMENT					
Drilling fluids	Ensure that the probability of spillage is extremely low, that actions are taken to reduce identified risks, and that drilling operations and equipment are at the level of international best practice for drilling in environmentally sensitive areas.	Refer to Section 4.2 and Section 5.4.1	There will be short term, localised impact due to increased water turbidity from the 36" hole. A spill of Petrofree would result in the short term increase in turbidity. A large spill of Petrofree could impact on the fringing corals of the Muiron Islands.	Disposal of excess water based fluid down annulus. Workboats and rig properly prepared for Petrofree. All hoses pressure rated and tested. Non-return valves fitted. Mud tank area bunded. Continuous fluid volume monitoring. Mud pits master value padlocked at all times. Conduction of rig and vessel audits to ensure proper equipment and practices.	No spillage of Petrofree. The EPA objective can be met.
Drilling cuttings	Ensure that drilling cuttings created by drilling do not adversely affect the surrounding environment.	Refer to Section 4.2.	Small arc of smothering by drill cuttings from 36" hole. In the advent of failure of the annulus to accept solids, the cutting would be deposited to the marine environment. Increased turbidity and some burial of seafloor fauna. The mound will dissipate quickly due to high tide and current activity, and area will be recolonised rapidly.	Disposed of the cuttings down annulus. If no lost circulation zone present, cuttings to be deposited on the seabed via a hose.	Small area of seafloor burial caused by initial drilling of the 36" hole. The EPA objective can be met.
Other operational discharges	Ensure that operational discharges associated with the project do not adversely affect the surrounding environment.	Refer to Section 4.2.	Minor short-term nutrient increases, lights may act as short-term attractant, generation of small volume of greenhouse gases.	Tertiary treatment of sewerage, onshore disposal of most wastes. Selection of low toxicity pipe dope. Tuning of engines for minimal gas emissions.	No significant environmental impacts. The EPA objective can be met.
SOCIAL SURROUNDINGS					
Ningaloo Marine Park	Protect the conservation values, biodiversity and ecosystem functions of Ningaloo Marine Park.	Well-developed coral reefs at Bundegi and along the west coast of the North West Cape Peninsular. Extensive macroalgal beds between Tantabidy and Point Murat. Filter feeding community in the vicinity of Chelonia. Refer to Section 3.0.	No potential impacts to the coral communities or macroalgal beds from routine operations. Possible turbidity effects and minor cuttings deposition on adjacent filter feeding communities. The risk of an oil spill reaching shorelines or Ningaloo Reef is very low, particularly in the summer months.	Down annulus disposal of drill cuttings and excess drilling fluid. Use of international best practices for drilling. Potential sources of oil spills have been identified. Risk reduction action put into place. Oil Spill Contingency Plan with response strategies.	No effect to the Ningaloo Marine Park. The EPA objective can be met.



Dated: 29 April 1998 ISm5294

NORTHWEST CAPE AND EXMOUTH GULF REGION
LANDSAT IMAGE (OCTOBER 1986 TO JANUARY 1996)
DOLA

Chelonia-1 and Chelonia-2 Exploration Wells EP 342

Consultative Environmental Review

1. INTRODUCTION

1.1 Summary of the Proposal

Apache Northwest Pty Ltd (the Proponent) is seeking approval to drill two exploration wells, Chelonia-1 and Chelonia-2 in Permit Area EP342, located in State waters at the head of the Exmouth Gulf, approximately 14 km to the northeast of North West Cape (Figure 1).

The proposal is for exploration drilling only. The Chelonia-1 well will be drilled initially and if hydrocarbons are encountered, the rig will drill a second well, Chelonia-2, from the same surface location. If hydrocarbons are not encountered, Chelonia-1 will be plugged and abandoned according to standard procedures required by the Department of Minerals and Energy under the *Petroleum (Submerged Lands) Act* 1982.

Both wells will be directionally drilled to a vertical depth of some 2,825 metres. The wells will have the same surface location, situated some 111 m outside the Ningaloo Marine Park Boundary and within 50 m of the Loggerhead-1 well which was drilled in 1992. The Chelonia prospect is located below the Ningaloo Marine Park.

Drilling operations would be conducted from a conventional jack-up rig using the most contemporary directional drilling technology. The expected duration of the Chelonia-1 drilling program is 26 days, with drilling being carried out in the 1998/99 summer period. Should hydrocarbons be encountered, the rig would remain on location for an additional 18 days for Chelonia-2.

The wells will be production tested using down-hole logging tools and should a resource be discovered, the wells will be sealed. Any further exploration or development of the wells would require another environmental assessment.

1.2 The Proponent

The proponent is Apache Northwest Pty Ltd (Apache), on behalf of the Joint Venture Participants in Exploration Permit Area EP342, the proposed location for the Chelonia-1 and Chelonia-2 drilling program.

The Joint Venture Participants for the program are:

Apache Northwest Pty Ltd (Operator)	29.7 %
Boral Energy Resources Limited	40.6 %
Gulf Australia Resources Limited	29.7 %

The proponent's address is : Apache Northwest Pty Ltd
256 St George's Terrace
Perth, Western Australia 6000

Contact person: Iva Stejskal
Environmental Manager

1.3 History of Exploration Drilling in Permits EP342

Prior to commencement of drilling activities in Western Australia, a proposal must undergo a review of the environmental impacts as stipulated in the *Environmental Protection Act* 1986. The then proponent, Lasmo Oil (Australia) Ltd (Lasmo), submitted a permit wide drilling application in September 1990. The project was assessed at a Consultative Environmental Review (CER) level (BBG 1990).

In March 1991, the Environmental Protection Authority (EPA), acting under the provisions of the Act, recommended that approval for a permit-wide exploration drilling program in petroleum permit area EP342 be given (EPA Bulletin 504) subject to a number of recommendations. The Minister for the Environment granted permission on 26 April 1991.

There have been three proponents in EP342 since the submission of the Lasmo CER: Lasmo from 1991 - November 1993 and Hadson Energy from November 1993 to 19 April 1996. Apache is the current proponent.

Six wells have been drilled offshore in EP342 under the permit-wide approval since 1991 (Figure 1; Table 1). Caretta-1 and Leatherback-1 were drilled in 1991 and intersected oil columns. Caretta-1 was judged as a sub-economic discovery and abandoned. The well was plugged with cement and the casing was cut below the sea-bed. Leatherback-1 was tested and flowed at an unstabilised rate of 2,626 BOPD from the Triassic Mungaroo Formation. This well was plugged and suspended as a possible future oil producer. A corrosion resistant well head cap was installed.

Loggerhead-1 was drilled in 1992 and was a directional well which extended under the Ningaloo Marine Park. Mydas-1 and Hawksbill-1 were drilled in 1993. None of these wells intersected significant hydrocarbon columns. Ridley-1 was drilled in July 1996 and intersected a 4 m oil column at 888 m in the Birdrong Sandstone. Each of these wells were plugged after which the casings were cut below the seabed.

In late 1997, Apache submitted an application for a drilling program in EP342 consisting of five wells. The wells were: Chelonia-1, Chelonia-2, Leatherback-2, Sawback-1 and Longneck-1. These wells were referred to the EPA who subsequently set Chelonia-1 and Chelonia-2 at a formal level of assessment and the remaining three wells at informal level of assessment.

Leatherback-2, Sawback-1 and Longneck-1 were drilled in late 1997. No hydrocarbons were encountered in any of these wells.

Table 1: Wells drilled offshore in EP342 since 1991.

Drilled	Well Name	Well Type	Inclination	Deviation Length (m)	Drill Days	Tested
1991	Caretta 1	Wildcat			24	Y
1991	Leatherback 1	Wildcat			33	Y
1992	Loggerhead 1	Wildcat	Deviated	2960	41	N
1993	Mydas 1	Wildcat			12	N
1993	Hawksbill 1	Wildcat	Deviated	1839.0	18	N
1996	Ridley 1	Wildcat			4	Y
1997	Leatherback 2	Appraisal			9	N
1997	Sawback 1	Wildcat			7	N
1997	Longneck1	Wildcat			7	N
					155 Days	

1.4 Need for the Proposal

Petroleum exploration and production is the single most significant economic activity in Australia's marine environment. The gross production value from Australia's petroleum industry generated $8.6 billion in 1995-96. Of this $8.6 billion, $2.4 billion was paid to government in royalties, resource rents and income tax. In the period 1994/95, the value of Western Australian offshore production exceeded $2.5 billion, representing 32% of national production.

Oil and gas development on the North West Shelf of Australia is becoming increasingly important as the production from Bass Strait fields continues to decline. Both the Australian Commonwealth and Western Australian Governments recognise and support the need for Australia to at least maintain present levels of self sufficiency in oil and gas. The Western Australian Government regularly releases permit areas for tender to petroleum companies and consortiums to encourage onshore and offshore hydrocarbon exploration.

The Chelonia prospect is located in the Carnarvon Basin, one of the most prospective regions for oil and gas resources in Western Australia. The exploration program is one of a number conducted in the region to date and part of the commitment Apache has to the region. Although the program will extend for less than two months, it assists in maintaining the petroleum industry expertise within the State and contributes to the ongoing commercial viability of the providers of services to the industry.

1.5 Consideration of Alternative Locations

The geological structure that the Chelonia drilling program is proposed to access has been determined from extensive seismic surveys and was identified prior to 1989. Loggerhead-1 was drilled in 1992 to ascertain the presence of hydrocarbons in an adjacent hydrocarbon structure; however, no hydrocarbons were encountered. Subsequent interpretation of seismic data has improved the understanding of the geology of the area, and the presence and location of the Chelonia structure.

The location of the Chelonia-1 and -2 surface location has been selected because:

- it is near a site previously disturbed during Loggerhead-1 and it is known that seabed recovery will be rapid (see Sections 3.10 and 4.2); and
- it is close to the prospect as possible given the limitations of access to the marine park. This will allow the shortest drilling time and length of well, thereby reducing safety and environmental risks.

1.6 Legislative Requirements and the CER Process

Exploration of offshore petroleum resources in Western Australia is undertaken subject to a number of State and Commonwealth Government Acts. The two wells proposed under this drilling program are located in State waters and are therefore administered by the Department of Minerals and Energy of Western Australia (DME) under *the Petroleum (Submerged Lands) Act* 1967, as amended.

Other principal environmental acts, both State and Commonwealth, which apply to the drilling program include:

- *Environmental Protection Act* 1986
- *Pollution of Waters by Oil and Noxious Substances Act* 1987
- *Endangered Species Protection Act* 1992
- *Wildlife Protection Act* 1950
- *National Parks and Wildlife Conservation Act* 1975 (including international trans-migratory bird treaties with China (CAMBA) and Japan (JAMBA)
- *Whale Protection Act* 1980.

The review of the environmental impacts of the proposed drilling program is controlled by the *Environmental Protection Act* 1986. The Chelonia-1 and -2 wells were referred to the Environmental Protection Authority (EPA) on 5 September 1997 for the determination of the level of assessment under Section 38 of the *Environmental Protection Act* 1986. The EPA decided to formally assess the proposed drilling program and set the level of assessment as a Consultative Environmental Review (CER). This level of assessment was publicly advertised and no appeals to the level of assessment were received.

The EPA guidelines for the preparation of this CER were provided by the Department of Environmental Protection (DEP) on 8 December 1997 and are set out in Appendix 1.

This CER:

- describes the project;
- describes the environmental setting in which the proposed drilling program will take place;
- presents an environmental analysis of exploration drilling and its potential effects;
- presents a quantitative risk assessment of the program; and
- details the management strategies to be adopted to minimise the actual and potential environmental effects arising from drilling.

This document has been prepared in accordance with the guidelines provided by the DEP to facilitate the environmental review process and document the issues raised. It will be reviewed by the EPA, DEP, Department of Conservation and Land Management (CALM), Department of Fisheries, Western Australian Museum (WAM), Environment Australia, other relevant agencies, community groups and individuals.

1.7 International Best Practice

As mentioned in Section 1.6 above, offshore drilling operations are subject to the general provisions of a number of international laws and conventions. These laws and conventions provide the framework for the implementation of the more comprehensive legislative rules and regulations at the national and State levels. Company procedures and guidelines at the operational level further enhance these rules and regulations.

Table 2 outlines some of the International, State, industry and company mechanisms which are used or referred to in order to ensure best practice performance for the Chelonia drilling program. Best practice applies the principles of:

(1) developing procedures and applications for environmental assessment and identifying risks; and
(2) minimising adverse effects through environmental management and progressive improvement.

These principles help identify and address all relevant aspects of the project to ensure safe and environmentally responsible operations. Performance measures or benchmarks are used to measure this environmental performance in order to achieve an optimal level of environmental protection.

Table 2: Best Practice mechanisms for the protection of the environment. Chelonia-1 and -2 Drilling Program.

	Application	**Objective**	**Performance measure areas**
		International	
1.	American Bureau of Shipping	Inspection of rig for safety and integrity as vessel (e.g. hull and leg thickness, lifeboat integrity, BOP integrity). Internationally accepted standards used.	Vessel Survey certificate. Registration of rig. Granting of insurance.
2.	Mobile Offshore Drilling Unit (MODU) Specifications	Inspection of rig for safety and integrity as drilling unit.	Certification. Granting of insurance.
3.	Safety of Life at Sea (SOLAS) International Convention	Protection of human life.	Compliance to standards and regulations. No fines.
4.	MARPOL 1978	To control pollution to the marine environment from oil and other sources from ships and offshore installations.	Compliance to standards and regulations. Certification of compliance. No corporate or individual fines.
5.	Oslo and Paris Convention (OSPAR) 1992 (Reference only)	Protection of the marine environment of the North Sea from exploration and production activities.	Compliance to relevant recommendations or decisions.

Australia and Western Australia			
6.	Australian Marine Safety Authority (AMSA) audit (under the Australian Maritime Safety Authority Act 1990)	Inspection of rig for safety and compliance to Australian standards.	Approval to allow rig into Australia. Performance audit and follow-up actions.
7.	APPEA Code of Practice	Provision of industry guidelines to ensure high and continually improving standards.	Baseline conditions.
8.	Petroleum (Submerged Lands) Act 1967 (Western Australia)	To maximise the extraction of hydrocarbon resources in a safe manner.	Approval of drilling program. Compliance to conditions, regulations and imposed restrictions. No fines. No shut-down. Ability to continue ongoing drilling program.
9.	Safety Case	To ensure that drilling program is run with due care to safety and the environment.	DME approval of drilling program. Setting conditions and standards. Evaluation of past performance.
10.	DME compliance audit	To measure compliance to safety and environmental standards, legislation and regulations. To identify risks, hazards and liabilities.	Follow-up actions of non-compliance items. Sign-off on performance.
Apache Energy			
11.	Contractors performance record	Audit of contractor code of practice and past performance in safety and environment to ensure ability to comply to international, national, state and company standards, legislation and regulations.	Award of contract by Apache.
12.	Drilling manual	To detail all drilling standards and procedures.	DME approval to proceed with drilling.
13.	Oil Spill Contingency Plan	To detail the response and clean-up of an oil spill.	Approval of plan by DME. Audit of field and desk-top exercises.
14.	Environmental impact assessment	To describe the proposal in its particular environment, identify the potential impacts and describe how the impacts will be managed.	Program approval by DME, DEP, and EPA. Ministerial conditions.
15.	Environmental management plan (based on ISO 14000).	To detail the procedures, conditions and commitments for the drilling program to ensure compliance and reduce impacts.	Approval by DME, DEP and EPA. Compliance audit.

Apache Energy			
16.	Joint Venture compliance audit	To ensure compliance to environmental standards, conditions and commitments for the drilling program.	Performance audit and follow-up actions.
17.	Incident reporting procedure	To report any incidents which may potentially impact the environment.	Reports to government. Follow-up actions.
18.	Inductions, training and education program	To give the contractor and drilling rig personnel means of identifying the risks and knowledge of the environmental implications of the program.	No incidents.

1.8 Public Consultation

In keeping with Apache's policy of open communication with government and the community, all interested parties will be kept informed and up to date on the progress of the Chelonia drilling program and all concerns will be addressed.

Copies of this CER will be forwarded to parties who have an interest in the project (Appendix 2). Further presentations will also be made to interested parties prior to the commencement of the project as per the communications strategy outlined in Appendix 2.

2. PROJECT DESCRIPTION

The drilling program summary for Chelonia-1 and Chelonia-2 are given in Table 3.

Table 3: Overview of the drilling program.

	Chelonia-1	**Chelonia-2**
Surface location	21° 44'38.87" S 114° 17'3.88" E	same
Type of well	Directional	Directional
Proposed drilling time	Within summer period 1 Nov – 31 Mar	Within summer period 1 Nov – 31 Mar
Water depth	20 m	20 m
Drilling days	26	18
Drilling rig	Jack-up rig	Jack-up rig
Drilling fluid	Water based and Petrofree	Water based and Petrofree
Vertical depth	2,825 m	2,810 m
Measured depth	4,089 m	3,263 m
Volume of cuttings *	15.8 m^3	None
Production testing	Yes	Yes
Reservoir access	6 days	3 days
Habitat type	Limestone pavement with sand veneer	Limestone pavement with sand veneer
Nearest landfall	Muiron Islands	Muiron Islands
Nearest sensitive resource	Intertidal sand and subtidal fringing reef S. Muiron Is: 4- 6 km	Intertidal sand and subtidal fringing reef S. Muiron Is: 4- 6 km

* This is the volume that will be deposited on the seabed prior to the setting of the first casing. The intent is to dispose the remaining cuttings and residual water based fluids down the annulus. The total quantity of drill cuttings to be generated is estimated to be about 445 m^3 for Chelonia-1 and 331 m^3 for Chelonia-2.

2.1 Drilling Procedure

The Chelonia-1 and -2 site is located at the head of Exmouth Gulf, and approximately 4 km to the SSW of South Muiron Island (Figure 1). The site is 12 km SSW of North Muiron Island and 14 km SW of Sunday Island. The nearest landfall on the mainland coast is North West Cape, approximately 14 km to the southwest. The Chelonia-1 and -2 wells will be drilled approximately 50 m to SE of the Loggerhead-1 well location (drilled in 1992), in a water depth of 20 m.

The program will involve drilling two wells from the same surface location. Both wells will be directional wells using contemporary technology. A detailed well design will be developed for each of the wells and submitted to the DME for approval.

The proposed surface location for the Chelonia wells is approximately 111 m outside the Ningaloo Marine Park Boundary and in State waters (Figure 2).

Drilling operations would commence as soon as the jack-up drilling rig was secured, and the rig would be moved from the location immediately after completing the program.

Directional drilling is the process of directing the well along some trajectory away from the vertical to a predetermined target. Directional drilling is a common and long-proven practice. A large number of offshore wells drilled on the North West Shelf are directional. Apache and its predecessors have successfully completed 39 directional wells on the North West Shelf since 1983 (Table 4). Loggerhead-1 and Hawksbill-1, for example, were directional wells. The well characteristics and formation pressures of the area are known from extensive experience with North West Shelf geology and formation structures, including several programs in the vicinity of Chelonia-1 and -2, particularly Loggerhead-1.

The drilling program for Chelonia-1 and -2 will involve drilling and setting vertical casing to approximately 500 m below the seafloor before deviating the well along a gentle curve towards the SW (220°) (Figures 3 and 4). This is very similar to the program carried out at the Loggerhead-1 site, located some 50 m away from the proposed Chelonia location, and the Wonnich appraisal drilling program (Apache 1995).

For Chelonia-1, the bottom hole target will extend about 2.5 km under the marine park at a measured depth of 4,089 m (Figure 3). The bottom hole target for Chelonia-2 will be 1.5 km under the marine park boundary at a measured depth of 3,263 m (Figure 4).

If hydrocarbons are encountered, the drill string will be pulled back and sidetracked to drill the second well. If no hydrocarbons are encountered, the well will be plugged and abandoned according to DME procedures.

At the completion of the drilling of each well, a production test utilising either burning or electric logging tools may be run to test for the presence of hydrocarbons. Should the well prove to be not commercial, it will be plugged in accordance with a DME approved program. Cement plugs will be set at various depths in the well bore to seal the well, the casing will be cut below the surface of the seabed and all above-seabed obstructions will be removed. A remotely operated vehicle will then be used to survey the seabed to ensure that no debris remains from the operation.

If the prospect is considered to be commercially viable, the well will be sealed using mechanical and cement plugs under a DME approved program, and suspended until a decision regarding development can be made. If a development option is considered to be economic, it will undergo its own full environmental assessment.

All work on the well will be undertaken in accordance with the regulations and requirements set out in the *Petroleum (Submerged Lands) Act* 1982, as amended, Schedule - Specific Requirements as to Offshore Petroleum Exploration and Production 1995.

On completion of the exploration well drilling program, the rig will be jacked down and towed away.

2.2 Site Description - Overview

The Chelonia location is to be drilled within 50 m of the Loggerhead-1 well, drilled in 1992. The well is located in some 20 m of water (Figure 5). Details of the site are provided by pre- and post-drilling surveys for this well (BBG 1992, 1993) and more recent inspections (Letter reports by BBG 1995 and 1997) (see also Section 3).

The surrounding substrate is limestone pavement overlain in places by a veneer of mainly gravel-size sediments. The pavement supports a sparse fauna of filter and particulate feeding macroinvertebrates (Plates 1 to 4). These consist mostly of leptogorgia (seawhips), sponges and bryozoans, with lesser numbers of gorgonians, ascidians, hydroids and turbinaria corals. Highest abundances and diversities occur where the pavement is bare of sediment or is upstanding. The pavement also supports a relatively high density of crinoid starfish that are attached to most raised organisms. The main flora is corraline algae, which coats and cements most of the finer sediments into loosely bound gravels.

This limestone pavement habitat type was found over a large number of sites, and is thought to extend over the central tidal channel between North-West Cape and South Muiron Island. The development of these communities can be attributed to the strong tidal currents experienced over this area. These currents provide a high turnover of nutrient particles and keep the pavement relatively free of sand.

Drilling of Loggerhead-1 by Lasmo in 1992 involved the disposal of an estimated 548 m^3 of drilling solids and fluid directly to the seafloor. This formed an elliptical mound with a NW-SE axis covering approximately 2,700 m^2. A re-inspection of the site in December 1995 found that the cutting mound had been dispersed by water currents, leaving only the gravel size cuttings. The pavement near the disposal site supported similar assemblages to that found over the neighbouring undisturbed sites. Attempts to find the mound in June 1997 were unsuccessful.

2.3 Logistics for the Drilling Program

2.3.1 Drilling rig

A jack-up drilling rig will be used for the drilling program. The drilling rig will be towed to the site and will be jacked up into position, supported by three legs bearing on the seafloor.

Two vessels, most likely the *Massive Tide* and *Canning Tide*, will be used to tow and position the rig and supply it with fresh water, food, dry bulk drilling fluid materials and drilling hardware. These vessels will operate between the rig and the Port of Dampier.

A dedicated Oil Spill Response Vessel (OSRV), fitted with an ocean-rated oil containment boom, oil recovery unit and oil dispersant spray application booms will remain at the drilling location throughout the entire drilling program.

The drilling rig, supply vessel, and OSRV crews will be accommodated onboard their respective vessels. Crew changes will involve transfers by helicopter via the Karratha airport.

2.3.2 Site survey

To determine the physical properties of the seabed, prior to installation of the jack-up rig, a sonar survey will be undertaken to confirm the bearing capabilities of the substrate.

Table 4: Summary of well types drilled by Apache and its predecessors since 1983, showing the number of directional (deviated) wells which have been drilled.

	Drilled	Well Name	Permit	Well Type	Inclination	Deviation Length (m)	Drill Days	Tested	Test Type	Testing Hours	Production Since
1.	1996	Agincourt 1	TL 6	Wildcat	Deviated	954.0	4	N		0	
2.	1996	Agincourt 1 S/T	TL 6	Wildcat	Deviated	1937.0	11	Y	SFT	0	
3.	1996	Agincourt 2	TL 6	Appraisal	Deviated	1905.0	8	N		0	
4.	1997	Agincourt 3H	TL 6	Development	Deviated	2349	15	N			1997
5.	1997	Agincourt 4H	TL 6	Development	Deviated	2777	27	N			1997
6.	1994	Alkimos 1	TL 1	Wildcat	Deviated	1969.0	14	N	Production	0	1994
7.	1996	Antler 1	WA209P	Wildcat	Vertical		5	Y	FET	0	
8.	1983	Arabella 1	WA192P	Wildcat	Vertical		23	N		0	
9.	1982	Bambra 1	TL 1	Wildcat	Vertical		96	Y	DST/RFT	7.35	-
10.	1983	Bambra 2	TL 1	Appraisal	Vertical		129	Y	DST/RFT	27.4	-
11.	1988	Bambra 3	TL 1	Appraisal	Vertical		15	Y	RFT	0	-
12.	1997	Bambra 4	TL 1	Exploration	Vertical	2152	10	N			
13.	1994	Belinda 1	TP/8	Wildcat	Vertical		6.6	N		0	-
14.	1995	Bellerophon 1	WA254P	Wildcat	Vertical		7	N		0	
15.	1997	Buck 1	WA 259P	Wildcat	Vertical	1050	6	N			
16.	1997	Bugle 1	WA259P	Wildcat	Vertical	1833	10	N			
17.	1986	Campbell 2	TL 5	Production	Vertical		30	Y	DST	25.4	1992
18.	1992	Campbell 3	TL 5	Appraisal Aband.	Deviated	1459.0	7	N		0	-
19.	1992	Campbell 4	TL 5	Appraisal Aband.	Deviated	1393.0	23	N		0	-
20.	1995	Campbell 5	TL 5	Production	Deviated	2246.0	42	Y	RFT	0	1996
21.	1982	Candace 1	WA192P	Wildcat	Vertical		29	N		0	
22.	1994	Centaur 1	WA209P	Wildcat	Vertical		8	Y	MDT	0	
23.	1997	Crecy 1	TL 6	Wildcat	Deviated	2066	8	N			
24.	1995	Darwin 1	WA237P	Wildcat	Vertical		22	N		0	
25.	1996	Doric 1	TL 1	Wildcat	Vertical		9	N		0	-

Table 4 continued

26.	1982	Dorrigo 1	TP 8	Wildcat	Vertical		39	Y	RFT/DST	7.31	
27.	1996	Elk 1	WA209P	Wildcat	Vertical		4	Y	FET	0	
28.	1983	Emma 1	WA192P	Wildcat	Vertical		28	Y	DST/RFT	0.30	-
29.	1983	Flores 1	TP 8	Wildcat	Vertical		17	Y	RFT	0	-
30.	1983	Georgette 1	TP 8	Wildcat	Vertical		22	N		0	-
31.	1996	Greenshank 1	WA246P	Wildcat	Vertical		8	N		0	
32.	1983	Harriet A1	TL 1	Production	Vertical		41	Y	DST/RFT	127.0	1984
33.	1983	Harriet A2	TL 1	Production	Deviated	2352.0	70	N		0	-
34.	1984	Harriet A3	TL 1	Production	Deviated	2054.0	60	Y	DST	21.0	1984
35.	1984	Harriet A4	TL 1	Production	Deviated	1972.0	35	Y	RFT	0	1984
36.	1984	Harriet A5	TL 1	Production	Deviated	2078.0	8	Y	DST	17.2	1984-1994
37.	1994	Harriet A5 S/T	TL 1	Production	Deviated	1980.0	6	N		0	1994
38.	1984	Harriet A6	TL 1	Production	Deviated	1999.0	21	Y	DST/RFT	15.15	1984-1995
39.	1990	Harriet A7	TL 1	Production	Deviated	2002.0	11	N		0	1990
40.	1994	Harriet A8	TL 1	Production	Deviated	2280.0	19	N		0	-
41.	1994	Harriet A8H	TL 1	Production	Horizontal	1942.0	0	N		0	1994-96
42.	1996	Harriet A8H1	TL 1	Production	Horizontal	1936.0	8	N	Production	0	1996
43.	1994	Harriet A9	TL 1	Production	Deviated	1960.0	9	N		0	-
44.	1994	Harriet A9H	TL 1	Production	Horizontal	1944.0	0	N		0	1994
45.	1995	Harriet A10	TL 1	Production	Deviated	2026.0	9	N		0	-
46.	1984	Harriet B1	TL 1	Production	Vertical		22	Y	DST/RFT	31.0	1984
47.	1985	Harriet B2	TL 1	Production	Deviated	1992.0	44	Y	DST	22.5	1984
48.	1985	Harriet B3	TL 1	Production	Deviated	2020.0	35	Y	DST/RFT	34.25	1984
49.	1990	Harriet B4	TL 1	Production	Deviated	2022.0	10	N		0	-
50.	1985	Harriet C1	TL 1	Production	Vertical		19	Y	RFT	0	1985
51.	1985	Harriet C2	TL 1	Production	Deviated	1966.0	23	N	RFT aband.	0	1985
52.	1990	Harriet C3	TL 1	Production	Deviated	1984.0	12	N		0	1990
53.	1994	Hawksbill 1	EP 342	Wildcat	Deviated	1839.0	18	N		0	-
54.	1996	Helicon 1	WA254P	Wildcat	Vertical	3078.0	17	Y	SFT	0	-

Table 4 continued

55.	1996	Helicon 1 CH1	WA254P	Wildcat	Deviated	2362.0	5	N		0	-
56.	1997	Janus-1	WA254P	Wildcat	Vertical	2501	10	N			
57.	1997	Jaubert 1	WA1P	Wildcat	Vertical	2025	24	Y	RFT	36	
58.	1997	Jaubert 1/ST 1	WA1P	Wildcat	Deviated	2105	13	Y			
59.	1983	Judy 1	EP 363	Wildcat	Vertical		13	Y	RFT	0	-
60.	1987	Kybra 1	WA192P	Wildcat	Vertical		27	N		0	-
61.	1997	Leatherback 1	EP342	Appraisal	Vertical	1840	9	N			
62.	1997	Longhorn 1	WA261P	Wildcat	Vertical	809	7	N			
63.	1997	Longneck	EP342	Wildcat	Deviated	1410	10	N			
64.	1992	Marra 1	TL 1	Wildcat	Vertical		14	N		0	-
65.	1993	Mydas 1	EP 342	Wildcat	Vertical		12	N		0	-
66.	1985	Nyanda 1	TL 1	Wildcat	Vertical		24	N		0	-
67.	1986	Orpheus 1	TL 1	Wildcat	Vertical		27	Y	RFT	0	-
68.	1986	Plato 1	TL 1	Wildcat	Deviated	2361	23	N		0	-
69.	1997	Reindeer 1	WA209P	Wildcat	Vertical	2905	27	Y	RFT		
70.	1996	Ridley 1	EP 342	Wildcat	Vertical		4	Y	SFT	0	-
71.	1987	Rosette 1	TL 1	Wildcat	Deviated		123	N		0	-
72.	1987	Rosette 1 S/T	TL 1	Wildcat	Deviated	2556.0	0	Y	DST	90.0	1992
73.	1997	Sawback 1	EP342	Wildcat	Vertical	1031	7	N			
74.	1990	Sinbad 1	TL 1	Wildcat	Deviated	2635.0	33	Y	DST	17.0	1992
75.	1992	Sinbad 2	TL 1	Production	Deviated	2183.0	35	N	Production	0	1992
76.	1993	Stag 1	WA209P	Wildcat	Vertical		8	Y	SFT	0	-
77.	1993	Stag 2	WA209P	Appraisal	Vertical		7	Y	FET/DST	47.9	-
78.	1994	Stag 3	WA209P	Appraisal	Vertical		5	N		0	-
79.	1994	Stag 4	WA209P	Appraisal	Vertical		6	N		0	-
80.	1995	Stag 5	WA209P	Appraisal	Vertical		5	N		0	-
81.	1995	Stag 6	WA209P	Appraisal	Deviated	783.0	5	N		0	-
82.	1995	Stag 6H	WA209P	Appraisal	Horizontal	722.0	7	Y	DST	178.0	-
83.	1996	Stag 7	WA209P	Appraisal	Vertical		4	Y	FET	0	-

Table 4 continued

84.	1996	Stag 8	WA209P	Appraisal	Vertical		10	N		0	-
85.	1997	Stag 9H	WA209P	Development	Deviated	3003	63	N			
86.	1997	Stag 10H	WA209P	Development	Deviated	2088	67	N			
87.	1997	Stag 11H	WA209P	Development	Deviated	3233	65	N			
88.	1997	Stag 12H	WA209P	Development	Deviated	4738	77	N			
89.	1991	Tanami 1	TL 1	Wildcat	Deviated	2064.0	31	Y	RFT	0	1991
90.	1991	Tanami 2	TL 1	Appraisal	Deviated	2291.0	19	N		0	-
91.	1994	Tanami 3	TL 1	Appraisal	Deviated	792.0	33	N		0	-
92.	1994	Tanami 3 S/T 1	TL 1	Appraisal	Deviated	1867.0	0	N		0	-
93.	1994	Tanami 3 S/T2	TL 1	Appraisal	Deviated	1901.0	0	N		0	-
94.	1992	Ulidia 1	TL 1	Wildcat	Vertical		11	Y	SFT	0	-
95.	1997	Wonnich 2	TP 8	Appraisal	Vertical	2385	13	Y	RFT		-
96.	1997	Wonnich 3	TP 8	Appraisal	Deviated	3430	33	N		0	-
							1552.6 days			27.8 days	

2.4 Safety Precautions

Before drilling operations commence, routine precautions will be undertaken by the drilling contractor to ensure the stability of the drilling rig and to minimise the risk of movement during any storm conditions. Previous site surveys and drilling at Loggerhead-1 have provided information on the nature and stability of the seabed and the underlying strata, particularly in relation to the depth of penetration by the rig legs. The positioning of the rig and jack-up operation will be closely supervised by the drilling supervisor, rig tow master, marine representative of the rig owners, and vessel skippers.

The well will be designed and engineered to standards approved by the DME to ensure that any well pressures remain under control. Annular, ram and drill string BOPs will be used and this system will be able to contain pressure far in excess of pressures expected to be encountered, and generally found in the Carnarvon Basin.

Casing sizes and lengths, and the intervals where the hole is cement sealed around the casing will be selected to maximise well control. Experience of the reservoir conditions and stratigraphy gained from drilling numerous wells in the local vicinity will facilitate well design. In particular, this experience provides a very good understanding of the reservoir pressures that may be encountered. Well design is conservative to ensure a margin of safety to control any higher than expected pressures.

An Emergency Response Manual and Oil Spill Contingency Plan, detailing safety procedures in the event of an emergency situation, will be submitted for approval from DME as required by legislation. Copies of the Emergency Response Manual and Oil Spill Contingency Plan are held by each member of the designated response team and are always available to crew members prior to commencement of the drilling program and at all times during the work program. This plan has been further refined following an oil spill response exercise, involving the field deployment of booms, vessels, and helicopter spray equipment, held during the Ridley-1 drilling program (September 1996). The current program will employ the Emergency Response Vessel and suitably trained spill response personnel.

3. DESCRIPTION OF THE ENVIRONMENT

3.1 Location

The proposed location of the Chelonia-1 and -2 drilling program is 21°44'38.87'' S and 114°17'3.88'' E, approximately 111 m outside the Ningaloo Marine Park boundary.

The site is approximately 4 km to the SSW of South Muiron Island, 12 km SSW of North Muiron Island and 14 km SW of Sunday Island. The nearest landfall on the mainland coast is North West Cape, approximately 14 km to the SW. The proposed well site lies in approximately 20 m of water in the tidal channel at the mouth of Exmouth Gulf commonly known as "The Gap" (Figure 5). The Chelonia wells will be drilled approximately 50 m to the SE of the Loggerhead-1 well location (drilled in 1992).

The following sections briefly describe the physical, biological and social environment of the region, and the existing environment at the proposed Chelonia drilling program (see Figures 6 and 7, and Table 5).

3.2 Climate and Oceanography

Climate

Exmouth Gulf lies within the southern region of the arid Pilbara, where the climate is typified by very hot summers, mild winters and very low rainfall. Average summer maximum temperatures at Onslow and Exmouth are 36° C - 37° C while average winter maxima are 24° C - 28° C (Western Mining Corporation 1990).

Average annual rainfall is low (265 mm at Onslow) but is highly variable. Most falls occur during the first half of the 'wet' season, which extends from January to July. Significant rainfall is usually associated with summer thunderstorms or cyclones and can be very intense. The highest one day recording at Onslow was 365 mm (Western Mining Corporation 1990).

Meteorology

The wind patterns in the area are highly seasonal with consistent patterns developing during summer and winter and transitional conditions during autumn and spring. The seasonality of the wind regime is controlled largely by the northward/southward movement of the Subtropical High Pressure Belt - a series of discrete anticyclones which move from west to east across the southern regions of Australia throughout the year. In winter, the axis of the anticyclonic belt lies across the Australian continent between 25° to 30°S. In summer the axis moves south of the Australian continent and lies between 35°S to 40°S.

The seasonal wind patterns in the area have been described by Steedman Science & Engineering (1992) and are reported below.

Summer season

During the summer months (November - March), Exmouth Gulf is southwest of the mean low pressure area over northern Australia. The winds in the area during summer are from the south and southwest and are recirculated continental air which moves seawards to the south

Table 5: Seasonal timetable of natural and social resources of the Exmouth Gulf and North West Cape region.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coral spawning												
Seabird nesting												
Turtle nesting												
Hatchling season												
Whale sharks												
Humpback whales												
Dugongs												
Turtles												
Dolphins												
Manta rays												
Prawn fishing												
Diving												
Recreational fishing												
Cyclones												

Present or occurring

Peak of season or activity

of the heat low, then is recirculated over the area of interest towards the Australian mainland. The term pseudo-monsoon has been used to describe the situation (Steedman Science and Engineering, 1992).

The semi-permanent heat low over northwestern Australia controls the air flow over the area. In general, air will flow into this low pressure area (with a general clockwise circulation). This results in a south and southwesterly flow of air over Exmouth Gulf. Wind speeds will typically range between 2 and 10m s-1 and occasionally reach 15m s-1.

Often this air mass has travelled over warm tropical waters, and therefore may be moist and unstable. This flow is the dominant feature during summer. It is occasionally interrupted by a period of easterly winds associated with a particularly intense high pressure cell in the Subtropical High Pressure Belt, or by a period of variable but often strong winds associated with the passage of a tropical cyclone.

The sea breeze effect in the area often results in stronger southerly winds during the afternoon.

Winter season

During the winter period (May - August), Exmouth Gulf lies on the northern periphery of the high pressure cells. As winds flow outwards from the high pressure cell in an anticlockwise direction, the area of interest is dominated by a flow of easterly and southeasterly air. Successive high pressure cells separated by cols (relatively low pressure area between two high pressure cells) and troughs do little to disturb the direction of the outflow as they move eastward, but they can have a marked effect on the speed of the winds. The wind speed increases in response to increasing pressure gradient and decreases as the pressure gradient relaxes. These Southeast Trades are cool and dry winds originating over continental Australia.

Intensification of the pressure gradients, generally caused by an intense high pressure system in the Great Australian Bight area, results in easterly gales.

Transition months

During the transition months of April and September, the heat low is transitory instead of semi-permanent and the air flow in the area depends on the dominant pressure feature, i.e. either the heat low or the subtropical high pressure belt. During these periods both summer (S, SW) and winter (S, SE, E) air flows may be expected.

The change from summer to winter conditions is generally quite sharp with only a short transition period.

Sea breezes

Superimposed upon the synoptic winds are local winds, particularly land and sea breezes.

During the summer months in particular, and generally throughout the year, the differential heating and cooling of the sea and land during the daily cycle results in local sea breezes (sea to land) in the afternoon and land breezes (land to sea) overnight.

In the Exmouth Gulf area a two stage sea breeze often occurs. Initially a local sea breeze will set in from the Gulf itself and later in the day the general west coast sea breeze (southerly) will override the local breeze.

Storms

The Exmouth Gulf area is affected by tropical cyclones during most years. The strongest winds recorded in the area are also the highest recorded in Australia. During tropical cyclone Trixie in 1975, wind strengths of 265 km.hr-1 were measured at Mardi, near Onslow. Cyclonic winds of similar intensity were recorded during Cyclone Orson in 1989 and Cyclone Olivia in 1996.

Oceanography

The Chelonia program drilling location lies in an area of high energy. Strong tidal currents flow through "The Gap" as a large portion of the tidal exchange for Exmouth Gulf is funnelled through the area. There is no protection from either wind wave generation or from oceanic swell energy.

Tides in the Exmouth Gulf area are semi-diurnal with four current reversals per day. Although tidal range is moderate (2.5 m during springs), the channel between North West Cape and South Muiron Island, incorporating the Chelonia location, experiences currents of up to 2.0 m s-1 during spring tides.

The Leeuwin Current, a warm water current that flows southwards during winter, seasonally affects water offshore of Exmouth Gulf. Pearce and Cresswell (1985) describe the general behaviour of the Leeuwin current in this area as generally weak to absent during summer and generally strong and well defined in winter. During winter, the warm waters of the current run southwards against the continental slope and at their centre (along the mid-continental slope) run at speeds of 0.2 to 0.3 m/s (1 to 1.5 knots). Pearce and Cresswell also describe a cold water counter-current that tends to flow northwards along the coast during summer.

Sea waves, caused by strong or persistent winds, are primarily from the south in summer and the south to east in winter. These waves are generally less than 2 m high and of short period (1-10 sec). These can become much steeper in the Chelonia when strong currents and winds act in opposing directions.

Offshore water temperatures in Exmouth Gulf vary seasonally from 24°C to 31°C. Inshore waters vary from 19°C to 33°C (LeProvost Environmental Consultants, 1992).

The levels of suspended matter in the water in the vicinity of the Chelonia site are mostly determined by the offshore water quality, interspersed with periodic turbidity from inshore areas. The turbidity of the water in the inshore areas of the Gulf varies greatly, but is never as clear as in the offshore areas.

Flood waters from the Ashburton River carry sediment into the Gulf, especially during cyclonic rain. Some of these fine terrigenous sediments are transported offshore and can be easily resuspended by wind waves or tidal currents.

Inshore waters are also particularly turbid during summer when re-suspension caused by the prevailing south-westerly winds and prawn trawling cause significant re suspension of fine sediments and when the higher water temperatures favour high plankton populations.

The offshore waters in the region are less affected by terrigenous material, and are relatively clear. Large swells caused by winter storms cause increased turbidity, while increased plankton levels generally reduce water clarity during summer.

Other conditions being equal, water turbidity is higher during spring tides and lower during neap tides.

3.3 Geology and Geomorphology

Exmouth Gulf lies in the geological province known as the Carnarvon Basin (Playford *et al.* 1975). This basin is one of five major post-Proterozoic basins in Western Australia, and can be subdivided into numerous sub-basins, ridges and shelf systems. The Chelonia prospect lies in the Exmouth sub-basin.

The North West Cape/Cape Range geology is of Miocene and Pleistocene limestones generated from marine sediments, uplifted and folded to form the range system. Erosion of these soft rocks has resulted in the heavily dissected nature of Cape Range, and the development of an extensive coastal plain. Fringing the coastal plain are generally broad beach and dune systems composed of Holocene deposits.

The geomorphology of the Chelonia region is of limestone pavements of Pleistocene origin, overlain by very thin veneers of recently derived biogenic sediments. The Muiron Islands are rocky extension of the North West Cape geological unit and are remnant from a previous coastline. These are composed of Holocene and Pleistocene limestone and conglomerates overlain with Holocene dunes and veneers.

Other islands, such as Sunday Island are sand cays formed on shallow subsea rises, underlain by limestone pavement. These pavements often extend as broad intertidal pavement reefs around the cays.

3.4 Intertidal Environment

The main intertidal habitats near Chelonia location are narrow sandy beaches, sand bars and small patches and platforms of intertidal beach rock around South Muiron Island, located approximately 4 km from the proposed drilling location. Intertidal sand beaches and beach rock communities also occur at North West Cape, approximately 14 km from the drilling location. Mangrove forests and mudflats in the region are restricted to the mainland coast on the east side of the Gulf. These are distant from the Chelonia operations and are unlikely to incur any impact.

This section addresses the following three major intertidal habitats which occur in the area:

(i) sandy beaches;
(ii) intertidal limestone communities;
(iii) mangrove communities.

Sandy beaches

The diversity of the fauna associated with the intertidal sandy beaches is generally low. Burrowing polychaete worms, ghost crabs (Ocypode ceratophthalmia) and bivalves (Donax spp.) dominate the fauna. Algal diversity and biomass is very low, due both to the harshness of the environment and the lack of suitable settlement substrate for most larger algae.

Intertidal limestone communities

Rocky intertidal habitats around the Muiron Islands and at North West Cape span a range of heights between extreme low water and extreme high water. The rocky intertidal habitats in the region may be characterised as dividing into three zones: high-intertidal, mid-intertidal, and low-intertidal. Permanent rock pools in the intertidal limestone platforms contain a subset of the flora and fauna of the adjacent subtidal habitats.

High-intertidal:
The high-intertidal zone is represented on the west coast of the Muiron Islands. Higher up the vertical rock face, above the ubiquitous mid-intertidal assemblages, molluscs such as periwinkles (Littorinoidae) and limpets (Acmeidae and Patellidae) dominate the fauna.

Mid-intertidal:
Most of the beach rock is low profile with little extension into the high-intertidal. Large populations of rock oysters (Saccostrea sp.) and chitons (Acanthopleura spp.) and abundant, highly mobile gastropods and crustaceans dominate the fauna of these areas. The gastropods are generally nocturnal foragers that shelter in crevices and ledges during the day. The large crustacean fauna is dominated by grapsid and xanthid rock crabs.

Low-intertidal:
The limestone rocks at the lower end of the tidal range are covered by water for a larger proportion of the day than in the higher zones and support the most diverse floral and faunal assemblages. The longer submergence time permits a larger number of less specialised species to persist. Species diversity is also favoured by the higher habitat complexity of this zone, generated by the increased microhabitats associated with varied substrates (pavements and rubbles) and the occurrence of large sessile invertebrates and algae.

The intertidal limestone platforms are generally covered with laminar brown algae (Sargassum sp.), filamentous brown algae and green algae (*Caulerpa, Halimeda, Ulva*). Sessile invertebrates in the lower intertidal include coral colonies (Faviidae; particularly *Goniastrea* spp. and *Pocillopora damicornis*) and small sponges.

The mobile invertebrate fauna is diverse, and includes molluscs, echinoderms, crustaceans and worms. The abundant molluscan fauna includes algal grazers (Trochidae, Cerithidae, Haliotidae and Chitonidae) and predators such as octopus and gastropods (Conidae, Mitridae and Cymatiidae). Other common fauna include holothurians (*Holothuria atra* is particularly abundant), ophiuroids (brittle stars), a wide range of decapod crustaceans and polychaete worms.

Whilst most of these species are generally residents of the intertidal zone, the intertidal pavements are also important feeding zones for transitory fish. The temporary fauna includes grazing and predatory fish, such as small reef sharks and rays that commonly follow the advancing tide over previously exposed pavements.

Mangrove communities

The mangrove communities (mangals) nearest to the Chelonia site consist of the extensive and complex mangals along the east coast of Exmouth Gulf, from Gales Bay to Urala Creek. These are important habitats for a variety of birds, insects, crustaceans, molluscs and fish, some of which are of commercial importance. Mangals also play an important role in stabilising shorelines (Clough, 1979), and in reducing the rate of coastal erosion.

3.5 Marine Environment

The Chelonia location lies in State waters and is adjacent to the northeastern boundary of the Ningaloo Marine Park. The local region contains a variety of marine habitats (Figure 7) which are determined by prevailing conditions such as depth, substrate type, current conditions and turbidity. This section addresses the following four main types of marine communities which dominate the Chelonia area, namely:

(i) coral reefs;
(ii) seagrass and macroalgal communities;
(iii) invertebrate filter feeding communities;
(iv) soft sediments.

Coral reefs

The broad, shallow Rowley Shelf contains a variety of coral habitats and an equally wide range of coral communities. The principal coral habitats include: turbid inshore pavements and raised limestone shoals; fringing coral reefs around the sand cays; and offshore reefs within generally clear water.

Specific coral types are associated with each habitat type and very different communities can occur over small distances, due to small-scale changes in conditions. This is particularly evident on the fringing reefs surrounding islands, where large differences in species composition and abundance can occur from one side of an island to the other.

The proposed Chelonia drilling location is situated on a flat limestone pavement substrate, which supports a diverse and abundant filter feeding community with minor hard coral elements. Corals are only secondary faunal organisms in this area, with the nearest true coral community occurring approximately 8 km northeast, on the protected eastern side of South Muiron Island. This reef complex contains broad coral communities displaying marked zonation in coral species composition and morphology as the water depth changes across the width of the reef. In the shallower areas, the community is characterised by small faviids and *Acropora* spp. interspersed with sand and rubble. The mid-depth zone is characterised by large areas of arborescent and tabular *Acropora*. The deeper margins of the reef support diverse communities dominated by massive *Porites* colonies.

Other coral reefs in the Chelonia region include high energy reefs with lower species diversity on the west side of the Muiron Islands, and communities more suited to turbid conditions at Sunday and Observation Islands.

The Chelonia drilling location is well removed from the extensive coral communities of the Ningaloo Marine Park. North West Reef is the nearest area of the park which supports significant coral communities, and lies about 12 km west of the proposed well site. Bundegi Reef, near Point Murat, supports a much more diverse and extensive coral community than North West Reef, and lies about 16 km southwest of the drill site. The northern extent of coral communities on the Ningaloo Reef occurs approximately 40 km southwest of the Chelonia location (Figure 7).

The fringing coral reefs of the Exmouth region lie within the tropical belt of the Indo West Pacific Faunal Region. The majority of the species occurring in the region are widespread throughout this Region with many of the species being distributed in waters off East Africa, the Red Sea, the Great Barrier Reef and South Pacific waters. The Ningaloo Reef has similar recorded levels of coral diversity to other reefs to the north such as the Montebello Islands, Dampier Archipelago, Ashmore reef and Scott/Rowley reefs. This degree of connectivity is thought to be due to the southward flow of the Leeuwin current (Veron 1995).

Seagrass and macroalgal communities

Seagrasses and macroalgae are important components of shallow tropical marine environments. They are sources of primary productivity, are the basis of specific biotic communities, and are the food source for important animals, such as dugong and green turtles.

Seagrasses do not appear to be particularly abundant adjacent to Chelonia site. The pavement and coarse sediment veneer on the seafloor, nor the 20 m water depth, is conducive to seagrass communities.

The shallow reef flats on the east side of the Muiron Islands support sparse Halophila spp., *Thalassodendron ciliatum* and *Thalassia hemprichii* seagrasses. Dugongs are abundant on these reef flats in winter, and may be feeding upon these seagrasses. Dugongs are also common near the North West Cape and Point Murat areas in winter, and presently unknown seagrass communities may occur in these areas.

Macroalgae are very common components of the marine environments in the Chelonia region. They are the dominant community type on extensive areas of shallow pavement, particularly around the Muiron Islands. Macroalgae often display large seasonal variations in biomass, with the peak usually occurring in autumn. Filamentous algae are an important component of the community at the Chelonia site, also displaying variations in seasonal abundance.

The most extensive areas of dense macroalgal communities in the area are the shallow marine environments on the energetic western coast of the Muiron Islands. Brown algae of the genus Sargassum are the most common of these plants. This community extends to within 3 km of the Chelonia site, along a shallow subtidal spur that extends 1 km south of South Muiron Island.

Invertebrate filter feeding communities

Deeper limestone pavements within the southern Rowley Shelf area often support a diverse community dominated by attached filter feeding invertebrates. Although often referred to as sponge communities or sponge gardens, these communities contain a very diverse assemblage of filter feeding organisms. These typically include a variety of gorgonids, including sea fans (Subergorgiidae and Plexuridae) and sea whips (Leptogorgiidae), colonial and solitary ascidians, bryozoans, algae, and scleractinian corals (eg. *Turbinaria*), as well as sponges. The seafloor communities at the Chelonia well site are composed of a diverse array of these organisms.

This filter feeding community occurs throughout much of the tidal channel between South Muiron Island and North West Cape. Filter feeders also dominate hard substrates deeper than 20 m on the west side of the Muiron Islands and in the more turbid waters of greater than 15 m depth in Exmouth Gulf which are not subject to trawling.

Soft sediments

The Chelonia site is subject to a high energy regime which precludes significant sediment deposition. The only soft sediments observed in the area are shallow coarse sand veneers over pavement. The nearest areas of soft substrates are in more benign locations, such as southeast of the Muiron Islands, where protection is afforded and erosional processes are reduced.

The Exmouth Gulf prawn fishery trawls the largest expanses of sediment substrates in the area. These areas tend to be bare of large, attached biota and show little sign of bioturbation or of crawling fauna, but are clearly important as a habitat for adult prawns. Sediments outside trawl areas and within the 20 m depth contour have much more extensive invertebrate communities. The most abundant macro-biota are usually echinoderms, including sand dollars (genus *Peroella*), sea urchins (genus *Diadematidae*), crinoid stars (Family Comasteridae) and heart urchins (*Lovenia* spp.). In some places, solitary corals (*Cycloseris cylolites*) are abundant.

3.6 Seabed Environment at the Chelonia Location

The marine environment in the immediate vicinity of the Chelonia location is well known having been investigated by Bowman Bishaw Gorham on at least five occasions between 1991 and 1997.

The seafloor substrate is composed of a low profile limestone pavement, with thin veneers of coarse sediments (Plates 1 to 4). These veneers are composed of coarse sand/gravel sized material, much of which is formed by coralline algae. The density of attached organisms varies throughout the area, dependant upon the thickness of the sediment veneer. Areas of emergent limestone provide the best habitat for the development of epibenthic communities and support the greatest diversity and density of attaching organisms.

The epibenthic community is predominantly a filter feeding community, characterised by large numbers of sea whips (*Junceella* sp.), sponges of various sizes and morphologies, and large bryozoans. Lesser components of the seafloor fauna include corals (*Turbinaria* spp. with lesser Faviids and *Goniopora* sp.), gorgonian fans, colonial and solitary ascidians, hydroids and minor soft corals. Plants are represented by foliose and encrusting coralline algae, mainly filamentous macroalgae, and very minor seagrass (*Halophila* sp.).

The most prolific of the motile organisms observed in the Chelonia area are crinoid starfish. These filter feeding animals occur in large numbers throughout the area. The immediate area of the proposed well site does not appear to support large numbers of fishes. Surveys to date have only encountered limited numbers and species, most commonly small tuskfish (*Choerodon* spp.), rockcod (*Ephinephelus* spp.) and anglefish (*Chaetodontoplus* spp.).

An exception to the relatively depauperate fish fauna was found at the remains of the cement collar to the Loggerhead-1 cement well collar, one and two years after abandonment. On each occasion a diverse and abundant fauna of fish and crustaceans was found in association with the remnant structure. These included schools of bronze bullseyes (*Pempheris analiss*), sand bass (*Psammoperca waigiensis*), wobbegong sharks (*Euchrossorhinus dasypogon*), grapsid crabs and panulurid crayfish. The immediate area around the well site is very low profile and these animals were apparently attracted to the refuge provided by the broken and undercut cement.

3.7 Important Vertebrate Fauna of the Region

The subtidal habitats in Exmouth Gulf, particularly around the islands, support a diverse assemblage of vertebrates. Bony and cartilaginous fishes, marine reptiles, mammals and birds are all well represented and are briefly discussed below.

Bony and cartilaginous fish

Fish species composition and abundance in the area vary with the habitat type. The diversity and abundance of fishes are greatest on the coral reefs and least on the soft sediments.

The diversity of bony reef fishes of the Ningaloo Reef and the Muiron Islands is only exceeded in Western Australia at the Rowley Shoals and Scott Reef, which may be sources of fish larval recruits to the southern areas (Hutchins 1994). Most of the fish species in the Chelonia area are widespread tropical species of the Indo-West Pacific region.

Cartilaginous fishes such as sharks and rays are also common in the Muiron Islands area. The most abundant sharks are whalers (Family Carcharhinidae) which are represented in the area by at least twelve species (Allen and Swainston 1988). Small sharks like the blacktip (*Carcharhinus limbatus*) and blacktip reef shark (*C. melanopterus*) are common in the shallows, and the grey reef shark (*C. amblyrhynchos*) is common in the deeper areas. According to local fishing experts, "The Gap" (including Chelonia-1) is one of the most inshore areas where oceanic whitetip sharks (*C. longimanus*) are commonly encountered (George King pers. comm. 1994) The giant manta ray (*Manta birostris*) lives throughout the area, but is most common on the seaward side of the Muiron Islands.

Marine reptiles

Five species of marine turtles and fourteen species of sea snake live in the region and may be present in the Chelonia area.

The five turtles species are the green (*Chelonia mydas*), flatback (*Natator depressus*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbreicata*) and leatherback (*Dermochelys coriacea*).

The Muiron Islands are very important areas for turtle nesting. Loggerhead and hawksbill turtles, which have limited nesting areas, both nest on these islands. The use of the beaches by loggerhead turtles is particularly significant, because these turtles are a declared endangered species and the Muiron Islands is one of their major breeding areas in Western Australia.

Green turtles, although common in the area, have been declared vulnerable and the Muiron Islands are a major nesting site. Juvenile green turtles are carnivorous, but the adults are herbivorous, mainly feeding on macroalgae. The macroalgal communities on the intertidal and shallow subtidal pavements around the Muiron Islands and North West Cape are probably important feeding areas, often supporting large numbers of adult green turtles.

Turtle nesting is seasonal and varies between species. Green turtles mainly nest between November and March, and the eggs hatch until May. Nesting of both hawksbill and loggerhead turtles occurs over a broader period, but peaks in summer.

Sea snakes live throughout the Exmouth Gulf area but are most common and diverse on the shallow flats along the eastern coast of the Gulf. All species are poisonous and have a diet mainly comprised of fish (Storr *et al.* 1986). None are known to be dependant on, or restricted to, the area around the Chelonia site.

Sea birds

The islands in the vicinity of the Chelonia site support a diverse assemblage of seabirds. These include a large number of migratory species which are most abundant in summer and autumn.

The most numerous sea birds are the wedge-tailed shearwaters (*Puffinus pacificus*), which form rookeries of tens of thousands of breeding pairs on the Muiron Islands. They nest in burrows under vegetation or rocky outcrops, above the high tide line.

Wedge-tailed shearwaters and nine other species of migratory sea birds reported from the Muiron Islands are protected under international agreements with either Japan (Japan Australia Migratory Birds Agreement) or China (China Australia Migratory Birds Agreement). Of these, the wedge-tailed shearwater, the common noddy (*Anous stolidus pileatus*) and the bridled tern (*Sterna anaethetus*) nest within the southern Rowley Shelf area.

Resident seabirds, or birds closely associated with marine habitats on the Muiron Islands, include the eastern reef heron (*Ardea sacra sacra*), the white-bellied sea eagle (*Haliaeetus leucogaster*), the osprey (*Pandion haliaetus cristatus*) and oystercatchers (*Haematopus* spp.).

Marine mammals

Marine mammals in the region include the dugong (*Dugong dugon*), nine species of whales and four species of dolphins.

Dugong are found in the Ningaloo Reef and Exmouth Gulf regions, especially in the shallow seagrass beds along the east coast of Exmouth Gulf (Preen *et al.* 1997). Dugong distribution appears to be tied to seagrass distribution and to water temperature. The observations of many dugong on the shallow reef flats around the Muiron Islands in May indicates that these areas may be important for dugong in winter, when inshore waters are coldest. Similarly, observations of many dugong travelling past Point Murat on the incoming tide (M. Forde pers obs. 1993) in June indicates that waters of the marine park near North West Cape could also be important feeding or refuge areas.

The most common whale in the Chelonia area is the humpback (*Megaptera novaeangliae*), which migrates from the Southern Ocean into the tropics over winter to mate and calve before returning to its feeding grounds in the Antarctic. Humpbacks generally travel further offshore than Exmouth Gulf, however those whales which pass through the gulf will probably enter or exit via "The Gap".

None of the other whale species in the area is likely to be encountered inshore near the Chelonia site.

Bottle-nosed dolphins (*Tursiops truncatus*) and the Indo-Pacific humpbacked dolphins (*Sousa chinensis*) are common residents within Exmouth Gulf (Marsh 1990). The common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), spotted dolphin (*Stella attenuata*) and rough toothed dolphin (*Steno bredanensis*) are less common in this area. However, any of these species may be present in the Chelonia area.

3.8 Ningaloo Marine Park

Ningaloo Marine Park and the contiguous Cape Range National Park are the most important conservation zones adjacent to the Chelonia area. The two parks are vested with the National Parks and Nature Conservation Authority and are managed as an integrated unit by the Department of Conservation and Land Mangement (CALM 1990; ANPWS 1990).

The Ningaloo Marine Park extends approximately 20 nautical miles from the coast, and spans approximately 260 km of coastline, from Bundegi Reef in Exmouth Gulf, around North West Cape and southwards to Amherst Point. Ningaloo Reef is Australia's largest fringing coral reef and supports a great diversity of corals, other invertebrates, fish, marine mammals and reptiles.

The other conservation zones in the area are A or C class terrestrial reserves over the most of the islands of Exmouth Gulf and the Rowley Shelf.

History of the Ningaloo Marine Park

The Ningaloo Reef is Australia's largest fringing reef and its most accessible major coral reef system. It fringes the coast for about 260 km along the Cape Range Peninsular, in places extending virtually from the beach and in other areas lying up to 5km offshore. Its most important values include: conservation, scientific interest, recreation, reef appreciation and replenishment.

The first recommendation for the creation of a reserve to protect the Ningaloo Reef tract was made by the Conservation Through Reserves Committee, in 1974. In 1975, the Environmental Protection Authority in its report "Conservation Reserves in Western Australia" recommended that an area from Point Anderson to North West Cape and extending from 40 m above high water to the 100m isobath should be declared as an aquatic reserve and vested in the National Parks Board.

A Government Working Group was formed in 1978 to review the Conservation Through Reserves Committee recommendation and to produce a management plan for its implementation. The draft management plan produced in 1983 recommended the declaration of the Ningaloo Marine Park extending northwards from Amherst Point around North West Cape and continuing into Exmouth Gulf to incorporate Bundegi Reef. Rather than a variable park width following the 100m isobath, the Working Group recommended that the seaward boundary should be set 10 nautical miles from the coast. The State Government adopted these recommendations in principle.

Following passage of the *Conservation and Land Management Act* 1984 with its provision of declaration of marine parks, and after further public consultation, the inner portion of the Ningaloo Marine Park occupying State waters was gazetted in 1987. Later that year the offshore portion occupying Commonwealth waters was declared under the *Commonwealth National Parks and Wildlife Conservation Act* 1975.

Integrated management plans for the State and Commonwealth parts of the Marine Park were adopted in 1989. As part of the bicentennial year in 1988, the Federal Government funded the establishment of the Milyering Information Centre for the park, which incorporates a field research station and supply base.

In 1994, the Western Australian Government released its "New Horizons in Marine Management" strategy, which expressly excludes petroleum exploration or production drilling in Ningaloo Marine Park. Access to resources in Ningaloo Marine Park from land-based rigs or by directional drilling was not precluded and projects would be assessed for environmental acceptability on their merits.

Ningaloo Marine Park - Objectives and conservation values

The principle objectives of the marine park are to provide for the conservation of the marine environment and its wildlife and other features while allowing opportunities for recreation, education and commercial use (CALM 1989; ANCA 1994).

State and Commonwealth management plans have been developed to protect the values of the park (CALM 1989; ANCA 1994). The primary conservation values of the park as defined by the Ningaloo Marine Park Working Group (1983) and the State and Commonwealth management plans include the maintenance of:

- ecological integrity;
- biological diversity;
- habitat types; and
- geomorphological and oceanographic attributes.

Protected species

The marine environments and shorelines in the vicinity of the proposed Chelonia drilling program are utilised by a number of animals that are afforded special protection. Some of these are resident, while the majority are migratory and only transient in the area.

Many migratory birds occurring in the study area have trans-equatorial migrations and are protected by agreements between Australia and both Japan and China. Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and

Birds in Danger of Extinction and their Environment (JAMBA) was ratified in 1981 under the Commonwealth *National Parks and Wildlife Conservation Act*, 1975. A similar agreement with China (CAMBA) was ratified under the same Act in 1988.

The marine fauna of the study area includes mammals, reptiles and fish which are protected. There are also conservation requirements for certain species in specific areas in the region.

All cetaceans are protected under the *Whale Protection Act* 1980. Humpback whales (*Megaptera novaeangliae*), which commonly occur in the area, together with blue (*Balaenoptera musculus*), which are occasional visitors, are also protected as rare and endangered animals.

All sea turtles are protected under the *Wildlife Conservation Act* 1950 and all are scheduled species.

The dugong (*Dugong dugon*) is provided special protection under Schedule 4 of the *Wildlife Conservation Act* 1950.

The large serranid fishes, commonly called grouper or cod, are considered vulnerable to exploitation. The potato cod (Epinephelus tukula) and the Queensland groper (*E. lanceolatus*) are protected under the *Fisheries Act* 1905.

Specific areas of protection to marine organisms occur in the Ningaloo Marine Park and in the prawn nursery zone on the eastern side of Exmouth Gulf. Within Ningaloo Marine Park, the capture of all organisms is prohibited in sanctuary zones at Bundegi Reef, Mangrove Bay, Mandu Mandu, Osprey Bay and Point Cloates. Throughout the remainder of the Marine Park, all invertebrates are protected from amateur collection, except for certain food and bait species.

The nursery zone for juvenile prawns, located in the eastern and southern sections of the Exmouth Gulf is declared as a conservation zone under the Fisheries Act, 1905.

3.9 Social Environment of the Region

History and demography

The towns of Exmouth and Onslow are the population centres closest to the Chelonia-1 well site. Exmouth is approximately 30km to the south-west of the proposed Chelonia-1 well site, on the western side of Exmouth Gulf. Onslow is located on the eastern side of the Gulf, approximately 90km east of the well site.

Exmouth was established in 1963 as a support centre for the US Navy Communications Station on the North West Cape and the Exmouth Gulf fishing industry. In 1993, the Australian Government took control of the communications station, resulting in the exodus of most of the US Navy personnel.

The focus of the town's workforce has changed markedly during the last five years, as a consequence of both the reduced staffing at the Australian communication station and the development of tourism and petroleum exploration industries in the town.

Tourism has expanded greatly in the area with the increasing popularity of the Ningaloo Marine Park, other offshore waters and Cape Range National Park. Exmouth's proximity to the Ningaloo Marine Park has resulted in its growing importance as a centre for eco-tourism operations such as whale-shark tours, dive tours of the Ningaloo Reef and Muiron Islands and tours of Cape Range National Park.

Exmouth is also proximate to the offshore Carnarvon Basin petroleum fields and the town has enjoyed economic benefits from petroleum industry activity. West Australian Petroleum Pty Limited (WAPET) serviced its recent Gorgon Field offshore exploration program from the Point Murat Pier. Other petroleum industry projects have used the town's resources for ancillary services, including supply, support vessels, transport and airport/heliport facilities.

Exmouth had a population of 2,500 in 1992 (DPUD, 1992) and is continuing to grow. The more traditional industries for the town, such as prawn trawling, pearling and fishing, remain as important components of the local economy.

Exmouth has most of the infrastructure and facilities of a modern town. It has a regional hospital, a diverse shopping centre, a large airport and a small, though robust, light industrial sector. A marina development is presently being constructed to service the increased commercial and recreational boat traffic in the area.

Onslow is a much older population centre than Exmouth. It was originally established in the early 1890's on the Ashburton River, approximately 20km east of its present position. However, the effects of cyclonic flooding and river siltation resulted in the town being relocated in the 1920's to its present location near Beadon Creek.

Onslow was originally established to service the burgeoning gold mining, pearling and pastoral industries of the 1890's. The town's commercial base declined with the wane of those industries, until WAPET established a supply base in the town to support the development of the Barrow Island Oilfield in 1964. WAPET's use of Onslow as a supply base was followed in the late 1980's by the development of facilities to service Apache Energy's offshore activities. Other industries that continue to operate from the town include limited prawn trawling, pearling and trap fisheries.

Onslow has a resident population of approximately 800, increasing to approximately 1,500 during the winter tourist season.

Onslow does not have the same level of infrastructure and facilities as Exmouth. Aircraft landing facilities are limited to a level claypan, which is only suitable for light aircraft and helicopters. Medical facilities are limited, and only basic shopping and transport services are available.

Commercial and recreational fisheries

The largest of the fisheries in the vicinity of the Chelonia location is the Exmouth Gulf Prawn Fishery, which involves sixteen boats fishing from April to November. Chelonia lies near the northwestern boundary of Exmouth Area A of the fishery. The seafloor substrates that occur in the vicinity of the proposed well location are unsuitable for prawn trawling and the wellsite is therefore removed from trawling activities.

The pearling industry is also active in the region. Pearl oysters (*Pinctada maxima*) are collected by divers in Exmouth Gulf before being transferred to farms where they are seeded to produce pearls. The nearest farm to Chelonia occurs about 70 km south of the site, in Roberts Bay, at the base of Exmouth Gulf.

In addition to pearl farming, southern Exmouth Gulf supports a beach seine fishery. Other aquaculture industries, such as clam farms, have been proposed in the area. These operations are too distant from the proposed well site to be influenced by drilling operations.

Most other commercial fishing activities in the region are located in deep water and are remote from the Chelonia site and hence beyond the influence of the drilling program. These include the Pilbara fish trap fishery and long line and trawling fisheries.

Recreational fishing is an important attraction of tourists to the area, so is of economic importance to both Exmouth and Onslow. The Chelonia site is not adjacent to any specific area of importance to the recreational fishing industry, however it lies within the generally popular recreational fishing area encompassing the Muiron Islands. The proposed drilling program is not likely to affect the stocks of recreational fish species in the area and would cause only very localised and short-term exclusion of fishing activity (within 500 m of the drilling vessel).

Tourism industry

The largest growth industry in the region over recent years has been the tourist industry. Exmouth has been the focus of most of this expansion, with minor increases in Onslow. The greatest attractions to the Exmouth area are the natural resources present in the Ningaloo Marine Park, Muiron Islands and Cape Range National Park.

Ecotourism industries based on diving, particularly during the whale shark season (February to June) have become increasingly popular over the past decade. The recreational fishing industry, which was the initial basis of the local tourism industry, has maintained its prominence in the town.

Campers heavily use the Cape Range National Park, particularly over the winter months and school holidays. Tour operators have established industries conducting day trips through the park, boat trips up Yardie Creek and kayak trips along the coastline.

With the newly completed Exmouth Boat Harbour, and the soon to be constructed ancillary resort and accommodation developments the tourism industries appear likely to continue expanding.

Petroleum industry

Exmouth Gulf lies in a very prospective petroleum province. The first significant flow of oil from an exploration well in Western Australia occurred from Rough Range-1, in the early 1950s. Since that time exploration wells have encountered hydrocarbon deposits with mixed success. BHP Petroleum have developed the Griffin field, to the north of Chelonia, offloading oil from a Floating production and Storage unit (the *Griffin Venture)* and piping gas ashore for treatment at Turbridgi.

Other discoveries in the region have been less successful, with the Pyrenees/ Macedon field offshore from Exmouth Gulf, and the Leatherback discovery near the Muiron Islands being presently uneconomic.

In the past petroleum companies have used the facilities at both Onslow and Exmouth to service their production and exploration activities. WAPET serviced both the Thevenard and Barrow Islands facilities from Beadon Creek at Onslow until 1997. Apache also utilised the Beadon Creek Wharf to service its Varanus Island installation.

WAPET serviced it's deepwater exploration program at the Gorgon field from Exmouth in 1995. It established temporary facilities at the communications base and utilised the Point Murat Pier for service vessel support.

3.10 Fate of the Drilling Solids Deposited At the Loggerhead-1 Well Site

Bowman Bishaw Gorham investigated the Loggerhead-1 well site in December 1992, immediately following the departure of the drilling vessel, then again in November 1993, twelve months after the completion of the drilling program. The results of these re-inspections were described in Bowman Bishaw Gorham (1993; 1994). Further observations of the site were made in December 1995 three years after the well was abandoned and 1997, six years after.

The initial inspection of the Loggerhead-1 well site in 1992 encountered a drilling solids mound approximately 0.5 m high and 6 m basal diameter. Surrounding this mound was a primary halo of deposited solids approximately 25 M wide and 60 m long, ranging in thickness from about 10 cm near the mound to 5 cm near the outer edge. A secondary halo of fine muds was discernible over a broad area surrounding the primary deposits.

The are of primary deposition incorporated the abandoned well which comprised an extruded cement collar approximately 0.4 m high and 5 m in diameter.

Reinspection of the site in November 1993, twelve months after drilling, showed a greatly reduced volume of drill cuttings. The discernible deposit now measured 10 m maximum width and 30 m length and consisted mainly of cuttings which had winnowed of retained drilling fluids. The maximum height of the deposit was still approximately 50 cm but this mound had reduced to a very small area. The secondary halo of solids had disappeared.

Drilling solids immediately surrounding the collar had mostly dispersed. The bare cement collar had been colonised by a range of organism, giving it the appearance of a small upstanding reef.

Investigation of the area in 1995, three years after drilling, found minimal remnant evidence of the previous exploration activity. The deposits of drilling solids had completely dispersed with only a scattering of cuttings remaining. These had been incorporated into the gravel veneers that were typical of the are prior to drilling and were discernible only by their darker colour. The cement collar had greatly eroded and now supported the same range of epifauna as occurs on the surrounding pavement. It was virtually unrecognisable as a manmade structure. Attempts to locate the mound in June 1997 were unsuccessful.

4. ENVIRONMENTAL ANALYSIS OF ROUTINE DRILLING OPERATIONS

The routine types of activities associated with drilling, the potential effects and the mitigating actions that will be put into place are detailed in Table 6. A discussion of some of these impacts is discussed below.

4.1 Physical Activities

Rig positioning and anchoring

The main physical effect associated with rig positioning is from the imprints on the seafloor caused by the legs of the drilling rig.

The number, area and depth of the depression will be dependent on the weight of the rig and the substrate type. The drilling rig being used for the proposed drilling program will leave three imprints on the seabed. Once the drilling rig is removed from site, the depressions will act as traps for detritus and sand. Observations after previous drilling show that these depressions rapidly fill with the surrounding sediment and therefore the effect is temporary and short-lived. A post-drilling survey using a remotely operated vehicle (ROV) will ensure that no anthropogenic debris is left on the sea-floor.

Anchoring of support vessels will be restricted to deeper waters removed from corals or subtidal reefs.

Access

For reasons of safety, a 500 m safety zone will apply around the rig location. This will prevent entry of any vessels not involved with the program within this area during the drilling operation.

The rig will be positioned in a way that no vessels supporting the rig will anchor within the Ningaloo Marine Park. However, there will be vessel movement through the portion of the park adjacent to the rig.

The two wells are located within Area A of the Exmouth Gulf prawn fishery. The drilling program could overlap the prawn fishing time as Area A is fished from the beginning of April to mid-May 1997 (G. Passmore *pers. com.* February 1998). However, the small cuttings mounds created will not prevent future fishing over the location.

Artificial lights

Due to safety regulations, lights on the rig must be kept alight 24 hours per day. These lights can attract some marine life and seabirds, and may result in a small concentration of animals in the immediate vicinity of the rig. The lights on the rig are not expected to attract turtle hatchlings. The nearest turtle nesting beach is approximately 4 km away and a light survey of a drilling rig has shown that lights would not be visible to hatchlings from that distance (CSIRO 1997).

Some species of seabirds may make temporary use of the structure, although the consequences of this effect are expected to be limited and temporary.

4.2 Solid and Liquid Wastes

Drill cuttings

During the drilling of the initial hole, the drill cuttings are unconstrained by casing and will be deposited on the seabed adjacent to the well. The maximum volume of cuttings is estimated to be 15.8 m^3, which will consist of tertiary sediments, of mostly gravel size, similar to those found over the existing seafloor. No chemically-based drilling fluids are used for this section; only seawater (90%) and clay (10%) are used. The intent in to discharge all the cuttings generated by the remainder of the program down the annulus and not to the sea floor. This practice will reduce the potential for physical smothering of nearby benthic communities, and minimise the generation of turbidity plumes. In the remote possibility that there is no lost circulation zone and annular disposal is not feasible, drill cuttings will be deposited onto the seabed via a flexible hose.

Previous drilling at the Loggerhead-1 site involved the disposal of 443 m^3 of cuttings and 105 m^3 of water based drilling fluid directly to the seafloor (BBG 1992, 1993) (see also Section 3.10). Solids disposal resulted in a mound of sediments at the centre of a thin veneer of solids that extended approximately 90 m along the NW-SE axis, and 45 m along the NE-SW axis. Surveys conducted in December 1992 and November 1993 showed that the main impact from disposal was restricted to the immediate area of the mound. Sedentary and attached fauna near the centre of the mound were buried by sediments, with resulting mortality decreasing with the thickness of solids. Fauna away from the mound were apparently unaffected. Sampling with sediment traps detected only very low levels of additional sedimentation within 200 m of the discharge point.

Attempts to relocate the main cuttings mound in December 1995 and June 1997 were unsuccessful, with only scattered cuttings being found over the area. The rapid dispersal of the cuttings from this site can be attributed to the fast water currents that flow over the area.

Chelonia-1 and -2 will be drilled within the area previously disturbed during Loggerhead-1, which will limit the potential for disturbance of pavement habitat. In addition, annular disposal will result in the discharge of approximately 2% of the original cuttings. This will minimise the extent of any re-disturbance and reduce the time before recolonisation is complete.

A detailed study was undertaken of the effects of drill cuttings on benthic communities during previous drilling operations in Exmouth Gulf (Mydas-1 and Hawksbill-1), when cuttings from the entire drilling programs were deposited on the seafloor (see Section 3.10). Only very localised (tens of square metres scale), and short-lived (less than months) changes in the sediment biota were identified (CSIRO, unpublished data). The same 26 broad faunal groups were represented before and after drilling at sites as close as a few meters from the discharge point. A number of the groups were at lower abundances near the discharge (within 100 m) immediately after drilling (1-2 months) but not at a later time (6-8 months). These short-lived effects were attributed to the physical presence, rather than any chemical action of the cuttings (C. Jacoby *pers. comm.* November 1996). By comparison, the much smaller volume that would be deposited during the present program due to annular disposal would cause lesser changes.

TABLE 6: Environmental Analysis of Impact - Routine Drilling Activities
Chelonia-1 and -2

Description	**Source**	**Quality/ Composition**	**Quantity**	**Treatment and/or Discharge Point**	**Potential Environmental Effect**	**Summary of Mitigating Actions**
Physical Activities						
Positioning of rig	Three legs of drilling unit.	Formation of three depressions into seabed.	175 m^2 each.		Act as traps for detritus and sand. Will rapidly fill with sand and become recolonized.	Localized, short-term disturbance expected on seabed based on previous studies.
Anchoring	Rig and supply vessels.		Two anchors.		Negligible. Anchoring will be confined to sandy bottom.	Anchoring guidelines will be developed to ensure that no anchoring will occur on coral reefs, bommies or within the Ningaloo Marine Park.
Artificial lights	Lights on rig.	Fluorescent lights meeting safety standards.			Lights are an attractant to marine life and some birds. May result in a small concentration of these animals over the short period of the drilling program.	Lights must be left on at all times due to safety regulations.
Noise	Helicopters, engines etc.		One flight per day three times a week.		Negligible. Potential for short-lived influence on behaviour of some birds.	Helicopter path is predominately over water and will not pass over nature reserves.

Table 6: continued

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Potential Environmental Effects	Summary of Mitigating Actions
Solid and Liquid Wastes						
Drilling fluids	By-product of drilling operations.	Water-based fluid. Petrofree (ester-based).	Zero to ocean.	Water based fluid will be discharged down annulus. Petrofree fluid will be used for the 12 ¼" section only and recycled for reuse.	Negligible. Some residual fluid will be retained on the cuttings, but these will be discharged into the lost circulation zone.	Solids control equipment will be optimized to ensure maximum separation of fluid from cuttings. Equipment to be routinely checked to ensure no spillage. Mass balance of fluid calculated on daily basis. All dump valves to be ticketed to prevent use. Handling and transfer procedures for Petrofree developed.
Drill cuttings	By-product of drilling.	Coarse to fine sand chips.	First 15.8 m^3	Will be deposited onto the seabed adjacent to the well. It is intended to deposit the remaining 760 m^3 into the lost circulation zone.	Deposited cuttings will result in the localised smothering of some seabed fauna. Extent of impact, given quantity of cuttings, should be no greater than tens of metres diameter around well. Recolonization will be rapid.	Cuttings from the 36" hole discharged at seabed. This minimises spreading and the turbidity plume.
Oil contaminated drainage water	Deck drainage, drainage from machinery spaces.	Water containing hydrocarbons.	Variable.	Oily discharges collected via a closed drainage system, treated to statutory limits using separation equipment, treated water discharged to sea, oil recycled.	Negligible. Very low concentration of hydrocarbons that will evaporate and dissipate very rapidly.	Separation equipment will have automatic shut down capability if oil content exceeds 15 ppm.

Table 6: continued

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Potential Environmental Effects	Summary of Mitigating Actions
Galley wastes	Kitchen wastes.	Putrescible and burnable wastes.	Variable, usually 9 L/day	Putrescibles and burnable materials will be bagged and placed in skips for onshore disposal.	Negligible.	Separation of putrescible wastes from solids (i.e. tins cans) by using clearly marked bins in the galley.
Sewage, gray water	By-product of habitation (~70 people).	Will contain dishwashing detergent, soap.	7 m^3 per day.	Treated via the tertiary sewage treatment plant and discharged above sea level.	Negligible. Detergents will break down rapidly and dilution will ensure oxygen depletion or nutrification will not occur.	Biodegradable soaps to be used on the rig. Sewage treatment plant to be maintained to ensure effective treatment.
Sea water	Deep well pumps for fire, water machines.	Seawater.	2.7 m^3 per day.	Discharged above sea level. No chemicals added. Ambient water temperature.	Negligible.	Negligible.
Cooling water	Diesel fuelled power generators.	Temperature slightly above ambient seawater (~3 ^{0}C).	550 m^3 per day.	Discharge above sea level.	Negligible. Water will be cooled and oxygenated upon discharge.	Water will be discharged at barge level (~15 m above sea level) to facilitate cooling and oxygenation.
Waste oil	Machinery.	Hydraulic and lubricating oils.	Variable.	Used oil contained in drums and returned to mainland for recycling.	Negligible.	Drums containing oil will be stored within a bunded area on the rig until transport to the mainland for recycling.
Solid wastes	By-products of drilling.	Paper, wood, steel.	Variable.	Landfill or recycling.	Negligible.	Waste will be segregated on the rig into clearly marked skips for appropriate waste disposal method.

Table 6: continued

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Potential Environmental Effects	Summary of Mitigating Actions
Pipe dope	Sealant, lubricant, cleaning of pipe-string.	Heavy metals, grease.	75 L per well.	Retained on drill cuttings and within drill fluid.	Negligible. Pipe dope is amalgamated with the drill cuttings and fluid that will be discharged down the annulus.	Use pipe dope with the lowest concentration of heavy metals and hydrocarbons, is biodegradable, but still meets safety and performance criteria.
Others						
Production testing	Hydrocarbon reservoir	Hydrocarbons	24 hours.	About 200 bbls to be brought to surface.	Black smoke if hydrocarbons burned. Fallout if incomplete combustion occurs.	'Green burners' to be used to ensure most efficient combustion to minimize black smoke and potential hydrocarbon fallout. Technical experts on the rig at all times.
Fishing	Workforce.			None.	None.	No fishing is allowed from the drilling rig or supply vessels.
Atmospheric emissions	Fuel burning equipment.	Combustion products.	Variable, depending on fuel usage. On average, 10,000 L fuel used per day.	Atmosphere.	Negligible.	Engines will be tuned to run at the most efficient capacity to minimise volume of emissions.

Drilling fluids

Both water-based fluid and Petrofree, an ester-based drilling fluid, will be used for the Chelonia wells. Petrofree will be used only for the 12 $^{1}/_{4}$" section. Water based fluid will be used above and below this section.

The water-based fluid consists of a potassium chloride (KCL), partially hydrolysed, polyacrylamide (PHPA) system. No hydrocarbons are used in this system; water is used as the base. Various chemically-benign agents such as barite and bentonite clays, vegetable fibres, calcium chloride, lime and starch may be added to the base system to aid lubricity, cooling and density.

The intent is to not discharge drilling fluid into the marine environment for either of the two wells. All drilling fluids are recirculated within an enclosed system and are re-used after separation from cuttings in solids removal equipment on the rig. Any residual water-based drilling fluid left over from the drilling program will be discharged down the annulus (the space between the casing strings) into a suitable porous stratum (lost circulation zone). However, in the remote possibility that there is not a lost circulation zone, excess water based fluid will be deposited onto the seabed via a flexible hose. The potential impact would be no more than that described in Section 3.10 in relation to the Loggerhead-1 well.

Petrofree will be separated from the cuttings via the solids control equipment and returned to the manufacturer for reuse at the completion of the drilling program. Only a minor amount of fluid will be retained on the drill cuttings and these will be discharged down the annulus of the well.

To decrease the risk of spillage of Petrofree into the marine environment, detailed transfer and handling procedures have been developed and are incorporated into the Chelonia Drilling Program document (Appendix 3).

Deck drainage, waste oily water and waste oil

Where machinery is present, and where cleaning solvents will be used, deck drains will be closed units. All runoff will be collected in a sump connected to an oily-water separator. After separation of oil from water, the oil will be returned to shore for recycling. The treated water is discharged to the ocean after reducing oil concentrations to below statutory limits. Rainfall is uncommon during the expected drilling time.

Waste oil (e.g. lubricating oil) is generated by machinery. This used oil is collected, stored and transported to shore for recycling.

Domestic wastes

Sewage, gray water from showers and laundry, and food scraps constitute the domestic waste generated.

Sewage will undergo tertiary treatment using an activated-sludge sewage treatment plant which macerates, partially digests and sterilises the sewage before discharge to the ocean. This flow-through system discharges a nominal volume of 35 m^3 per day (1.46 m^3 per hour). Dilution and dispersion, coupled with the short duration of the program, would limit the potential for oxygen depletion or eutrophication of nearby habitats.

Organic kitchen wastes will be macerated and disposed offshore. This consists of about 9 L of material per day. All other kitchen wastes are bagged, placed in skips and taken onshore to an approved disposal site. Kitchen, shower and laundry water are discharged directly overboard.

These discharges are intermittent. Rapid dilution of the discharges, and the short duration of the program will limit the potential for negative impacts.

Solid wastes

Solid wastes are generated during routine human and drilling activities. This waste includes paper, scrap steel, metal, packaging, etc.

All solid wastes are segregated into marked skips prior to disposal onshore at an appropriate site. Drums and scrap metal are re-used or recycled, and non-reusable solids are disposed of onshore at an appropriate landfill site.

Pipe dope

Pipe dope is used as a sealant and lubricant between the drill pipe threaded connections. It consists generally of grease and may contain traces of heavy metals (e.g. zinc and lead) to provide the required lubricity.

The pipe doping with the lowest concentration of heavy metals and hydrocarbons, but which will still meet safety and performance criteria, will be used. No pipe doping will be discharged onto the seabed as it will become amalgamated with the drill cuttings which will be reinjected into the annulus of the well.

4.3 Atmospheric Emissions

Greenhouse gases, the principal being CO_2, will be generated during the drilling program by machinery and engines. To minimise the production of emissions, all engines will be tuned to maximum efficiency.

4.4 Summary of the Effects of Routine Operations

The overall effects of routine operations of the drilling program are expected to be minimal, short-term and confined to the immediate vicinity of the drilling rig.

No drilling fluid chemicals, and only a small volume of drill cuttings will be discharged onto the seabed, as all attempts will be made to dispose of these materials down the annulus into the porous, lost-circulation zone of the geological formation. In the remote chance that this is not possible due to the lack of a lost circulation zone, excess water based fluid and cuttings will be deposited onto the seabed.

Drilling effects at the well site will be limited to the deposit of a small mound of drill cuttings. Detailed studies of the impact of drill cuttings disposal on the local benthic fauna indicate that only highly localised and short-lived changes in the benthic fauna will result (Hinwood *et al.* 1994). With annular disposal, the small volume of cuttings to be released will be deposited over an area previously affected by drilling and not over undisturbed habitat. Due to the strong currents in the area, cuttings mound will be smoothed and rapidly dispersed over time. While present, the mound will be colonised by fish and other fauna.

In the very remote chance that annular disposal is not possible due to the lack of a lost circulation zone, a larger cuttings mound will be generated on the seabed. However, previous studies carried out in the Exmouth region have shown that due to the high current energy of the region, the cuttings mound would dissipate rapidly and recolonization would occur immediately: minimal evidence would be found within three years.

The adjacent marine resources should not be affected by the routine discharges (gray water, cooling water, sewage, etc.) due to the dilution that will occur before and after the discharges enter the sea and the use of biodegradable detergents.

Marine fauna, such as dolphins, dugongs and turtles may avoid or be temporarily attracted to the rig during the drilling operations. This should not pose a threat to their well-being. Lights will not pose an impact on turtle hatchlings due to the distance to the nearest turtle nesting beach (~4 km on the southern end of South Muiron Island).

The proposed drilling program will not impact on the commercial prawn fishing industry as little activity occurs in the prawning area where the Chelonia wells are proposed to be drilled. Should prawning occur here, the small drill cuttings mound will not impede fishing effort.

The drilling program will not adversely affect the values and uses of the Ningaloo Marine Park. Turbid water will be generated for a short period of time while the 36 inch hole is being drilled: this increased turbidity must be put into context with sediment plumes generated naturally by the strong tidal currents in the region. Once casing has been set and the disposal of cuttings is down the annulus, there will be minimal turbidity. The small pile of cuttings will not diminish the ecological status of the seabed.

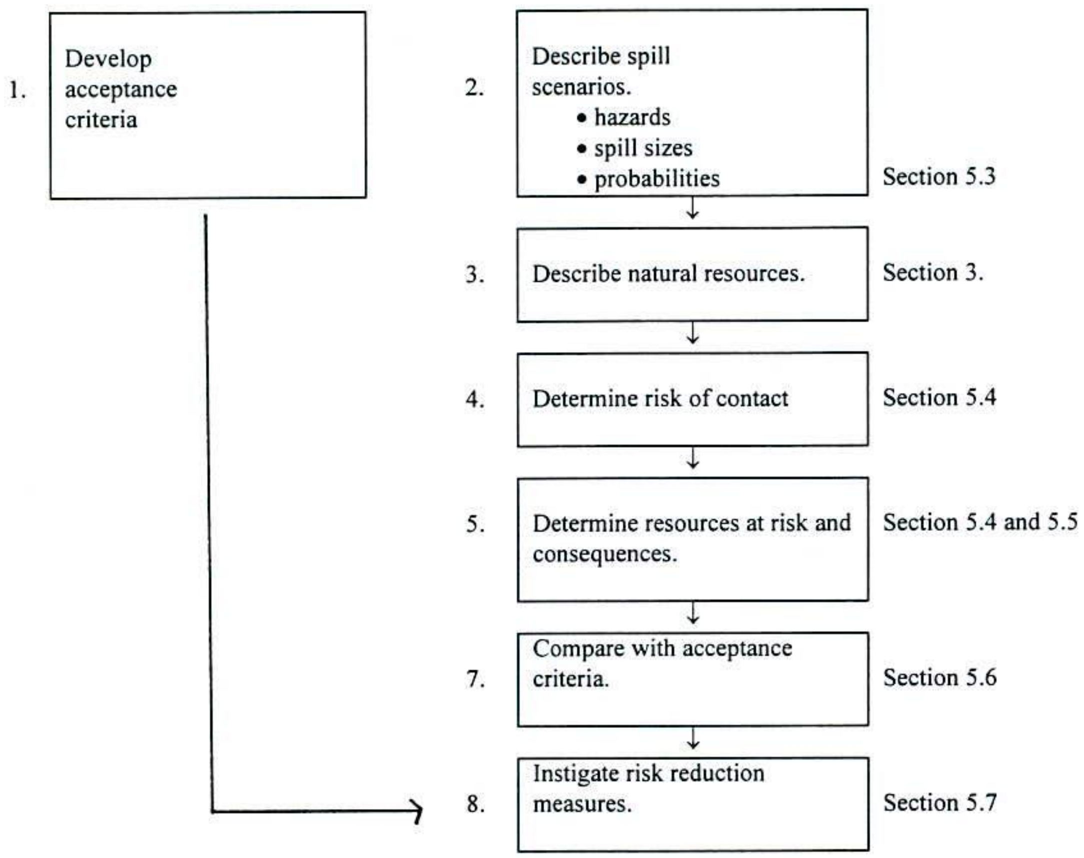
Tourism and recreational fishing will not be affected by the presence of the drilling rig.

5. ENVIRONMENTAL RISK ANALYSIS OF ACCIDENTAL DISCHARGE

5.1 Overview of Environmental Risk Assessment

This section describes the environmental risk assessment used for potential events that may result in the accidental spillage of hydrocarbons into the marine environment during drilling operations. The purpose of this analysis is to identify risks and develop risk-reducing measures for preventing and mitigating impacts from an accidental spill. The analysis has been carried out based on the methodology developed for the Norwegian Oil Industry Association (OLF) (Norwegian Petroleum Directorate 1992; OLF 1994; DNV 1996).

Environmental risk assessment can comprise of eight basic steps:



Acceptance Criteria Matrix

Acceptance criteria are developed as guidelines to express an acceptable level of risk from a specific activity based on the probability of a spill occurring and the potential consequences of a spill on the surrounding resources. This is a concept that has been developed by the Norwegian Petroleum Directorate (1992). In accordance with the Norwegian regulations, operators are obligated to establish acceptance criteria prior to conducting a full environmental risk analysis.

The acceptance criteria for environmental risk is based on a combination of risk frequency and consequence where expected frequency is defined as:

$f = f_o \times P_i$.

f_o = frequency of an incident
P_i = probability of impact.

Acceptance criteria can be presented as a matrix based on defined categories of risk frequencies and consequences. The categories developed for the Chelonia-1 and -2 drilling program are based on the Norwegian guidelines (OLF, 1994) and EPA Bulletin 278 (EPA 1987).

The risk frequency categories used by Apache are the following:

Likelihood category	**Frequency**	**Description**
High	$<10^{-3}$	Likely to occur often during a particular activity or operation.
Significant	10^{-3} - 10^{-4}	Likely to occur several times.
Moderate	10^{-4} - 10^{-5}	Likely to occur sometimes.
Low	10^{-5} - 10^{-6}	Unlikely, but possible to occur.
Very low	$>10^{-6}$	Very unlikely to occur.

These categories are more stringent than those suggested by the Norwegian guidelines due to Apache using the EPA guideline of 10^{-6} as an upper level of acceptable risk. A risk of 10^{-4} is generally the upper level of risk used in Norway.

At present, the consequence categories are based on recovery time and the categories used are:

Consequence category	**Recovery time**
Minor	< 2 years
Small	2 - 5 years
Moderate	5 - 10 years
Significant	10 – 20 years

Recovery rates are based on the assumptions that (1) all conditions necessary for recovery will exist after the incident, (2) that suitable area for resettlement, feeding and reproduction will exist and (3) there is a source of propagules for resettlement or a viable adult population for repopulation.

Using the frequency and consequence categories defined above, the guidelines for determining the acceptability of the Chelonia drilling program are given in the following base risk criteria matrix:

Probability					
	$<10^{-3}$				
	$10^{-3} - 10^{-4}$				
	$10^{-4} - 10^{-5}$				
	$10^{-5} - 10^{-6}$				
	$>10^{-6}$				
		<2	2-5	5-10	10-20

Recovery time - years

Risks are sufficiently low to be acceptable.

Risks are tolerable but require risk reduction measures to be implemented.

Unacceptable risk.

This base matrix will be used as guideline to ascertain the acceptability of the project after the probability of incidents and transport have been determined, and the potential impact to adjacent resources assessed (see Section 5.6 below).

5.2 An Overview of Sources of Spills from Oil and Gas Operations

5.2.1 Commonwealth of Australia offshore areas

In almost 30 years of operation, the oil and gas industry in Australia has drilled over 1,500 exploration and development wells and produced over 3,500 million barrels (556,500 million L) of oil. During this same period, the total amount of oil spilled to the marine environment from all offshore oil exploration and production activities has been estimated to be under 1,000 barrels (159,000 L), with the majority of these spills occurring during production activities (Volkman *et al.* 1994).

Six blowouts have occurred in Australia of which three occurred during exploration drilling. All six were gas blowouts and none resulted in an oil spill. There have been no blowouts in Australia since 1984, which is evidence of the technological and procedural improvements that have occurred over the last decade.

The Australian Maritime Safety Authority (AMSA) holds an oil spill incidents database from 1970 to the present. Over 4,000 incidents are recorded, with the predominant incidents being related to ships. Only six incidents are related to drilling operations and the size of spills ranged from 600 to 1,500 L. Details of the causes of the incidents are limited, but based on the information provided two causes were (1) diesel spillage - two incidents and (2) a failed seal during well abandonment - one incident. The causes of the remaining three incidents are unknown.

5.2.2 Western Australia offshore areas

A database containing spills to the marine environment greater than 80 L has been compiled by the Department of Minerals and Energy of Western Australia (DME) since July 1989. Oil, drilling fluid and chemical spills are recorded in this database. Between July 1989 and December 1997, a total of 310 exploration, appraisal and development wells have been drilled in the State and Commonwealth waters of Western Australia.

Since the inception of the database, there have been 65 oil spills, 19 drilling fluid spills and 3 chemical spills recorded for all oil and gas activities (seismic, drilling and production) in Western Australia (Table 7).

No blowouts have occurred in Western Australian waters. Knowledge of the characteristics of the Chelonia prospect, including reservoir pressure, makes the chances of a blowout extremely unlikely.

Oil spills

Between July 1989 and December 1997, three oil spills have occurred during drilling operations, one resulting in a spill of 1.89 barrels (293 L), one spilling one barrel (159 L) and the last spilling 0.25 bbls (40 L) (Table 8). The causes for these incidents were, respectively, a collision between a supply vessel and drilling rig at night resulting in the rupture of the fuel tank on the vessel, a hole in the fuel transfer hose between the support vessel and rig, and an overflow of oily water from a waste tank..

A total of 15 incidents resulting in spillage of oil were a result of production testing: two incidents within State waters and 13 incidents in Commonwealth waters. The majority of these incidents came from one operation due to insufficient combustion during production testing, resulting in the fallout of oil. The average volume of oil released into the marine environment during each of these incidents was about 6 barrels (930 L).

Drilling fluid spills

All recorded spills of drilling fluid occurred during the drilling of development wells. A total of 19 spills were recorded in the DME database resulting in 994 barrels of fluid being discharged accidentally into the marine environment over an eight year period. The main causes for these spillages were overflow of the mud tanks and drain valve, or dump failure.

Table 7: The number of oil, drilling fluid and chemical spills from oil and gas activities in Western Australia (State and Commonwealth waters). This table covers seismic, drilling and production activities.

Year	Oil spills		Drilling fluid spills		Chemical spills	
	Number of incidents	Volume spilt (bbls)	Number of incidents	Volume spilt (bbls)	Number of incidents	Volume spilt (bbls)
1989*	5	79	1	104	0	0
1990	12	94	2	16	0	0
1991	5	23	3	28	3	19
1992	5	32	0	0	0	0
1993	18	137	0	0	0	0
1994	7	225	2	504	0	0
1995	7	25	3	49	0	0
1996	5	4.5	5	466	0	0
1997	1	80	3	47	0	0
Total	65	699	19	1,214	3	19

* data from 1.8.89 to 31.12.89

Table 8: Summary of all oil spills occurring during drilling operations off the Western Australian coast during 310 wells between July 1989 and December 1997. This table does not include fallout from production testing (see 5.2.2 above).

Barrels of oil spilled	Nature of oil	Incident
0.25	Diesel	Overspill of oily water tank
1	Diesel	Hole in diesel transfer hose
1.89	Diesel	Rupture of fuel tanks due to collision.

5.2.3 Apache Energy's activities

Since 1983, Apache and its predecessors in all its permit areas have drilled 96 wells over 1,552 drilling days (Table 9).

Table 9: Summary of the number of wells drilled and tested by Apache in all permits since 1983.

Number of wells drilled	Drill days	Number of incidents	Volume of oil spilt (bbls)	Number of wells tested
96	1,552	2	5	37

In this time, two incidents occurred during drilling:

- in 1991, a small volume of crude oil (3.1 bbls; 492 L) was released into the marine environment due to incomplete combustion of some of the oil during production testing of the Leatherback-1 well. The oil residue affected 700 m of sand beach on South Muiron Island. The beach was cleaned up by hand and no evidence of oil was present one month after the incident (BBG 1991).

- in 1992, approximately 1.9 barrels (302 L) of diesel fuel were spilled at the Ulidia exploration well site (near Varanus Island) when a support vessel collided with the drilling rig and ruptured the vessel's fuel tank. No environmental impact from this spill was recorded to due the rapid evaporation of the diesel.

No drilling fluid has been accidentally spilt during any of Apache's drilling operations.

5.3 Sources of Discharge and Spill Size Frequencies

Two sources of waste that may enter the marine environment due to accidental discharge are drilling fluid and hydrocarbons.

The potential sources and sizes of liquid discharge from the drilling activities are summarised in Table 10. Generally, the sources are:

- leakage or spillage of diesel or lubricating oil;
- leakage or spillage from diesel transfer hose;
- leakage of chemicals from drums stored on the drilling rig or supply vessels;
- accidental discharge of drilling fluid from the shakers or transfer hoses;
- rupture of a fuel tank;
- uncontrolled discharge at surface during production testing; and
- uncontrolled discharge at surface due to loss of control of a well.

An international database (Oil Spills Risk Database) was used to carry out the quantitative risk of an incident which would result in the spillage of oil. This database consists of spill events which occurred in the North Sea and United States waters between 1975 and 1989 (DNV 1996) and has been used to generate spill-size frequency curves for specific types of spills (Figures 8 to 10). Using these curves, the risks for five particular spill types ranging from 2,500 L to 600,000 L were extracted for use in the overall risk assessment (see Section 5.4.2 below). These extrapolated risk frequencies for these spill types are included in Table 10.

5.4 Fate and Transport

5.4.1 Spillage of Petrofree drilling fluid

The drilling fluids proposed to be used for this program have deliberately been chosen for their low toxicity that will reduce the impact of accidental spillage. All the wells will use water based drilling fluid: however, Petrofree, an ester based fluid, will be used for the 12 ¼ inch section of the Chelonia wells. The discharge of main concern is accidental spillage of Petrofree and the potential fate is discussed below.

Properties of Petrofree

Petrofree is a biodegradable invert emulsion system (i.e. the ester base is emulsified within water) which is derived from palm oil and alcohol. It contains no aromatic hydrocarbons, is readily degradable under aerobic and anaerobic conditions and exhibits low toxicity to marine organisms.

Petrofree has undergone testing in both Australia and overseas to determine its biodegradability and toxicity to marine life. Test results have been supplied by the manufacturers, Baroid Australia Pty Ltd, and these are summarised in Appendix 4.

The Australian Institute of Marine Science (AIMS) was commissioned to predict the dispersal of Petrofree drilling fluid using the MUDMAP model developed by Applied Sciences Association, with hydrodynamic information provided by the GCOM3D oceanographic model (Hubbert 1993).

Two different size fluid spills originating at the Chelonia location were modelled over a one hour release period:

- 90 m^3 (90,000 L) - which represents the maximum size spill possible, equivalent to the total loss of a fluid tank on a supply vessel; and
- 5 m^3 (5,000 L) - a moderately large spill that might result from an accident during fluid transfer to the rig.

In each case, discharges were considered to be from above the water surface.

Table 10: Sources, consequences and prevention of accidental fluid discharge into the sea during drilling.

Source of spill	Potential maximum size	Type of hydro-carbon	Estimated risk of occurrence	Potential effects	Preventative actions
Leakage from engines or machinery	20L	Lub oil Diesel	Not determined	Consists of engine oil or hydraulic fluid. Negligible impact. Small amounts of diesel would dissipate and evaporate very quickly.	Drip trays and sumps placed under all engines. Oil collected in deck sump, emptied on regular basis and treated via oily water separator.
Spillage of chemicals from drums	205 L	Light oils	Not determined	Minor as the main chemical would be light oils.	Drums are stored on pallets and in bunded areas away from open grates wherever possible.
Leakage or spillage of diesel	2,500 L	Diesel	9.0×10^{-4}	Diesel would evaporate very quickly.	Strict refuelling procedures to be followed.
Oil fallout during production testing	8,000 L	Light crude	7.0×10^{-7}	The expected characteristics of the oil are those of a light crude. The light ends would evaporate quickly.	Transfer of tank to vessel to be carried out only in suitable weather and seastate conditions.

Table 10: continued

Source of spill	**Potential maximum size**	**Type of hydro-carbon**	**Estimated risk of occurrence**	**Potential effects**	**Preventative actions**
Rupture of rig fuel tank due to impact	80,000 L	Diesel	7.0×10^{-5}	Some risk of fire. Could have significant impact on marine resources depending on direction of current and wind.	Fuel tanks are located above the surface of the water and are contained within the hull of the rig. Chances of impact are slim as hull will be higher than vessel and tanks are protected by ballast tanks.
Rupture of support vessel fuel tank	80,000 L	Diesel	7.0×10^{-5}	Safety issue with potential fire or sinking of vessel. Could have an impact on marine resources, but oil would be light and evaporate quickly.	Work adjacent to rig and offload equipment only in suitable weather conditions. Fuel is divided among separate tanks.
Spillage of Petrofree drilling fluid	90,000 L	Palm oil derivative	Not determined due to insufficient data.	Fluid would disperse. Ester component would separate from solids and float on surface. Heavier inert particles would sink to the bottom. Will contribute to short term water column turbidity.	Continuous monitoring of fluid volumes and regular visual inspections carried out. All dump valves locked and ticketed. Detailed transfer and handling procedures.
Blow-out	600,000 L	Light crude	5.0×10^{-5}	If a gas blowout, little effect to the marine environment, but would contribute methane to the atmosphere. Could have major impact on marine resources if an oil blowout occurred.	Blow-out preventors, pressure testing all casing, maintaining proper drilling fluid weights, kick drills, known reservoir pressures, double checking with mud logging unit.

Methods

Physical properties of Petrofree drilling fluid were used for the modeling (Peter McNoughton, Baroid - personal communication, February 1998). Petrofree is composed of approximately 35% by weight of various solid, inert minerals (e.g. barite, calcium chloride, lime) as a slurry in an ester base derived from palm oil. The inert minerals and ester combination has a density of approximately 1.2 kg L^{-1} on delivery, which is varied during drilling operations by the addition of solids required for well control.

The ester component of the fluid has a density of 0.86 kg L^{-1}. The ester component of Petrofree has a high affinity or bonding to solids: if spilt, there would not be much separation between the ester component and the inert mineral particles due to this tight bonding factor. Any spillage of Petrofree would sink very rapidly although over time some ester separation would occur. However, biodegradation would occur straight away. The primary impact of any spillage of Petrofree will be potential sedimentation by the inert minerals. Toxicity testing indicates that Petrofree has a very low toxicity to subtropical and tropical marine animals (Appendix 4).

The solid component of the fluid (i.e. the inert minerals) has a combined density of approximately 1.8 kg L^{-1} and will sink at a rate that is related to the size of the particles. The mean particle size of the solid component of Petrofree was reported to be in the range of 5 to 30 μm depending on its preparation. The mean particle size will increase as drilling proceeds due to the incorporation of fine rock particles. However, the maximum size is limited to 70 μm by the secondary shaker filters used to screen out cuttings as the mud is recirculated. For the purposes of the modelling, a mean particle size of 25 μm was used to represent uncirculated fluid. This size range was conservative as it allowed for greatest spread of fluid towards more distant areas. A number of spill predictions were also re-run using a mean particle size of 50 μm to represent fluid that has been circulated and as a conservative guide to the sediment loads that might impact areas closer to the well site. Standard formulas for the fall rate of particles (Dyre 1987) indicate that particles of 25 μm will sink at an average rate of 0.04 cm s^{-1} in the absence of turbulence, while particles of 50 μm will sink at 0.15 cm s^{-1}.

For each spill size, mud dispersion was predicted under several randomly selected periods of wind that were recorded at Thevenard Island in May and June (winter period) and November-December (summer period). The vector plots for winds in the winter and summer period are given in Figures 11 and 12. Spills were started during both ebbing and flooding tides (Figures 13 and 14) and modelled over a 48-hour period. Spill transport and deposition rates were predicted based on water flows provided by the hydrodynamic model, taking into account tidal and wind-induced forcing of water over the local bathymetry (Figure 5). These forces are the most significant in the area around the well site. It should be noted that winds will induce shear forces that act on the surface of the water, and that their influence will be reduced at increasing depth. Consequently, tidal forces, which are independent of the season, would have increasing influence on transport as the particles sink.

Verification of the GCON3D model for the area has been carried out using mat-tracking exercises and current metering (GEMS 1996; Appendix 5).

Results

The predicted distribution of Petrofree particles on the sea floor for winter and summer conditions are shown for the different spill size and tidal state combinations in Figures 15-18 (winter) and Figures 19-22 (summer). In general, the predictions indicated that the bulk of the material would settle out fairly rapidly while the lighter particles may remain in the water column for up to 24 hours. Heaviest concentrations were generally predicted to accumulate on the sea floor up to 5 km from the well, with most material falling out around the period of minimum flow speeds as the tide turned (slack tide). Particles that remained in the water column for up to four tidal oscillations were predicted to travel up to 12 km from the well. The potential spread of the plume was predicted to vary among the seasons as described below.

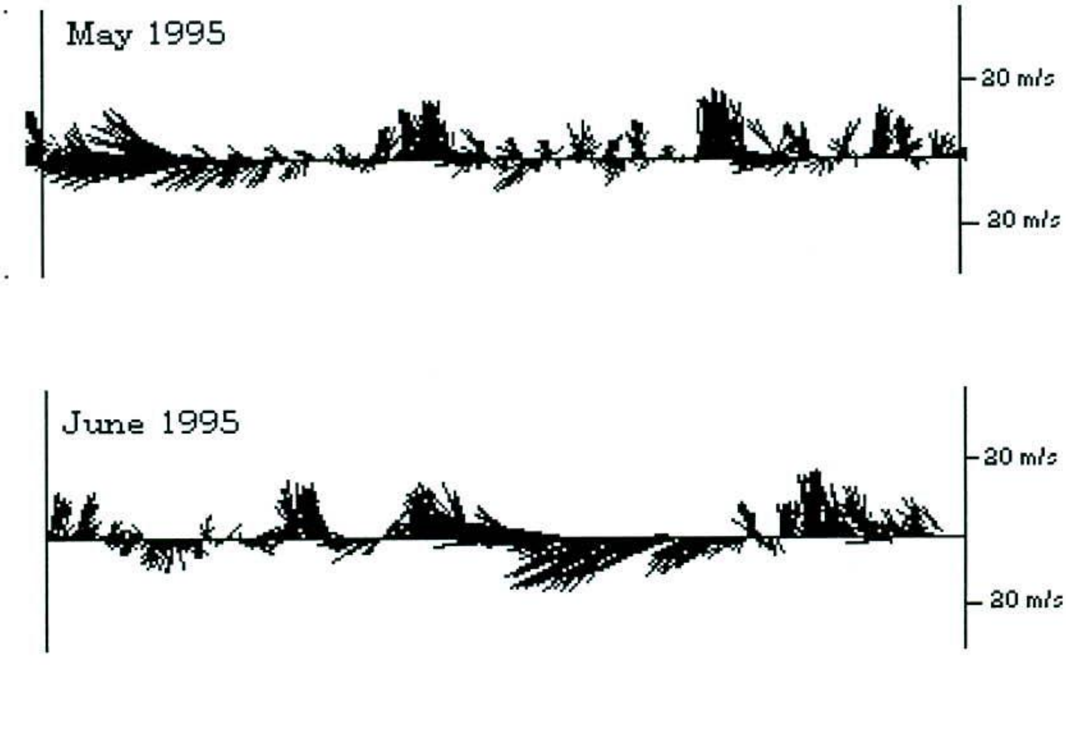


Figure 11: Vector plots of the hourly wind speed and direction data used in spill predictions for the winter period. The lengths of the lines indicate the wind speed (m/s). The angle of each line represents the direction that the wind was blowing to (e.g. lines upwards indicate a southerly wind). Data were recorded at Thevenard Island in May and June 1995.

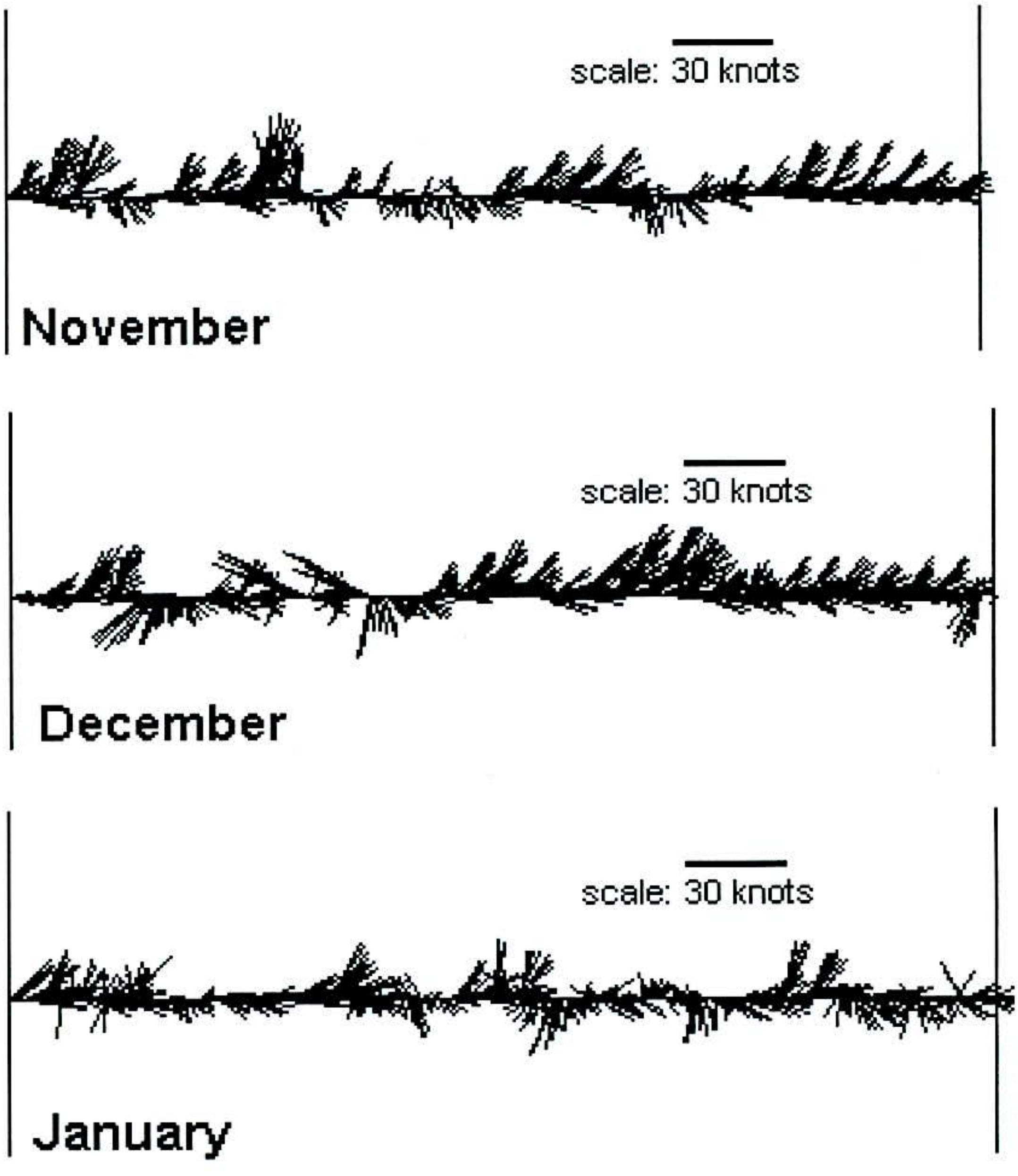


Figure 12: Vector plots of the hourly wind speed and direction data used in spill predictions for the summer period. The lengths of the lines indicate the wind speed (m/s). The angle of each line represents the direction that the wind was blowing to (e.g. lines upwards indicate a southerly wind). Data were recorded at Thevenard Island in November, December and January 1995.

Winter

The net movement under winter wind conditions was predominantly to the southeast (if released on the flood tide) or northwest (if released on the ebbing tide). Maximum sediment loads on the seabed were predicted to be of the order of 1 g m^{-2} for a 5 m^3 release and 10 g m^{-2} for a 90 m^3 release. Some parts of the modelled trajectories were predicted to impinge on the North West Cape, reflecting the influence of the predominantly easterly wind during the winter. However, the sediment loads near the Cape were predicted to be very low (<0.1 gm/m^2) regardless of the original size of the spill.

Summer

The net movement of each of the trajectories was to the north-east and away from the Ningaloo Marine Park, showing the influence of the predominantly south-west winds during the prediction period of November to December. Maximum predicted concentrations at the sea floor for a 90 m^3 spill were of the order of 30-40 g m^{-2}, while concentrations at the furthest extent were below 3 g m^{-2}. For larger particle sizes (i.e. 50 μm) which have more rapid sink rates, the maximum concentrations were predicted to be up to 60 g m^{-2}. Some of the model trajectories did impinge upon the shallow areas surrounding South Muiron Island suggesting that there is some risk that some fluid may accumulate in this area if spilled in summer. However, these concentrations were generally low (0-9 g m^{-2}).

Natural sedimentation process

Sedimentation is a normal process that local marine biota are normally subjected to. A common feature of the Gulf is the presence of sediment plumes generated by strong tidal currents. The implications of inert fluid deposition following an accidental spill of Petrofree must therefore be considered in the context of the normal sedimentation rates in the area.

Sediment trap sampling was carried out near the Muiron Islands by Bowman Bishaw Gorham for Lasmo Oil as part of an environmental assessment of the Leatherback-1 drilling programme (BBG 1991). Sediment traps moored 1,200 m from the rig to measure background levels of sedimentation measured average sediment deposition rates of 36 g m^{-2} per day over a 30 day period. The additional maximum load that was predicted to accumulate from a large spill of fresh Petrofree (30 g m^{-2}) is therefore of a similar magnitude to the daily load that occurs naturally. Although data is not available, sedimentation during storm or cyclonic events would be substantially higher.

The maximum load for larger grain size (60 g m^{-2}) would be about twice the mean, but within the range of natural sedimentation, especially during storm conditions. Concentrations predicted to accumulate in shallow areas around South Muiron Island (up to 9 g m^{-2}) would represent approximately 25% of the daily load. These concentrations would be expected to have only slight effects upon the local biota. Corals and other filter feeding animals, for example, are capable of active and passive removal of sediment from their surfaces. Mortality of corals as a result of excess sedimentation requires significantly higher and sustained sedimentation (e.g. > 259 g m^{-2} per day for over 3 months; Simpson 1988).

5.4.2 Fate and transport of spilled oil

The wind- and tidal-induced surface currents immediately prior to and following a spill will largely dictate transport of a spill. The fate of petroleum in the marine environment is dependent on a complex interaction of both physical (e.g. evaporation, temperature, sea state, wind and wave intensity) and biotic (e.g. biodegradation) factors which will result in changes in the composition and toxicity of oil over time.

Weathering and dispersal characteristics

If oil is encountered at Chelonia, it is expected to be similar to the oil encountered at Leatherback-1.

Leatherback-1 oil is a slightly weathered light crude (API gravity of around 30°), with a high wax content (~12%) and relatively high pour point (~27 °C). Weather testing of Leatherback crude at summer temperatures (32 °C) showed rapid evaporation in the first eight hours with the loss of approximately 35% of the total mass of oil. Weathering after this time continued at a reduced rate (Apache 1997; BHP 1992).

The hydrocarbon composition of Leatherback crude indicates that this oil has undergone weathering due to water washing while in the reservoir. This water washing has caused the depletion of the monocyclic aromatic and polycyclic aromatic hydrocarbons (MAHs and PAHs). These compounds include the hydrocarbons that contribute to the toxicity of oil, namely benzene, toluene, ethybenzene and xylene (BTEX). Other water-soluble compounds such as phenol, cresol and alkylphenols are also depleted in Leatherback crude. Leatherback has a BTEX concentration of about 3% as compared to 30-35% found in the lighter crudes such as Wonnich or Harriet. This indicates that should Leatherback crude be spilled onto the water, the oil would contain very low concentrations of the soluble hydrocarbons most likely to cause toxic effects to marine animals in the water column.

Toxicity carried out on fresh Stag crude oil, which is a highly weathered oil containing no light end compounds, has indicated that this oil is non-toxic to five species of marine invertebrates (Neff 1988). Fresh Leatherback oil contains a small abundance of light end compounds (~ 3%), and can be regarded as slightly toxic to marine organisms. Given the estimated time for further weathering following a spill (Table 13), the majority of the remaining light end compounds in Leatherback oil would have been lost mainly by evaporation. The loss of the light ends would result in a further reduction in the toxicity of the oil.

Leatherback crude oil showed a propensity to form an oil-in-water emulsion in the presence of wind and wave turbulence at 32 °C. This emulsion was unstable and proved to be amenable to some dispersants in the early stages of weathering. Tar ball formation commenced as early as 2 hours after contact with the water, and was quite pronounced after 4 hours (MSL 1992). This characteristic will reduce the evaporation rate of the oil and its amenability to chemical dispersion, but will also reduce the potential for the oil to disperse into the water column and be adsorbed by sediments.

Diesel oil has a higher evaporation rate than Leatherback crude. It is estimated that 50% of all materials will have evaporated within 10 hours, including 80% of the more toxic light end aromatics. Weathering after this time will slow with an estimated loss of 70 to 80% within 40 hours (Apache 1997). Diesel has a relatively low pour point and will spread rapidly to a thin film and will resist forming an emulsion. Thinly spread oils photo-oxidize readily and are more easily dispersed by wind and wave action.

Probability of oil reaching sensitive resources

The Apache GCOM3D/Oilmap current and oil spill computer modelling system was used to predict the risk that oil spills might migrate to sensitive shallow water habitats within the Gulf. A description of the model and the results of field validation are presented in Appendix 5. The GCOM3D ocean current model was set up at a horizontal scale of 500 m over a region covering the Exmouth Gulf and the North West Cape.

The GCOM3D current model was used to simulate two month long periods of ocean currents, each a month long, over the model region, based on a series of historical wind data from the region and tidal constituents measured within the Gulf. The two runs provide a large sample of the potential wind and tide conditions that would occur during each season. The conditions would be highly representative of those experienced during each season due to the consistent winds on the North West Shelf (see Section 3.2).

Hourly average wind speed and direction data from Thevenard Island were used as examples of wind patterns found over open water on the outer gulf, as this wind station experiences the most similar wind patterns to the study area (D. Beebee, SSU, Bureau of Meteorology *pers. com.*). Vector plots of the wind records measured during a winter period show the predominance of easterly and south easterly winds over Exmouth Gulf (Figure 11). In contrast, vector plots of the wind records for a summer period demonstrate a predominance of southerly, south easterly, south westerly and westerly winds (Figure 12). Winds tend to blow from the south-east during the mornings and from the south-west in the afternoons.

Tidal data was supplied to GCOM3D as the amplitudes and phases of seven major tidal constituents derived from Exmouth, Onslow, the Muiron Islands and wider field stations on the North West Shelf. The length of each run (one month) ensured that all tide conditions were covered in the modelling (neap, springs, flood, ebb).

Having generated predictions of tide and wind-induced surface water movements during the two month long summer and winter study periods, Oilmap was used to calculate probability contours for the transport and persistence of oil from the proposed Chelonia location under four different incident scenarios (Table 11). The scenarios used for predicting spill probabilities used the physical characteristics of two oil types, Leatherback crude and diesel fuel, at maximum spill quantities that might be expected if specific incidents occurred (Table 11: derived from Table 10).

Table 11: Scenarios used for the prediction of spill trajectories.

Possible incident	**Oil Type**	**Quantity**	
Leakage or spillage during diesel handling	Diesel	2,500 L	(16 bbls)
Oil dropout during production testing	Leatherback crude	8,000 L	(50 bbls)
Rupture of support vessel fuel tank	Diesel	80,000 L	(503 bbls)
Blowout	Leatherback crude	600,000 L	(3,774 bbls)

Predictions were made using Monte Carlos sampling procedure to calculate the probabilities that a spill will contact particular locations on the water or shoreline. The procedure involved generating a number of individual simulated spill events (100 for each scenario), with each spill starting at a randomly selected date and time during the long run of GCOM3D predictions. The trajectory of each spill was predicted over a four day period. The random sampling process is important, as it will ensure that a representative set of wind and tide conditions for the season of interest are selected for modeling. The most common combinations of wind and tide conditions will have the highest representation while rarely occurring combinations will be selected, but will be less represented. This procedure is also a realistic assessment of accident risk, as an incident could potentially occur under any of the prevailing combination of wind and tide conditions.

The influence of the Leeuwin current or associated counter currents was not included within the model predictions due to their complexity and lack of quantitative data (A. Pearce, *pers. com.*). Instead, a qualitative assessment was made of the likely contribution that these offshore currents may make to a spill movement based on sea surface temperature structures visible in satellite images (Appendix 5).

Having generated 100 separated spill trajectories for each scenario, Oilmap then calculated the frequency at which particular locations within the model region were contacted by oil. This information is used to generate probability contours showing the potential risk of contact by oil.

The model provided predictions of the following parameters:

- the probability that specific locations would receive oil;
- the minimum time before the oil may arrive; and
- the maximum volume of oil reaching shorelines.

The predictions indicate the worse case and assume that no action is taken to contain the oil or to reduce the volume on the water surface. In practice, action would be taken to reduce the volume of oil that may contact sensitive locations.

The results of the predictions are summarised in Tables 12 and 13. Figures 23 and 24 show the probability contours for the transport of oil under summer and winter wind conditions for each of the four spill scenarios. Figures 25 and 26 indicate the volume of oil that could potentially contact the various coastlines. The volumes given are the worse case scenarios over the 100 modelled spills. They do not indicate the actual volume of oil that would contact the resources for every wind and tide condition.

The probability contours shown in Figures 23 and 24 indicate the predicted risk from spills of the specified oils to a location during the period of interest. It is important to understand that these contours **do not** indicate the total area that would be affected by a single spill. Rather, they indicate the **probability** that oil may be transported to specific locations due to the various combinations of wind and tide conditions that prevail during the season. Locations with a high probability are predicted to be at risk of contact during a wider range of wind and tide conditions than those with a low probability. Low probability of contact denotes tide and wind combinations that are uncommon for that particular season.

It should also be noted that the size of a spill would affect the spread of a slick, but have little effect on its trajectory. The contour lines predicted for small and large spills have similar appearances due to the similar trajectories of the spill, regardless of size: the differences in contour lines would be due to the spread of the spill. Larger spills would have a wider spread and hence the contour lines would be wider than for smaller spills.

The Chelonia surface location is located in an area that experiences strong tidal currents which tend to oscillate along a north-west to south-east axis through the channel separating the Muiron Islands from North West Cape ("The Gap"). The semi-diurnal tides in the area will give these oscillations a period of about 6 hours and these currents captured most spills for one or more tidal cycles. These oscillations are predicted to give the oil an extended time to evaporate over open water.

The tidal flow patterns for the area during ebbing and flooding tides were predicted to provide the primary steering of near-field slick transport. Under both the summer and winter wind conditions, the major axis of the probability contours was aligned with the major NW-SE current flow. These currents typically kept oil in open water for the first 12 hours. Once the oil escaped the influence of these currents, the winds were predicted to have a major influence on the far-field transport of the slick.

In the winter period, modelling predicted a greater potential spread of hydrocarbons resulting in a 1 to 10% chance of oil reaching the North West Cape in the area west of Point Murat (Table 12). This was also where the largest volume of oil could possibly reach in the event of a large spill such as a blowout. However, it must be borne in mind that the risk of a blowout occurring in the first instance is extremely low. The risk of oil contacting the Muiron Islands was <10% for any spill size. Modelling also indicated a greater probability that oil may migrate out of the Gulf where it may be subjected to the influence of the Leeuwin Current.

The majority of the spill trajectories during the summer months did not contact the islands and shorelines of the Gulf. The probability that the Muiron Islands would be contacted by oil was predicted to be between 1% and 10%, depending on the location, oil type and volume (Table 13). Most modelled spills took longer than 15 hours to contact land. The land with the greatest risk of contact was Sunday Island (16% chance of contact during a blowout). Oil contacting the shorelines of this island took between 23-29 hours to contact in the case of a major spill, giving the oil time to weather and evaporate. Generally, the risk of contact from a small diesel spill was very low.

NOAA satellite images from four times in summer and four times in winter were examined for evidence of thermodynamic structure (Appendix 5). Images collected during July show the warm Leeuwin current flowing south to seaward of the Gulf waters and along the North West Cape. A stable feature of the images from July is the presence of a flow of cool, dense water moving eastward from the Indian Ocean to concentrate and direct the Leeuwin current towards the coast. Imaged collected in December also indicate an eastward flow of cool water from the Indian Ocean at a similar latitude. However, in contrast to the winter images, this flow corresponded with a clear break between the warm northern waters and the cool waters from the south and there is no evidence of the Leeuwin current. Cool dense water can be seen impinging upon the west coast of North West Cape coastline and migrating northwards inshore of warm waters coming from the north.

The implications of the observed thermodynamic currents for spills that may emerge from Exmouth Gulf are that:

- spills in winter, when the Leeuwin current is flowing, may be expected to migrate towards the south south-east and consequently may increase the risk of contacting the Ningaloo Reef than was predicted for tidal and wind-induced currents only; and

- spills in summer, when the Leeuwin Current is absent and cool water currents are driven north along the west side of North West Cape, may be expected to remain offshore.

In general, the probability of oil reaching sensitive localities was low for any size of spill due to the overall influence of tides and winds.

Table 12: Predicted risks due to specific oil spills from the Chelonia location under winter wind conditions. Results are based on 100 model spills during different wind conditions recorded in May-June 1995.

Spill fluid	Spill volume (Litres) (*barrels*)	Probability of the spill occurring	Locations affected	Probability of contacting locations if spilled	Overall probability of contact due to a spill	Maximum volume during any spill trajectory (Litres)	Minimum time during any spill trajectory (hours)
Diesel	2,500	9.0×10^{-4}	West of Pt. Murat	5.0×10^{-2}	4.5×10^{-5}	198	37
	16		Pt. Murat to Exmouth	4.0×10^{-2}	3.6×10^{-5}	110	25
			South of Exmouth	5.0×10^{-2}	4.5×10^{-5}	107	19
			South Muiron Island	3.0×10^{-2}	2.7×10^{-5}	270	39
			North Muiron Island	5.0×10^{-2}	4.5×10^{-5}	69	54
			Sunday Island	4.0×10^{-2}	3.6×10^{-5}	235	33
			Observation Island	-	$<9.0 \times 10^{-6}$	-	-
			Table Island	-	$<9.0 \times 10^{-6}$	-	-
			Round Island	-	$<9.0 \times 10^{-6}$	-	-
			Flat Island	-	$<9.0 \times 10^{-6}$	-	-
			Serrurier Island	-	$<9.0 \times 10^{-6}$	-	-
			Peak island	-	$<9.0 \times 10^{-6}$	-	-
Leatherback crude	8,000	7.0×10^{-7}	West of Pt. Murat	8.0×10^{-2}	5.6×10^{-8}	1,130	41
	50		Pt. Murat to Exmouth	7.0×10^{-2}	4.9×10^{-8}	445	15
			South of Exmouth	9.0×10^{-2}	6.3×10^{-8}	930	15
			South Muiron Island	7.0×10^{-2}	4.9×10^{-8}	821	28
			North Muiron Island	4.0×10^{-2}	2.8×10^{-8}	170	49
			Sunday Island	1.0×10^{-1}	7.0×10^{-8}	1,359	27
			Observation Island	-	$<7.0 \times 10^{-9}$	-	-
			Table Island	-	$<7.0 \times 10^{-9}$	-	-
			Round Island	-	$<7.0 \times 10^{-9}$	-	-
			Flat Island	-	$<7.0 \times 10^{-9}$	-	-
			Serrurier Island	-	$<7.0 \times 10^{-9}$	-	-
			Peak island	-	$<7.0 \times 10^{-9}$	-	-
Diesel	80,000	7.0×10^{-5}	West of Pt. Murat	6.0×10^{-2}	4.2×10^{-6}	11,900	18
	500		Pt. Murat to Exmouth	5.0×10^{-2}	3.5×10^{-6}	13,558	25
			South of Exmouth	1.1×10^{-1}	7.7×10^{-6}	19,457	35
			South Muiron Island	6.0×10^{-2}	4.2×10^{-6}	14,547	36
			North Muiron Island	1.0×10^{-2}	7.0×10^{-7}	1,032	41
			Sunday Island	4.0×10^{-2}	2.8×10^{-6}	2,591	32
			Observation Island	-	$<7.0 \times 10^{-7}$	-	-
			Table Island	-	$<7.0 \times 10^{-7}$	-	-
			Round Island	-	$<7.0 \times 10^{-7}$	-	-
			Flat Island	-	$<7.0 \times 10^{-7}$	-	-
			Serrurier Island	-	$<7.0 \times 10^{-7}$	-	-
			Peak island	-	$<7.0 \times 10^{-7}$	-	-
Leatherback crude	600,000	5.0×10^{-5}	West of Pt. Murat	8.0×10^{-2}	4.0×10^{-6}	16,535	16
	3,770		Pt. Murat to Exmouth	1.0×10^{-1}	5.0×10^{-6}	26,716	15
			South of Exmouth	1.1×10^{-1}	5.5×10^{-6}	54,054	26
			South Muiron Island	6.0×10^{-1}	3.0×10^{-5}	4,698	29
			North Muiron Island	7.0×10^{-1}	3.5×10^{-5}	10,647	41
			Sunday Island	1.1×10^{-1}	5.5×10^{-6}	11,379	38
			Observation Island	-	$<5.0 \times 10^{-7}$	-	-
			Table Island	-	$<5.0 \times 10^{-7}$	-	-
			Round Island	-	$<5.0 \times 10^{-7}$	-	-
			Flat Island	-	$<5.0 \times 10^{-7}$	-	-
			Serrurier Island	-	$<5.0 \times 10^{-7}$	-	-
			Peak island	-	$<5.0 \times 10^{-7}$	-	-

= no contact during any of the model trajectories. Probability of contact, if spilled, is less than 1×10^{-2}.

Table 13: Predicted risks due to specific oil spills from the Chelonia location under summer wind conditions. Results are based on 100 model spills during different wind conditions recorded in December-January 1995.

Spill fluid	Spill volume (Litres) *(barrels)*	Probability of the spill occurring	Locations affected	Probability of contacting locations if spilled	Overall probability of contact due to a spill	Maximum volume during any spill trajectory (Litres)	Minimum time during any spill trajectory (hours)
Diesel	2,500	9.0×10^{-4}	West of Pt. Murat	-	$<9.0 \times 10^{-6}$	-	-
	16		Pt. Murat to Exmouth	-	$<9.0 \times 10^{-6}$	-	-
			South of Exmouth	-	$<9.0 \times 10^{-6}$	-	-
			South Muiron Island	4.0×10^{-2}	3.6×10^{-5}	472	16
			North Muiron Island	1.0×10^{-2}	9.0×10^{-6}	33	52
			Sunday Island	9.0×10^{-2}	8.1×10^{-5}	1,464	19
			Observation Island	-	$<7.0 \times 10^{-9}$	-	-
			Table Island	-	$<7.0 \times 10^{-9}$	-	-
			Round Island	-	$<7.0 \times 10^{-9}$	-	-
			Flat Island	-	$<7.0 \times 10^{-9}$	-	-
			Serrurier Island	-	$<7.0 \times 10^{-9}$	-	-
			Peak island	-	$<7.0 \times 10^{-9}$	-	-
Leatherback crude	8,000	7.0×10^{-7}	West of Pt. Murat	-	$<7.0 \times 10^{-9}$	-	-
	50		Pt. Murat to Exmouth	-	$<7.0 \times 10^{-9}$	-	-
			South of Exmouth	-	$<7.0 \times 10^{-9}$	-	-
			South Muiron Island	6.0×10^{-2}	4.2×10^{-8}	1,355	15
			North Muiron Island	2.0×10^{-2}	1.4×10^{-8}	336	44
			Sunday Island	1.1×10^{-1}	7.7×10^{-8}	1,788	23
			Observation Island	-	$<7.0 \times 10^{-9}$	-	-
			Table Island	-	$<7.0 \times 10^{-9}$	-	-
			Round Island	-	$<7.0 \times 10^{-9}$	-	-
			Flat Island	-	$<7.0 \times 10^{-9}$	-	-
			Serrurier Island	-	$<7.0 \times 10^{-9}$	-	-
			Peak island	1.0×10^{-2}	7.0×10^{-9}	241	56
Diesel	80,000	7.0×10^{-5}	West of Pt. Murat	-	$<7.0 \times 10^{-7}$	-	-
	500		Pt. Murat to Exmouth	-	$<7.0 \times 10^{-7}$	-	-
			South of Exmouth	-	$<7.0 \times 10^{-7}$	-	-
			South Muiron Island	8.0×10^{-2}	5.6×10^{-6}	11,351	21
			North Muiron Island	3.0×10^{-2}	2.1×10^{-6}	5,959	40
			Sunday Island	1.2×10^{-1}	8.4×10^{-6}	3,252	29
			Observation Island	-	$<7.0 \times 10^{-7}$	-	-
			Table Island	-	$<7.0 \times 10^{-7}$	-	-
			Round Island	-	$<7.0 \times 10^{-7}$	-	-
			Flat Island	-	$<7.0 \times 10^{-7}$	-	-
			Serrurier Island		$<7.0 \times 10^{-7}$	-	-
			Peak island	1.0×10^{-2}	7.0×10^{-7}	954	30
Leatherback crude	600,000	5.0×10^{-5}	West of Pt. Murat	-	$<5.0 \times 10^{-7}$	-	-
	3,770		Pt. Murat to Exmouth	-	$<5.0 \times 10^{-7}$	-	-
			South of Exmouth	-	$<5.0 \times 10^{-7}$	-	-
			South Muiron Island	1.3×10^{-1}	6.5×10^{-6}	16,565	20
			North Muiron Island	6.0×10^{-2}	3.0×10^{-6}	11,700	21
			Sunday Island	1.6×10^{-1}	8.0×10^{-6}	3,900	23
			Observation Island	-	$<5.0 \times 10^{-7}$	-	-
			Table Island	-	$<5.0 \times 10^{-7}$	-	-
			Round Island	-	$<5.0 \times 10^{-7}$	-	-
			Flat Island	-	$<5.0 \times 10^{-7}$	-	-
			Serrurier Island	-	$<5.0 \times 10^{-7}$	-	-
			Peak island	-	$<5.0 \times 10^{-7}$	-	-

- = no contact during any of the model trajectories. Probability of contact, if spilled, is less than 1×10^{-2}.

5.5 Key Resources at Risk and Potential Impact

A detailed description of the existing environment surrounding the Chelonia location was provided in Section 3. A literature review of the effects of oil on natural and social resources is given in Appendix 6 with an overview given in Table 14. The sensitivity classifications for marine resources, and the measures recommended for their protection and clean-up are given in Table 15.

No correlation can be made between the size of a spill and the level of impact. The effects of an oil spill on the surrounding resources are a function of a complex interaction of numerous factors such as proximity of the spill to resources, sea state, weathering characteristics, and oil toxicity (see Section 5.4.2). For example, during the Gulf War, 6-10 million barrels of oil were released into the marine environment, the largest ever from a single spill. Studies showed that this did not cause a 'catastrophic' impact on the marine flora and fauna of the Arabian Gulf: some habitats (coastal saltmarshes and algal mat communities) showed considerable oiling effect, while the majority of habitats, including corals, benthos and seagrass) showed relatively few effects (Saenger 1994; Yogi 1995). Conversely, the 50,000 barrel Bahia las Minas oil spill in Panama did result in significant oil impact to a number of tropical coastal habitats (Keller 1992).

The key resources that are at risk from an accidental oil spill in winter are the sandy beaches, intertidal rock platforms and subtidal reefs of the Muiron Islands, the northern tip of North West Cape and Sunday Island (Figures 27 - 29.). In summer, there is minimal risk of oil reaching the North West Cape.

The shorelines of the Muiron Islands and the northern section of North West Cape are largely composed of narrow sandy beaches with smaller areas of intertidal rock platform. Sunday Island is completely ringed by a sandy beach. These habitats would have the greatest likelihood of receiving oil, as they are at the water surface. The potential impact to the fringing reefs would be low as they are predominantly subtidal and therefore less likely to be exposed directly to oil. Also, as discussed in Section 5.4.2, any oil reaching the shorelines would be highly weathered and most likely in a 'tar-ball' form, thereby reducing the amount of oil which would be dispersed into the water column and thereby taken up by filter feeding organisms such as corals.

The sandy beaches support a relatively low diversity of resident invertebrate fauna, with a high rate of turnover due in part to the high frequency of physical disturbance. Turtles use the beaches for nesting during the summer months, and are also used for foraging and roosting by seabirds. Sandy beaches would be given the highest level of protection and clean-up in the event of a spill.

The rock platforms are vegetated with macroalgae, and support an assemblage of molluscs and crustaceans. Sampling of these latter assemblages show that they can vary in abundance and composition over relatively short time periods (less than 6 months; LeProvost Environmental Consultants 1990).

The fauna and flora in shoreline habitats could be subject to initial mortality through localised smothering and the toxic effects of stranded oil. Biota should begin to recolonise once the oil begins to weather. Studies of oil affected shorelines have typically reported initial fluctuations in the composition of the recolonising fauna, due to species-specific differences in the availability of recruits and responses to any remaining hydrocarbons. The rate at which assemblages return to their pre-spill state will differ depending on the degree of contamination, and characteristics of the fauna (GESAMP 1993).

Table 14: Overview of the consequences of an oil spill on natural and social resources. A light crude oil is used as the source of impact. The impact of a spill will be dependent on such factors as: size of the spill, extent of exposure of resources, extent of weathering of the oil and emergency response measures taken to reduce adverse effects.

Resource	**Importance**	**Impact**	**Expected recovery time ***
Plankton	Component of marine food chain. Primary producers. Many marine species have larval stage in plankton.	Major impact will be to plankton on surface of the water where oil is located. Plankton in water column may be affected as light crude is quite soluble.	Immediate Spatial movement and effective reproductive strategies will result in rapid recovery.
Subtidal seabed communities	Potentially high biological productivity. Feeding grounds for turtles, dugongs and fish.	Effect minimal except in shallower waters where oil may reach the seabed. Toxic components in oil may affect flora and fauna. Heavier oil may persist in sand sediment for period of time.	1 year. Rapid recovery due to spatial movement of animals and high reproductive capacity of colonizing species.
Rocky intertidal shores	Dominated by oysters and barnacles. Includes array of other fauna and flora. Rock platforms used by birds.	Damage by smothering or toxic effects. Oil may not adhere to rock for a long period of time. Low potential for oil accumulation except in crevices and pools. Natural cleansing by waves reduces persistence of oil.	1-2 years.
Mud tidal flats	Supports mangrove communities. High productivity. Feeding grounds for wading birds.	Oil may not penetrate very deep due to fine sediment, but may accumulate at high tide level. Burrows of animals may act as pathways for oil, assisting penetration. Severe impact to fauna may lead to reduced food supply for wading birds.	2-10 years. Dependent on penetration of oil and tolerance of animals.

* see Appendix 6 for references

Table 14 continued

Resource	Importance	Impact	Expected recovery time
Algae and seagrass beds	Stabilise shoreline and seabed. Highly productive. Food source for turtles and dugongs. Nursery grounds for marine invertebrates. Provide shelter.	Algae are considered to be relatively resilient to oil. Intertidal seagrass beds most prone to damage. Tolerance to oil varies amongst species. Depressed growth rate, leaves turning brown, covering by algae are reported responses. Animals associated with seagrasses could be heavy impacted.	Algae: 1 year Seagrass: 1 year – decades Associated fauna: 1-5 years
Corals	Provide habitat for high density and diversity of animals. Nurseries for many fish. Important for tourism.	Minimal impact if coral remains submerged and oil is mixed in the water column. Localised tissue rupture, increased algae growth, excessive mucous production are potential responses. If coral dies, habitat composition may change to predominantly algae. Some corals long lived and slow growing. Recovery dependent on recruitment success.	1 year - decades
Mangroves	Highly productive. Source of food and shelter for wide diversity of organisms. Nursery grounds for some marine species. Stabilize shoreline.	Oil may persist in sediment, especially where penetration has occurred (i.e. down animal burrows). Response range from defoliation, chlorisis to death of trees. Infauna may be killed by smothering by oil or by its toxicity.	Trees: 10-50 years Fauna: 2-5 years
Fin fish	Commercial and recreational value. Contribute to food chain.	Low risk of impact to adults in open water due to mobility. Toxic component may cause tainting or death to fish in sheltered waters. Larvae and eggs floating on surface prone to impact.	Years in enclosed waters.

Table 14 continued

Resource	Importance	Impact	Expected recovery time
Seabirds	Add to conservation status and biodiversity of area. Some species protected.	Death may result due to damage to plumage and ingestion.	Could be slow to medium recovery depending on reproductive potential, number of animals affected and weathered state of oil.
Turtles	Add to conservation status and biodiversity to area. Food source to indigenous people. Some species protected.	May be prone to eye infections if contact made with oil. Mobile and can therefore avoid oil. Greatest impact will be to nesting turtles and hatchlings.	Could be slow to medium recovery depending on reproductive potential, number of animals affected and weathered state of oil.
Marine mammals	Add to conservation status and biodiversity of area. Some species protected.	Appear to be able to avoid oil. However, if come into contact, may suffer eye infections, skin irritations, inhalation of fumes, ingestion of oil. Dugongs may be affected if food source impacted.	Could be slow to medium recovery depending on reproductive potential, number of animals affected and weathered state of oil.
Commercial fisheries	Economic value.	Local reduction in numbers or tainting of stock may result in economic impact.	Could be slow to medium recovery depending on reproductive potential, number of animals affected and weathered state of oil.
Tourism	Economic value.	Access to oiled beaches could be restricted, fishing may be restricted and some natural resources used for diving may be restricted for access.	Short to medium term.

TABLE 15: RESOURCE CLASSIFICATION AND SENSITIVITY CODES

Coastal Feature	Sensitivity	Comments	Protective Measures	Clean-Up Methods: Preferred	Clean-Up Methods: Possible	Clean-Up Methods: Avoid
Mangroves Intertidal Sand & Mudflats	S1	Low energy areas. Oil may penetrate substrate and persist for long time. Important nursery and spawning areas. These areas should receive high priority for protection and clean-up	2, 3	1, 7	3, 14	5, 8, 10, 11, 12, 13
Coral Reefs	S1	High sensitivity to oil. High priority to be given to barrier reefs which may be exposed to floating oil. No dispersants to be used.	2, 3	1, 3, 7	8	5, 9, 10, 11, 12
Pearl Leases	S2	Oil pollution can cause severe economic damage, but resource can be replaced.	2, 3	7	3, 13	5
Intertidal Lime - Stone Platform	S3	Some short term reduction in numbers of animals will occur - should recover quickly after oil removed.	2, 3	7	3, 8	9, 10, 11, 12, 13
Sandy Beaches	S3 S1 (Nov-Feb).	Clean-up priority to be given to turtle nesting beaches. S1 priority to be given during turtle nesting season (Nov-Feb).	1, 2, 3, 4	1, 3, 6, 7, 8	9, 14	5, 10, 13
Jetties, Piers	S3	Short-term disruption to amenity. To be cleaned as a priority.	2, 3	1, 3 , 6, 7, 8	9, 12	5
Exposed Rock, Shores & Cliffs	S4	Wave reflection may keep oil offshore. Landed oil will weather quickly. Animals will recolonise quickly. Oil may accumulate in cracks and tide pools.		7	9, 12, 13	10, 11
Open water	S4	Monitor direction and spread of spill		7 5 if oil may return to shore		

Protection and Clean-Up Option

1. Containment and recovery using booms
2. Divert to less sensitive area or shore
3. Sorbant materials
4. Earth/sand barriers
5. Chemical dispersant
6. Skimmers, vacuums
7. Natural cleansing (leave alone)
8. Manual clean-up of oil
9. Low pressure seawater flushing
10. High pressure seawater flushing
11. Hot water steam cleaning
12. Low pressure warm seawater wash
13. Mechanical cleaning of oil or substrate removal
14. Bioremediation

Sensitivity Code

S1
Extreme Sensitivity
High protection and clean-up priority.

S2
High Sensitivity
Protection and clean-up priority as resource use and circumstances dictate.

S3
Moderate Sensitivity
Protection and clean-up priority as resource use and circumstances dictate.

S4
Low Sensitivity
Low protection and clean-up

Beaches would have a high priority for protection from a spill in order to prevent oil being absorbed and slowly released over time, which could delay recovery.

Shallow subtidal habitats fringing the Muiron Islands and Sunday Island include areas of macroalgae growing over limestone pavement, areas of unvegetated sand, and limestone reefs supporting hard corals. These subtidal habitats may receive some protection due to the overlying water.

Macroalgae can survive dissolved hydrocarbons but are susceptible to direct contact with oil and oil droplets, which cause necrosis of the plant tissue (Thorhaug & Marcus 1987). Rapid recolonisation of affected macroalgal beds has been observed following oil spills (AGC Woodward Clyde 1992), and weathered hydrocarbons may provide additional nutrients for algal growth (GESAMP 1993). In addition, the natural life-cycle of the most common macroalgal species in the region (*Sargassum* spp.) involves the annual loss and regrowth of the vegetative portion, allowing for recovery within a yearly cycle. However, as mentioned earlier, any oil reaching these habitats would be highly weathered.

The fauna associated with macroalgae (macrobenthos) are sensitive to oil and respond in a similar way to sediment infauna. High initial mortality and lowered community diversity, followed by a period of fluctuating community composition, have been reported following severe oil pollution (Suchanek 1993). The period of disturbance will vary but can be relatively short due to the short life cycle and high rate of recruitment of this fauna. For example, five weeks after the *World Prodigy* spill (30,000 tonnes or 45,000,000 L), only relatively subtle differences in community composition could be detected. Most species were at similar abundances at both affected and control sites, although recently recruited juveniles dominated affected sites (Widbom & Oviatt 1994).

Small fauna (meiofauna) inhabiting subtidal sediments appear sensitive to dissolved hydrocarbons but populations are capable of rapid recovery following oil spills. For example, abundances of some species had decreased at affected sites 12 days after the *Agip Abruzzo* oil spill (878 tonnes or 1,318,050 L), but assemblages were indistinguishable from controls within a few weeks (Danovaro *et al.* 1995).

Corals are sensitive to hydrocarbons, although the effects will vary depending on factors such as the concentration and period of exposure, and the species involved. One of the most critical factors controlling the effect of oil spills on corals is the position of the corals relative to the water surface. Even relatively short periods of direct immersion (e.g. 30 minutes) in oil can cause tissue necrosis and mortality of the affected colonies (Reimer 1975). Accordingly, corals exposed at or above the water surface will be most at risk. In contrast, several studies have indicated that subtidal corals may be protected from floating oil by the water column. For example, in a number of separate experiments, corals of several species were not detectably harmed in field experiments where oils were contained over the colonies for prolonged periods (e.g. 1 to 6 days, and longer than would occur in a spill; Knap 1987, LeGore *et al.* 1989, Ballou *et al.* 1989). Short periods of exposure to concentrations of dissolved oils and oil/dispersant mixtures (such as might occur when a slick passes over a reef) had no detectable effects in another experiment (Dodge *et al.* 1984).

5.6 Comparison with Risk Acceptance Criteria

Tables 16 to 23 present the following information:

- a list of the key resources of the area taking into account the seasonality of these resources;
- the probability of oil contacting these resources;
- the recovery time of these resources in the event of a spill based on the literature; and
- the acceptance criteria matrices overlayed with the key resources reference numbers.

In both the winter and summer period, the majorities of the key resources fell within the acceptable risk or risk reduction measure categories of the matrix. Recovery times, and therefore risk categories, were not put onto dugongs, humpback whales, and whale sharks as there is limited, if any, reference in the literature to the impact and recovery time of these animals from oil spills. Recovery times for these animals would be dependent on such factors as reproductive potential, the number of animals affected, the volume of oil contacting the animals and the weathered state of the oil. In addition, the following must be taken into account with respect to the Chelonia drilling program:

- Dugongs are found mainly in sheltered areas along the coastlines of the mainland and islands. If oil reaches these areas. It would be highly weathered and most likely in the form of wax balls (see Section 5.4.2).
- Whale sharks are present in the region during March and May. It is proposed not to drill in the peal period.
- Humpback whales migrate through the region between June and October. Drilling will not be carried out during this time.
- Turtles are present in the region at all times and drilling will be carried out during the nesting and hatchling period. Again, should a spill occur and actually reach the coastline, it would be highly weathered and in the form of tar balls.

The incident of which could have the greatest potential impact on the natural and social resources, and the conservation value of the region would be a blowout due to the volume of oil that could reach the shallow water and coastal resources. However, with the present technology and safety precautions, the risk of a blowout occurring is extremely low.

For smaller spills, the probability of large enough volumes of oil reaching the shallow water and coastal resources is low due to the distance of the Chelonia-1 and -2 well location from these areas. In passing over open water, the oil would evaporate and weather substantially reducing the volume and toxicity of the oil which may make contact. In the low chance that oil would reach any shorelines, it would probably be in the form of tar balls.

The risk of oil reaching the Ningaloo Reef is extremely low although in winter there is a small chance of oil reaching the northern portion of North West Cape that consists mainly of rocky shores and subtidal algae beds. The risk of oil reaching this portion of the Cape is negligible in the summer given the strength of the current and the direction of the prevailing winds. However there is a slightly greater chance of oil reaching the Muiron Islands in the summer than the winter.

Based on the overall risk analysis, the environmental risk of the Chelonia-1 and -2 drilling program to the key resources of the region is considered to be acceptable as long as the risk reduction measures discussed in Section 5.7 are utilised.

Table16: Key resources at risk from a spill: 2,500 L diesel spill
Winter conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	**1**
	Sandy beaches			x	x	x	x	2-5 yrs	**2**
	Fringing coral reefs		x		x	x	x	10-20 yrs	**3**
	Rocky shores/platforms	X	x					1-2 yrs	**4**
	Seabird nesting +							5-10 yrs	**5**
	Dugongs	X				x			
	Humpback whales	X							
	Other cetaceans	X	x	x	x	x	x		
	Whale sharks	X	x		x	x			
Ecological sensitivity		very high	high	high	very high	very high	low		
Probability of contact*		4.2×10^{-6}	3.5×10^{-6}	7.7×10^{-6}	4.2×10^{-6}	7.0×10^{-7}	2.8×10^{-6}		

* refer to Tables 12 and 13
\+ usually not present/active in winter (see Table 5)
° see Appendix 6 for recovery times references

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	**4**	**2**		**3**	Other locations
$>10^{-6}$	**4**	**2**		**3**	N. Muiron Island
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction measures required

Unacceptable

Table 17: Key resources at risk from a spill: 8,000 L light crude spill
Winter conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		X		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	X					1-2 yrs	4
	Seabird nesting +							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales	x							
	Other cetaceans	x	X	x	x	x	x		
	Whale sharks	x	X		x	x			
Ecological sensitivity		very high	High	high	very high	very high	low		
Probability of contact*		5.6×10^{-8}	4.9×10^{-8}	6.3×10^{-8}	4.9×10^{-8}	2.8×10^{-8}	7.0×10^{-8}		

*refer to Tables 12 and 13
+ usually not present/active in winter (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$					
$>10^{-6}$	4	2		3	All locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 18: Key resources at risk from a spill: 80,000 L diesel spill
Winter conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting +							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales	x							
	Other cetaceans	x	x	x	x	x	x		
	Whale sharks	x	x		x	x			
Ecological sensitivity		very high	high	high	very high	very high	low		
Probability of contact*		4.2×10^{-6}	3.5×10^{-6}	7.7×10^{-6}	4.2×10^{-6}	7.0×10^{-7}	2.8×10^{-6}		

*refer to Tables 12 and 13
+ usually not present/active in winter (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	4	2		3	Other locations
$>10^{-6}$	4	2		3	N. Muiron Island
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 19: Key resources at risk from a spill: 600,000 L light crude spill
Winter conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting +							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales	x							
	Other cetaceans	x	x	x	x	x	x		
	Whale sharks	x	x		x	x			
Ecological sensitivity		very high	high	high	very high	very high	low		
Probability of contact*		4.0×10^{-6}	5.0×10^{-6}	5.5×10^{-6}	3.0×10^{-5}	3.5×10^{-5}	5.5×10^{-6}		

*refer to Tables 12 and 13
+ usually not present/active in winter (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	4	2		3	Muiron Islands
$>10^{-6}$	4	2		3	Other locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 20: Key resources at risk from a spill: 2,500 L diesel spill, Summer conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales +	x							
	Other cetaceans	x	x	x	x	x	x		
	Whale sharks +	x	x		x	x			
Ecological sensitivity		very high	high	High	very high	very high	low		
Probability of contact*		9.0×10^{-6}	9.0×10^{-6}	9.0×10^{-6}	3.6×10^{-5}	9.0×10^{-6}	8.1×10^{-5}		

*refer to Tables 12 and 13
+ usually not present/active in summer (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	4	2	1,5	3	South Muiron, Sunday Is.
$>10^{-6}$	4	2	1,5	3	Other locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 21: Key resources at risk from a spill: 8,000 L light crude spill
Summer conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales +	x							
	Other cetaceans	x	x	x	x	x	x		
	Whale sharks +	x	x		x	x			
Ecological sensitivity		very high	high	High	very high	very high	low		
Probability of contact*		7.0×10^{-9}	7.0×10^{-9}	7.0×10^{-9}	4.2×10^{-8}	1.4×10^{-8}	7.7×10^{-8}		

*refer to Tables 12 and 13
+ usually not present/active in summer (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$					
$>10^{-6}$	4	2	1,5	3	All locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 22: Key resources at risk from a spill: 80,000 L diesel spill
Summer conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			X	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting +							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales	x							
	Other cetaceans	x	x	X	x	x	x		
	Whale sharks	x	x		x	x			
Ecological sensitivity		very high	high	High	very high	very high	low		
Probability of contact*		7.0×10^{-7}	7.0×10^{-7}	7.0×10^{-7}	5.6×10^{-6}	2.1×10^{-6}	8.4×10^{-6}		

*refer to Tables 12 and 13
+ usually not present/active in summer (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	4	2	1,5	3	Muiron Island
$>10^{-6}$	4	2	1,5	3	Other locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

Table 23: Key resources at risk from a spill: 600,000 L light crude spill
Summer conditions

		West of Pt. Murat	Pt. Murat to Exmouth	South of Exmouth	South Muiron Is.	North Muiron Is.	Sunday Is.	Recovery time°	Ref No.
Land status	Reserve status	Ningaloo Marine Park			C class	C class			
	Other	Conservation Recreation			Camping Diving	Camping Diving			
Natural assets	Turtle nesting +				green loggerhead	green loggerhead		5-10 yrs	1
	Sandy beaches			x	x	x	x	2-5 yrs	2
	Fringing coral reefs		x		x	x	x	10-20 yrs	3
	Rocky shores/platforms	x	x					1-2 yrs	4
	Seabird nesting +							5-10 yrs	5
	Dugongs	x				x			
	Humpback whales	x							
	Other cetaceans	x	x	x	x	x	x		
	Whale sharks	x	x		x	x			
Ecological sensitivity		very high	high	High	very high	very high	low		
Probability of contact*		5.0×10^{-7}	5.0×10^{-7}	5.0×10^{-7}	6.5×10^{-6}	3.0×10^{-6}	8.0×10^{-6}		

*refer to Tables 12 and 13
+ usually not present/active in summer (see Table 5)
° see Appendix 6 for recovery times

$<10^{-3}$					
$10^{-3} - 10^{-4}$					
$10^{-5} - 10^{-4}$					
$10^{-5} - 10^{-6}$	4	2	1,5	3	Muiron Islands
$>10^{-6}$	4	2	1,5	3	Other locations
	<2	2.5	5-10	10-20	
Probability	Recovery time (years)				Location

Acceptable risk

Risk reduction

Unacceptable

5.7 Risk Reduction Measures

Risk reducing measures comprise measures that reduce the chances of an incident occurring in the first instance as well as consequence reducing measures which include contingency plans. Risk reducing measures may be:

- technical: type of equipment
location of equipment
design
- operational: procedure relating to operations
maintenance
supervision
communication
timing of operations
- organisational: distribution of responsibility
training
manning

Tables 24 to 29 present the various actions for the most likely incidents that could result in the spillage of fluid (drilling fluid or hydrocarbons) into the marine environment and which will be incorporated into the Chelonia drilling program.

Some of the specific risk reduction measures that will be applied to the Chelonia-1 and -2 drilling program include:

- drilling to be carried out during the summer period when prevailing winds would move an accidental oil spill out towards open water:
- a dedicated oil spill contingency vessel would be on stand by at all times; and
- a procedure for handling Petrofree will be developed.

A short discussion of three activities which could lead to oil spills of >2,500 L and their management is given below.

Refuelling accidents

Spills of diesel fuel during refuelling caused by hose breaks, coupling failures or tank overfilling generally involve volumes less than 2,500 L with quantities minimised by properly designed equipment with prompt shutdown of pumps by automatic safety valves.

A refuelling procedure has been developed (Appendix 7) in order to minimise the risk of spillage. The following measures are included in the procedure:

- if possible, the rig will be fully fuelled before being brought on site in order to minimise the number of refuelling operations required at the drill site;
- the transfer hoses will be fitted with 'dry' couplings and be wire reinforced;
- a vacuum breaking system will be in place to drain the fuel left in the hose after completing the transfer, back to the supply vessel tanks;
- drip trays will be provided beneath the refuelling hose connections on the supply vessel and the rig;
- fuel transfer will be carried out in daylight hours;
- refuelling will occur only at times when sea conditions are sufficiently calm for there to be minimal risk to the transfer lines;

- crew of both the rig and the workboat will stay in continuous contact during the whole of the operation via handheld radios and will actively monitor the operation for its entire duration;
- suitable absorbent material will be held on the supply vessel and the rig to mop up any small spills; and
- the hose will be equipped with flotation devices to ensure the hose does not sink and is visible at all times during refuelling.

Production testing

If hydrocarbons are found, production testing may be carried out to ascertain flow characteristics and to assess the size of the reservoir. Testing involves allowing small quantities of oil to flow to the rig and directed to burners.

Testing may take up to five to six days. High efficiency burners, which atomise the hydrocarbons and mix them with compressed air, are used to ignite and thoroughly burn the mixture. Care is taken to avoid fallout of free oil, which can occur if combustion is incomplete or if the burners become plugged by well debris (i.e. sediment). Oil flow will cease if fallout occurs. Measures taken to minimise the risk of fallout include:

- use of specialised 'green' burners which optimise the burning process. These are an improved design on those used at the Leatherback-1 well;
- continuous monitoring of the test equipment;
- incorporating sensors to monitor fluid pressure, temperature and flow rate; and
- combining sufficient quantities of compressed air and water with the oil to allow an optimal burn.

Well control

The only time there can be loss of well control resulting in hydrocarbon flow to the surface is when the reservoir zone has been encountered. Access into the reservoir will last about 3-6 days, depending on the well.

Extensive training, procedures and equipment are always in place to maintain well control and prevent loss of well control. Considerable attention is placed on well control issues as a blowout would not only impact the environment, but could also result in loss of life. All key personnel involved in the drilling operation have undertaken well control training, and must undergo retraining every two years.

After the initial surface hole is drilled, pressure resistant casings are installed to form a sealed recirculation system filled with drilling fluids. The weight of this mud is used to keep reservoir fluids downhole. During drilling, "pressure kicks" can occur. A kick is defined as a well control problem where there is a flow of formation fluids into the well bore. If the pressure within the formation being drilled is greater than the hydrostatic pressure of the drilling fluid acting on the well bore, an influx of formation fluids (oil, gas, water) into the well bore can occur. The severity of the kick will depend on the porosity of the formation to allow fluid to flow through it, and the difference between the formation pressure and drilling fluid pressure. Maintaining the correct density of the drilling fluid down the well bore prevents kicks. This is achieved by adjusting the concentration of various components of the drilling fluid so that the fluid hydrostatic pressure is greater than the formation pressure. Blowout preventers (BOPs) provide a secondary line of defence by shutting in the well until the reservoir pressure can be overcome by higher density fluids. The drilling rig will be fitted with four blowout preventers arranged in line to provide additional lines of defence.

Formation pressures and drilling fluid densities are constantly monitored by drilling engineers, backed up by alarm systems. There is a number of warning signs that indicate that a kick is taking place. These include an increase in flow rate, an increase in the drilling bit penetration rate (indicating a change in the type of rock being drilled) and an increase in surface volume of drilling fluid. If one or more warning signs of a kick are observed, steps are taken to check for flow from the well and the well is immediately shut-in. Modifying the density of the drilling fluid rectifies the problem.

The release of hydrocarbons to the marine environment can only occur if a surface blowout occurs. In Australian offshore waters, there have been six well blowouts since offshore drilling operations commenced in the 1960s. Because of technological and procedural improvements, there have been no blowouts since 1984 (four blowouts occurred in the 1960s, one in 1971 and one in 1984). These were primarily gas blowouts and in only one case was a negligible amount of oil spilt (Volkman *et al.* 1994). Blowouts are extremely rare and most result in the release of gas rather than oil. A well will only blow out in the unlikely event that all warning signs are ignored <u>and</u> if the casing, wellhead or the BOPs failed. The drilling fluid system, casing design and BOPs will be designed to control all expected formation pressures and meet government and company standards.

A well is designed and operated to specifications approved by government and in accordance with government regulations including:

- testing of the BOP stack prior to commencement of operations;
- pressure testing of all casing strings (except for the surface or structural casing);
- pressure integrity testing of the formation;
- continuous monitoring for abnormal pressure parameters during drilling below the 30" casing; and
- ensuring the drilling crew is fully trained in emergency well control procedures by implementing regular emergency practice drills during the drilling program.

The well characteristics and formation pressures of the area are known from extensive experience with Northwest Shelf geology and formation structures, including several programs in the northern section of the Exmouth Gulf.

The risk of loss of well control at the Chelonia-1 and -2 wells is unlikely given

- the experience and understanding of the stratigraphy and likely downhole pressures of the region;
- the subsequent casing and cementing design;
- the use of BOPs;
- the use of fail safe control valves; and
- the well design being conservative enough to allow for any unexpected pressure in the formation.

Table 24: Risk identification and reduction measures.

Hazard: Leakage from engines or machines						
	Potential maximum size	Type of discharge				
	20-50 L	Lube oil or diesel	Chance of incident occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Probability of occurrence			Extremely low as spill would be contained within bunded area on rig.	Unlikely		
Estimated volume of weathered oil contacting resources* (litres)				None		
Habitat types in spill trajectory					Open water	
Potential impacts of an oil spill					Negligible impact	
Estimated recovery time						Immediate
Other sources of impact					cyclones natural predation fishing natural turbidity	
Actions to minimise and manage the hazard and reduce the probability of occurrence			• drip trays and sumps placed under all engines and machinery. • no open drains leading into the marine environment. • daily inspections. • sumps cleaned out on regular basis. • oily water treated in oily-water separator on rig.	• chances of oil reaching reef or shore minimal due to small quantities and rapid evaporation rate of diesel.		

* the quantity of oil reaching the reefs and shorelines based on using the worst case of 100 randomly selected trajectories.

Table 25

Hazard:	**Leakage or spillage from diesel transfer hose**					
	Potential maximum size	Type of discharge				
	2,500 L (16 bbls)	Diesel	Chance of incident occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Probability of occurrence			9.0×10^{-4}	3.6×10^{-5} to 9.0×10^{-5}		
Estimated volume of weathered oil contacting resources *				33 - 1,464 litres		
Habitat types in spill trajectory					algae subtidal corals intertidal corals sand/coral rubble limestone cliffs sandy beaches	
Potential impacts of an oil spill					Low potential for long term chronic oiling. Low potential for oil retention. Rapid recovery.	
Estimated recovery time						Rapid. Immediate start to recovery.
Other sources of impact					cyclones predation fishing high rainfall	
Actions to minimise and manage the hazard and reduce the probability of occurrence			• **detailed refuelling procedures developed**. • refuelling procedure incorporated into drilling program which must be approved by DME. • refuelling only to occur at the discretion of the skipper of the vessel and master of the rig. • weather forecasts sent directly to the rig by the met bureau twice a day. Can be increased to hourly basis in emergencies - i.e. cyclones, oil spills. • hose and couplings checked for integrity prior to refuelling.	• oil spill contingency plan (OSCP) approved by DME. • OSCP with strategies for deflection and containment. • 24 hour link with met bureau. • oil spill model for predictions. • oil spill model validated with field data. • oil spill equipment, including ocean rated boom, on standby at rig at all times. • evaporation and spreading behaviour of diesel incorporated into oil spill model.	• clean-up procedures for different habitat types detailed in OSCP. • endpoints to be monitored in case of spill are defined in the OSCP. • pollution and clean-up insurance.	• use of relevant technology to assist natural recovery (e.g. bioremediation) • detailed monitoring of relevant endpoints. • wildlife rescue and rehabilitation in conjunction with CALM.

Table 26

Hazard:	**Oil Fallout from production testing**					
	Potential maximum size	Type of discharge				
	8,000 L (50 bbls)	light crude oil	Chance of incident occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Probability of occurrence			7.0×10^{-7}	1.4×10^{-8} to 7.7×10^{-8}		
Estimated volume of weathered oil contacting resources *				336 - 1,788 litres		
Habitat types in spill trajectory					algae subtidal corals intertidal corals sand/coral rubble limestone cliffs sandy beaches	
Potential impacts of an oil spill					Low potential for long term chronic oiling. Low potential for oil retention. Rapid recovery.	
Estimated recovery time						Rapid. Immediate start to recovery.
Other sources of impact					cyclones fishing predation high rainfall	
Actions to minimise and manage the hazard and reduce the probability of occurrence			• continual, 24 hr observation • immediate shutdown if fallout occurs • efficient green burners to be used • technical experts on rig at all times • guidelines incorporated into drilling program which must be approved by DME	• oil spill contingency plan (OSCP) approved by DME. • OSCP with strategies for deflection and containment. • 24 hour link with met bureau. • oil spill model for predictions. • oil spill model validated with field data. • oil spill equipment, including ocean rated boom, on standby at rig at all times. • AMOSC trained oil spill equipment operators	• clean-up procedures for different habitat types detailed in OSCP. • inventory of resources on GIS and interfaced with OSCP • endpoints to be monitored in case of spill are defined in the OSCP. • priority areas for deflection or clean-up defined in OSCP • pollution and clean-up insurance.	• use of relevant technology to assist natural recovery (e.g. bioremediation) • detailed monitoring of relevant endpoints. • wildlife rescue and rehabilitation in conjunction with CALM.

Table 27

Hazard:	**Rupture of support vessel fuel tank.**					
	Potential maximum size	Type of discharge				
	80,000 L (500 bbls)	Diesel	Chance of spill occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Probability of occurrence			7.0×10^{-5}	2.1×10^{-6} to 7.0×10^{-7}		
Estimated volume of weathered oil contacting resources *				1,032 - 19,457 L (6.5 - 122 bbls)		
Habitat types in spill trajectory					algae, rocky shores subtidal corals, sandy beaches intertidal corals, sand/coral rubble	
Potential impact					Potential for emulsified tar balls to reach shorelines. Some free oil may penetrate sand. Natural cleansing. Minimal impact to subtidal resources due to rapid evaporation.	
Recovery potential						1-5 years.
Other sources of impact					cyclones, cyclonic rains predation, oxygen depletion fishing	
Actions to minimise and manage the hazard, and reduce the probability of occurrence			• hull of drilling rig is double skinned. • fuel tanks also protected by ballast tanks. • radio contact between rig and supply vessel at all times. • support vessel stands away crane arm distance from rig during offloading and onloading. • work near drilling unit only in suitable seastate - to the discretion of the skipper of the vessel and master of the rig. • weather forecasts sent directly to the rig by the met bureau twice a day. Can be increased to hourly basis in emergencies.	• oil spill contingency plan (OSCP) approved by the DME. • OSCP has strategies for deflection and containment of spill. • oil spill equipment, including an ocean rated boom, on standby at rig at all times. • oil spill model for spill predictions. • 24 hour link with met bureau.	• clean-up procedures for different habitat types detailed in OSCP. • endpoints to be monitored in the case of a spill defined in OSCP. • insurance for clean-up. • baseline monitoring carried out since 1995 and ongoing on yearly basis.	• suitable clean-up methods for assist recovery (e.g. bioremediation). • detailed monitoring of relevant endpoints. • set up wildlife rehabilitation centre in conjunction with CALM.

Table 28

Hazard: Blow out						
	Potential maximum size	Type of discharge				
	600,000 L (3,774 bbls)	light crude	Chance of spill occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Probability of occurrence			5.0×10^{-5}	3.0×10^{-5} to 6.5×10^{-6}		
Estimated volume of weathered oil contacting resources *				3,900 - 54,054 L (24 - 340 bbls)		
Habitat types in spill trajectory					algae rubble flats intertidal coral subtidal coral rocky shores sandy beaches	
Potential impact					Potential for emulsified tar balls to reach shorelines. Some free oil may penetrate sand. Natural cleansing. Minimal impact to subtidal resources due to rapid evaporation.	
Estimated recovery time						1 year - decades Dependent on resource.
Other sources of impact					cyclones predation fishing cyclonic rains oxygen depletion	
Actions to minimise and manage the hazard, and reduce the probability of occurrence			• International, National and State applications to be complied with. • all management procedures specified in Vessel Safety Case which must be approved by DME. • only trained, certified personnel used on rig floor. • four blow-out preventors (BOPs) used. • routine pressure testing of BOPs and casing to legislative standards. • utilize drilling fluid weight designed to known reservoir pressure.	• Oil spill contingency Plan (OSCP) approved by DME. • OSCP details strategies for deflection and containment • link with state, national and international oil spill plans and resources. • oil spill equipment, including and ocean-rated boom, on standby at rig at all times. • oil spill model for predictions. • 24 hour link with met bureau.	• clean-up procedures for different habitat types detailed in OSCP. • endpoints to be monitored in the case of a spill defined in OSCP. • continued research into toxicity testing protocols. • insurance for clean-up. • monitoring carried out since 1991.	• suitable clean-up methods for assist recovery (e.g. bioremediation). • detailed monitoring of relevant endpoints. • set up wildlife rehabilitation centre in conjunction with CALM.

Table 29

Hazard: Spillage of Petrofree drilling fluid						
	Potential size	Type of discharge				
	5,000 - 90,000 L	Petrofree	Chance of spill occurring	Chance of oil reaching resources	Potential consequences	Recovery potential
Estimated volume of fluid contacting resources (litres)					Little separation of the ester component from inert particles. Ester would float, particles would sink and be distributed onto seabed.	
Habitat types in spill trajectory					open water subtidal reefs sandy seabed	
Estimated recovery time					Some increase in water turbidity. Some sediment fallout into benthic biota.	
Other sources of impact					natural turbidity from cyclones	6-12 months
Actions to minimise and manage the hazard, and reduce the probability of occurrence			• all sources of leakage identified (transfer hose, fluid tanks, shale. shakers, solids control pit, main mud pit). • **procedures for transfer developed and incorporated into drilling program which is approved by DME.** • continuous fluid volume monitoring using computer systems which can detect change of less than 800 L fluid change. • visual monitoring and continual maintenance of system. • mud tanks area bunded. • master valve of mud pits padlocked at all times. • rig floor sealed, not open to marine environment.	• run trajectory model to ascertain dispersion of fluid plume. • visual monitoring and mapping of plume via helicopter.	• establish monitoring program to ascertain if any impact occurred due to turbidity plume.	• allow natural recovery if sedimentation did occur.

6. ENVIRONMENTAL MANAGEMENT

6.1 Environmental Objective and Policy

The stated objective of the environmental management plan to be implemented for the proposed Chelonia drilling program is:

> "to achieve and demonstrate sound environmental practice by managing all activities of the drilling program which may have an impact on the natural environment, or where an impact is unavoidable, minimise, ameliorate and manage the damage."

In accordance with this objective, the following components have been developed for the management of the drilling program:

- Leadership commitment and environmental policy
Addresses the top down commitment and responsibilities, and that the policy is in place to ensure the protection of the environment.

- Risk evaluation
Identifies the potential environmental risks and hazards for the program.

- Regulations and commitments
Identifies relevant legislation, conditions and commitments applicable to the environmental aspects of the program.

- Operational procedures
Generates risk reduction measures including asset integrity inspections, work instructions, procedures and emergency response plans.

- Communications
Ensures the knowledge, acknowledgment and advice of the environmental conditions and surrounding resources to the workforce and the community.

- Audits and review
Addresses the assessment of performance and compliance.

At a broad scale, the program will be managed to comply with the Apache Limited Environmental Policy which is given in Appendix 9.

6.2 Key Roles and Responsibilities - Environment

The key roles for ensuring the protection of the environment and their associated responsibilities are listed below.

Managing Director

- Ensure availability of budget and personnel resources.
- Take responsibility for compliance with the environmental policy.
- Implement an emergency response strategy in the case of an incident.
- Maintain communication with company personnel, government agencies and the media.

Environmental Manager

- Provide Environmental Management Plan to the Drilling Manager.
- Liaise with the Senior Drilling Engineer to ensure compliance to procedures, commitments and conditions.
- Conduct environmental audit of the drilling rig to ensure compliance.
- Carry out environmental education and inductions.
- Participate in the oil spill response strategy.

Drilling Manager

- Ensures overall compliance with the Environmental Management Plan with advice and guidance from the Senior Drilling Engineer and Environmental Manager.
- Reports environmental incidents to the Environmental Manager.
- Assists the Managing Director in the development of a response strategy in the event of an incident.

Drilling Supervisor

- Monitors the relevant environmental legislative requirements, commitments, conditions and procedures.
- Maintains clear communication between the company and drilling contractor.
- Reports environmental incidents and ensures follow-up actions.
- Carries out follow-up actions from environmental audits.

Offshore Installation Manager (OIM) / Captains of support vessels

- Communicates hazards and risks to workforce and importance of following good work practices.
- Ensures procedures are carried out correctly.
- Reports environmental incidents to Drilling Supervisor.

Drilling rig personnel and contractors / Crew of support vessels

- Apply this management plan in letter and in spirit.
- Follow good housekeeping procedures and work practices.
- Encourage improvement wherever possible.
- Report any incidents to the OIM.

6.3 Emergency Response

It is recognised that an accidental spillage of oil may occur during the drilling program. Emergency response manuals have been prepared. The two relevant documents are:

- Oil Spill Contingency Plan. Permits EP452, TP/9 and WA-247. Apache Document HE-00-EF-003.

- Emergency Response Management Manual. Apache Document HE-00-ZF-025.

These documents will be located at the relevant locations on the drilling rig and be accessible to all personnel.

An ocean rated boom (Sea Curtin) has been purchased by Apache and this boom will be on the Oil Spill Support Vessel which will be on stand-by at the drilling location at all times.

An oil spill exercise that will include the deployment of the boom, weather permitting, will be carried out at the beginning of the drilling program.

6.4 Education Program

Personnel involved in drilling operations will be given an environmental and safety induction by qualified members of staff. The induction course will be given to the contractors during the routine pre-spud meetings, and to the workforce on the drilling rig and supply vessels at the commencement of the drilling program. The topics covered will include:

- regulatory and procedural requirements;
- environmental policy principles;
- environmental resources at risk;
- environmental procedures to be used.

6.5 Community Consultation

Open consultation and communication with the relevant stakeholders will be carried out to exchange information, identify and address concerns, and meet regulatory requirements. Relevant stakeholders include prawn fishermen, the towns people of Exmouth, tourism companies, conservation groups and government agencies (see Appendix 2).

6.6 Environmental Audit

An environmental audit will be undertaken to verify that applicable policies, practices, commitments and conditions have been met during the drilling of Chelonia-1 and -2. Monitoring of environmental management performance will involve the inspection of equipment and operations by an independent auditor and/or the Apache Environmental Manager. The Drilling Supervisor will be responsible for ensuring any recommendations are carried through.

6.7 Environmental Commitments

Apache, on behalf of the Joint Venture Participants, will undertake the commitments given in Table 30 for the Chelonia drilling program in addition to the Proponent Management Commitments and Ministerial Conditions which will be set for this project.

Table 30: Chelonia-1 and Chelonia-2 Drilling Program

Environmental Management Commitments

Commitment (what)	**Objective (Why)**	**Action (How/where)**	**Timing (When)**	**Whose advice (To whom)**	**Measurement criteria**
1. An Environmental Management Plan (EMP) using ISO 14000 principles shall be prepared for the drilling program.	To ensure compliance with commitments and Ministerial conditions which will be set using the principles of ISO 14000.	The EMP shall be made available to all personnel on the drilling rig. A list of guidelines and procedures as given in the CER will be (1) placed on appropriate locations on the drill rig, (2) incorporated into the drilling contract.	Prior to the commencement of the drilling program.	Apache (DME DEP)	Letter from DME approving the EMP.
2. Apache and each of the Participants will hold extensive insurance for liability, control of well and clean-up.	To ensure ample financial resources for clean-up and remedial action in the case of an oil spill.	Certification of currency of insurance in accordance with directions from the Minister for Minerals and Energy.	Prior to the commencement of the drilling program.	Joint Venture Partners (DME)	Certificate of Insurance from underwriters.
3. Drilling will be carried out in the summer period.	To minimise the risk of an oil spill impacting sensitive resources.	Drilling will be carried out between 1 November and 1 March (summer period).	During the drilling of the well.	Apache (DEP DME)	Letter of confirmation at the end of the drilling program.

Commitment (what)	Objective (Why)	Action (How/where)	Timing (When)	Whose advice (To whom)	Measurement criteria
4. An Oil Spill Contingency Plan (OSCP) will be prepared.	To develop strategies for the containment, deflection and clean-up of oil spills.	Upgrade the existing EP342 OSCP to include the Chelonia drilling program.	Prior to locating equipment at the drilling location.	DME DEP DoT (Apache)	Letter from the DME approving the OSCP.
5. An ocean rated oil spill boom shall be on standby at the location at all times.	For rapid deployment response in the case of an oil spill.	The boom shall be stored on the dedicated oil spill vessel which will be on location at all times.	Prior to the commencement of the drilling program.	DME AMOSC (Apache)	Letter of confirmation to DME from Apache stating that vessel was on site a tall times.
6. An oil spill response exercise shall be carried out.	To ensure an efficient response in the case of an oil spill.	A desk-top and field exercise will be carried out to the point of deployment of equipment.	Within three days of spudding the well.	Apache (DME)	Letter of confirmation to the DME from Apache outlining the scope of the exercise and the results.
7. The risk of diesel spillage during refuelling shall be minimised.	To protect the marine environment.	A refuelling procedure will be prepared and implemented including a dry coupling system and carrying out refuelling when any spillage would be carried away from sensitive resources.	Before the commencement of the drilling program.	DME DEP (Apache)	Approval of the procedure by the DME. Letter from Apache to DME with performance report.

Commitment (what)	**Objective (Why)**	**Action (How/where)**	**Timing (When)**	**Whose advice (To whom)**	**Measurement criteria**
8. The risk of crude oil fallout during production testing shall be minimised.	To protect the marine environment.	Immediate shutdown if fallout occurs.	During production testing activities.	DME (Apache)	Approval of the procedure by the DME. Letter from Apache to DME with performance report.
9. All endeavours will be made to dispose drill cuttings and excess drilling fluid down the annulus.	Protection of the marine environment.	The procedure for disposing drill cuttings will be incorporated into the drilling program for the Chelonia well.	Prior to locating equipment at the drilling location.	Apache (DME DEP)	Letter from DME for approval of drilling manual.
10. A debris survey shall be conducted.	To confirm that no debris has been left on the seafloor.	A remotely operated vehicle will be used. Report and video submitted to Apache.	At the completion of the drilling program prior to the rig moving off site.	Apache (DEP DME)	Letter of confirmation that all debris has been removed from Apache to DME.
11. There shall be no access to islands and support vessel anchorage away from coral reefs shall be provided.	Protection of the Muiron Islands and reef habitats.	Confirmation of anchoring positions in log of support vessel. Flight plans will be made for helicopters.	During the entire drilling program.	DEP DME CALM (Apache)	Sighting of vessel and helicopter log books by DME.

Commitment (what)	Objective (Why)	Action (How/where)	Timing (When)	Whose advice (To whom)	Measurement criteria
12. A community consultation program will be carried out.	To inform the community of the drilling program and address their concerns.	A communication strategy will be developed.	Before the commencement of the drilling program.	Apache (DME DEP)	Letter to DME from Apache outlining the actions carried out and when.
13. All personnel on site will undergo an education and training program.	To give the personnel the means of identifying the risks and knowledge of the environmental implications of the drilling program.	Inductions to be given to all personnel. Posters and maps are to be provided to rig. Guidelines to be provided to the rig.	Prior to the spudding of the well.	Apache (DME)	No incidents.
14. An environmental audit of the drilling operations will be undertaken.	To ensure compliance to commitments, guidelines and procedures.	An environmental audit will be carried out using ISO 14000 as the standard.	Within two weeks after drilling has commenced.	Apache (DME DEP)	Results audit will be submitted to DME by Apache.

6.8 Guidelines and Procedures

In undertaking the Chelonia drilling program, Apache, on behalf of the Joint Venture participants in EP342 will ensure that the following guidelines and procedures are placed on the drilling rig and followed:

Oil spills

- Sufficient oil spill clean-up materials (e.g. absorbent pads, 'kitty litter') will be stored on the drilling rig and support vessels to clean up small oil spillages.
- An Oil Spill Response Vessel will be in attendance during the drilling program. This vessel will carry shore protection booms, sorbants, spray equipment and dispersants.
- In order to minimise the risk of spillage during refuelling, the refuelling procedure will be followed.
- Drainage from the rig where oil or cleaning chemicals are used or stored will be contained on the rig. Spills on the deck will be cleaned up immediately. Oil will be prevented from going down any drains by ensuring that the drains are closed to the marine environment.
- Drip trays will be used under all machinery drip tubes and fuel points.
- Oil spills greater than 80 L will be reported to Apache Perth immediately by the Drilling Supervisor. Apache will then forward the report to DME, the DEP and CALM. A record will be made of any spills less than 80 L and submitted to Apache at the end of the drilling program.

Waste disposal

- All endeavours will be made to dispose of drill cuttings and residual water-based drilling fluids down the annulus and into the lost circulation zone.
- Hazardous substances and wastes will be stored in a safe manner. Material Safety Data Sheets will be available for all hazardous substances. Oil and chemical drums will be stored in bunded areas and on top of pallets where possible.
- Waste generation will be minimised. All materials will be recycled wherever possible.
- Waste will be segregated and the appropriate disposal method for each type of waste generated will be used.
- Combustible waste materials will either be burnt at the rig, or returned to shore and disposed of at an approved waste disposal site.
- Sewage and waste from the galley will be macerated. Sewage will be treated through a treatment plant and diluted with seawater prior to discharge to the ocean.
- No disposal of debris, garbage or litter will occur to the sea. Particular care will be taken to ensure that synthetic materials such as plastic bags and cups are not disposed of from the drilling rig.
- Waste oil and grease from machinery will be returned to shore for recycling at an approved site for disposal. A log of these wastes will be kept.

- At the completion of the program, remotely operated vehicle surveys of the ocean floor will be conducted. This will confirm that no debris has been left on the ocean floor and will provide useful information on the seafloor area disturbed by drilling activities.

- Pipe dope with the lowest concentration of heavy metals and grease will be used whenever practical.

Conservation

- Workboats will stand off from island and reefs and not allow crew access to these areas. Captains will be instructed to avoid anchoring in areas where coral reefs occur. The vessels will be equipped with a chart showing the locations of the reefs.

- No helicopters will fly over any of the islands at any time. Helicopter flying will be restricted to daylight hours except if necessary in an emergency.

- A record will be kept of all cetacean sightings and these will be sent to CALM and Environment Australia.

7.0 REFERENCES

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8.0 GLOSSARY

API gravity:	the universally accepted scale for expressing the specific gravity of oil
abandon:	to close off a well after drilling or production. One or more cement plugs are placed in the borehole to prevent migration of fluids between the different formations
aromatic:	the term used to describe organic compounds which contain one or more unsaturated ring structures, eg. benzene (C_6H_6)
aerobic:	in the presence of oxygen
anaerobic:	in the absence of oxygen
annulus:	the space between the drill string and well bore
bbls:	barrels (1 barrel = 159L)
benthic:	relating to communities of marine organisms which live on and have a direct dependence on the ocean floor
biota:	the animal and plant life found within an environment
blow-out:	an uncontrolled kick. A blow-out can occur at the surface or underground between two separate permeable formations
Blow Out Preventer:	a hydraulically operated wellhead device designed to ensure that a blow-out cannot occur
BRT	Below rig floor
BSB	Blow seabed
BSL	Below sea level
CALM:	Department of Conservation and Land Management
casing:	the steel pipe that is cemented into a well to prevent the wall from caving in and to stop unwanted fluids from entering the hole from the surrounding rocks
CER:	Consultative Environmental Review
community:	any naturally occurring group of different organisms sharing a particular habitat
crustaceans:	animals, mostly aquatic, with a hard, close fitting shell which is shed periodically
cum	Cubic metres
demersal:	refers to fish that live on or adjacent to the sea-floor
DEP:	Department of Environmental Protection
directional well:	a well drilled in such a way that its controlled direction departs progressively from the vertical. Also known as a deviated well
DME:	Department of Minerals and Energy of Western Australia
DoT	Department of Transport

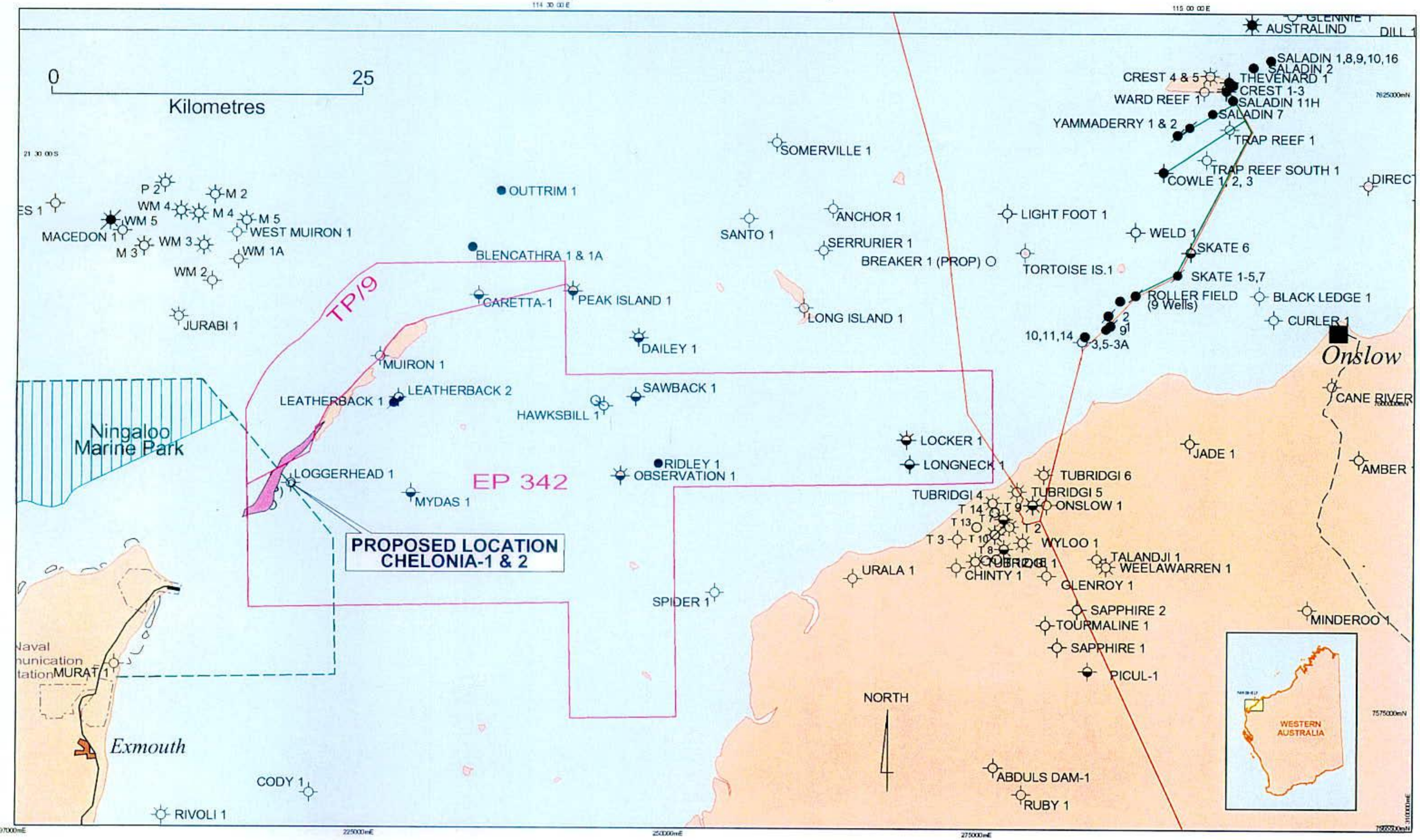
drill string:	lengths of steel tubing roughly 10m long screwed together to form a pipe connecting the drill bit to the drilling rig; the string is rotated to drill the hole and also serves as a conduit for drilling fluids
ecosystem:	a natural complex of plant and animal populations and the particular sets of physical conditions under which they exist
EPA:	Environmental Protection Authority
fluid density:	weight of a certain volume of drilling fluid and is related to the pressure gradient
geomorphology:	the study of the form and development of the earth, especially its surface and physical features, and the relationship between these features and the geological structures underneath
habitat:	a physical portion of the environment that is inhabited by an organism or population
hydrocarbons:	organic compounds consisting of the elements carbon and hydrogen only
ingest:	take in (food) to the stomach
intertidal:	the part of the littoral zone which lies between mean high and mean low tide
kcm:	thousand cubic metres
kick:	the influx of formation fluids into the well bore. Occurs if the pressure within the formation is greater than the pressure or force exerted by the drilling fluid
lost circulation	the loss of drilling fluid and cuttings into a porous formation
m^3	cubic metres - 1 m^3 = 1,000 L
MD	Measured depth
molluscs:	a group of soft bodied, unsegmented animals, ususally with a hard shell such as shellfish
NMP	Ningaloo Marine Park
OSCP:	Oil Spill Contingency Plan
pelagic:	relating to communities of marine organisms which belong to the open seas living free from direct dependence on bottom or shore
permeable:	ability of rock to allow fluid movement
psia:	pressure per square inch absolute
spud:	to commence the actual drilling of the well
subtidal:	the littoral zone below the low tide mark
supratidal:	the part of the shoreline that lies above the high tide mark

tonne	1 tonne = 1,500 L
toxic:	capable, through chemical action, of killing, injuring, or impairing an organism
TVD	True vertical depth
W/HD	Wellhead
WBM	Water based muds
weathering:	physical disintegration and chemical decomposition of oil

Apache ENERGY

EP 342 & TP/9
LOCATION MAP

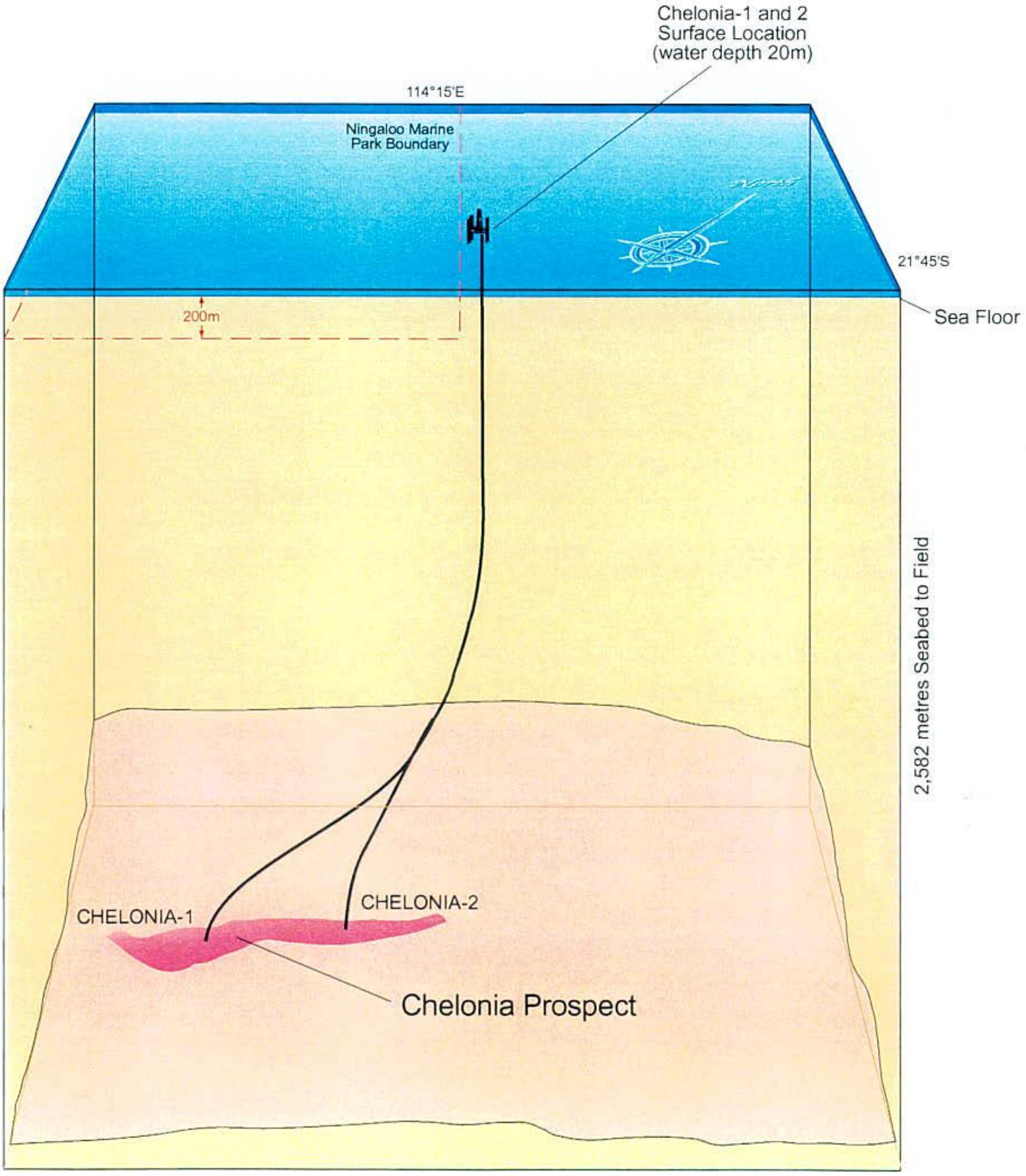
Commonwealth Waters



Dated: 15 January 1998 Reference ISu4285 ISu5107

Figure 1

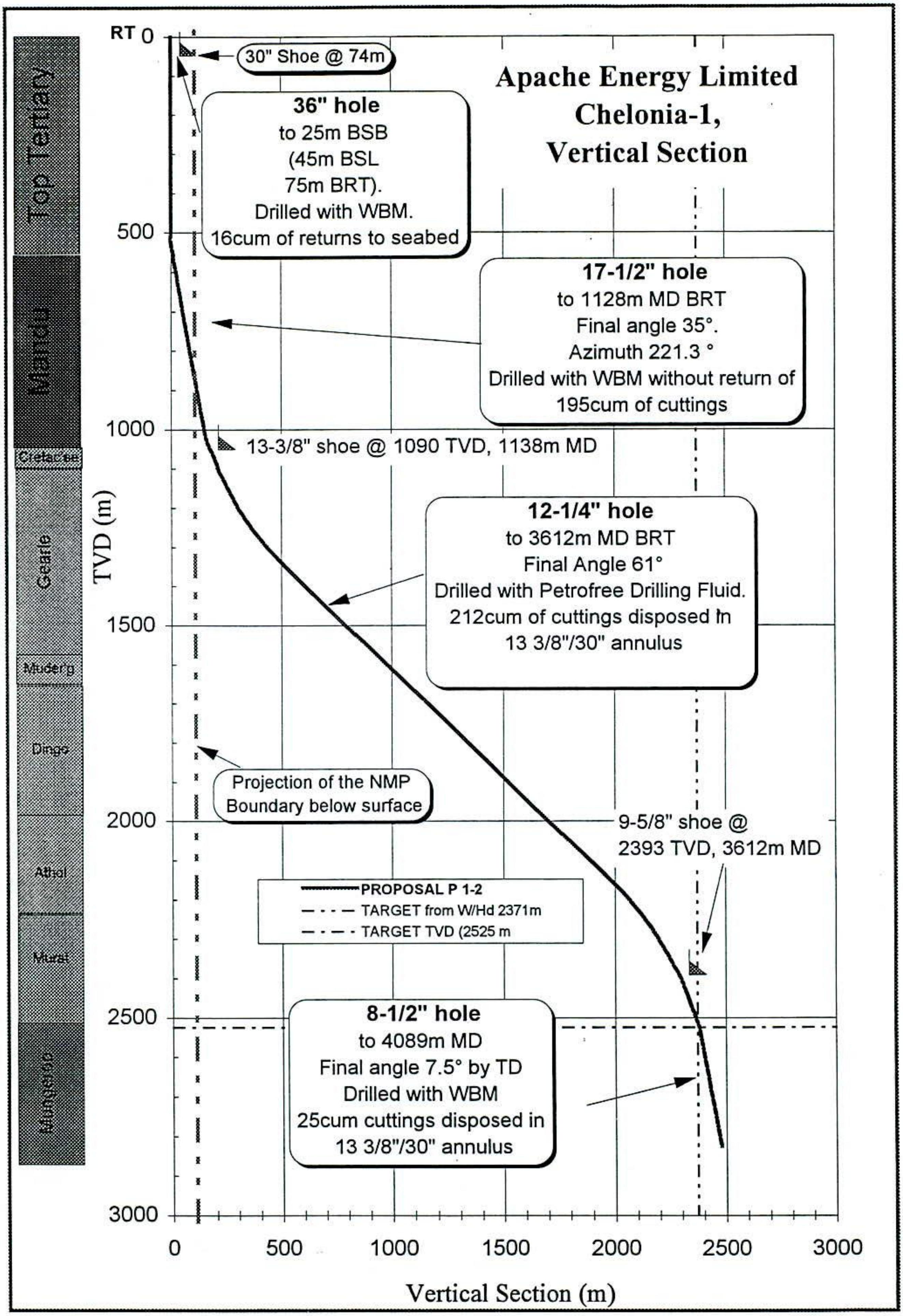
SCHEMATIC VIEW OF THE CHELONIA PROSPECT LOOKING NORTH - WEST



Vertical Exaggeration

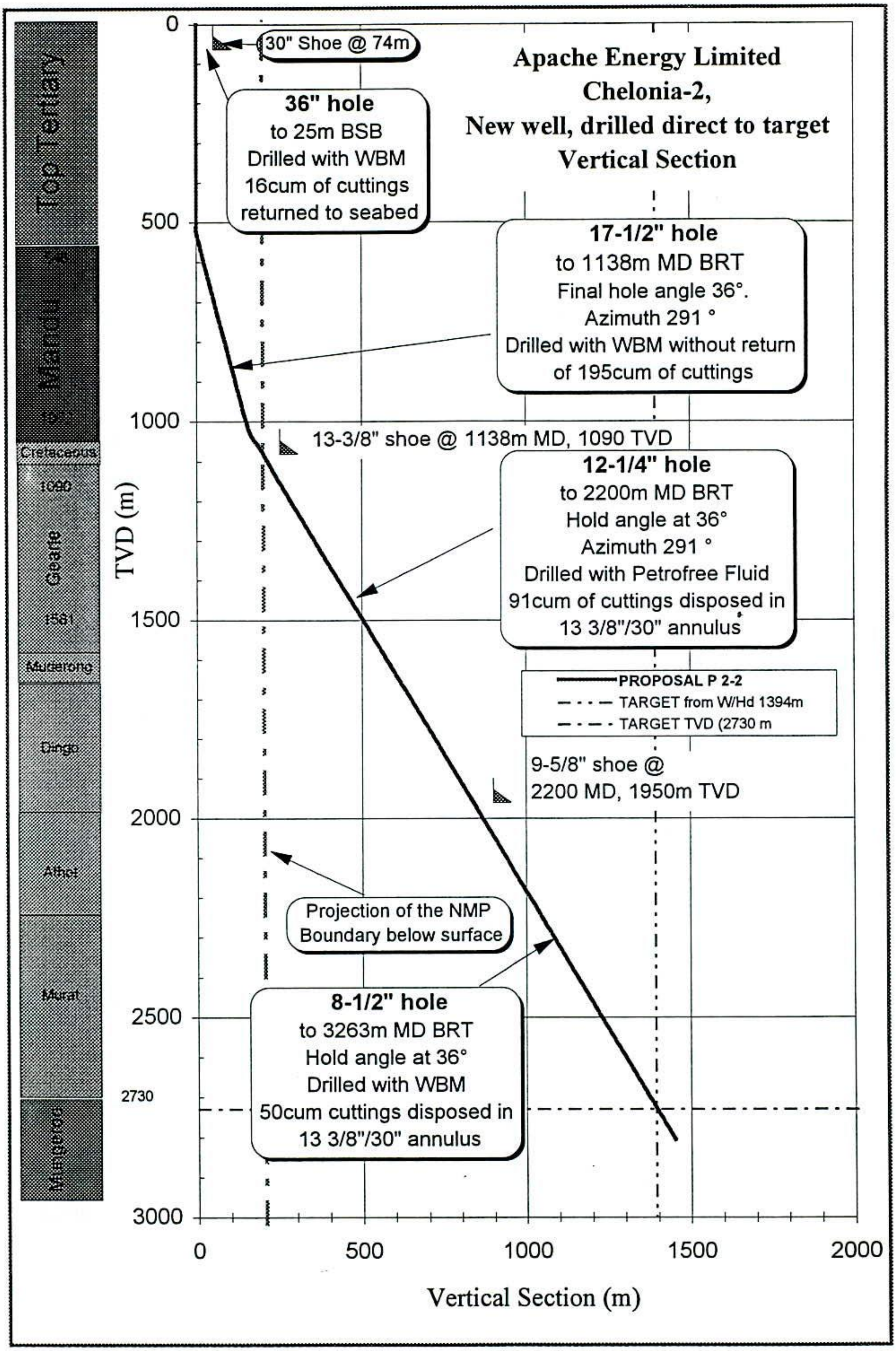
Taken from MD.m3588 Dated: 3 September 1997 IS.m4289(a)

Figure 2



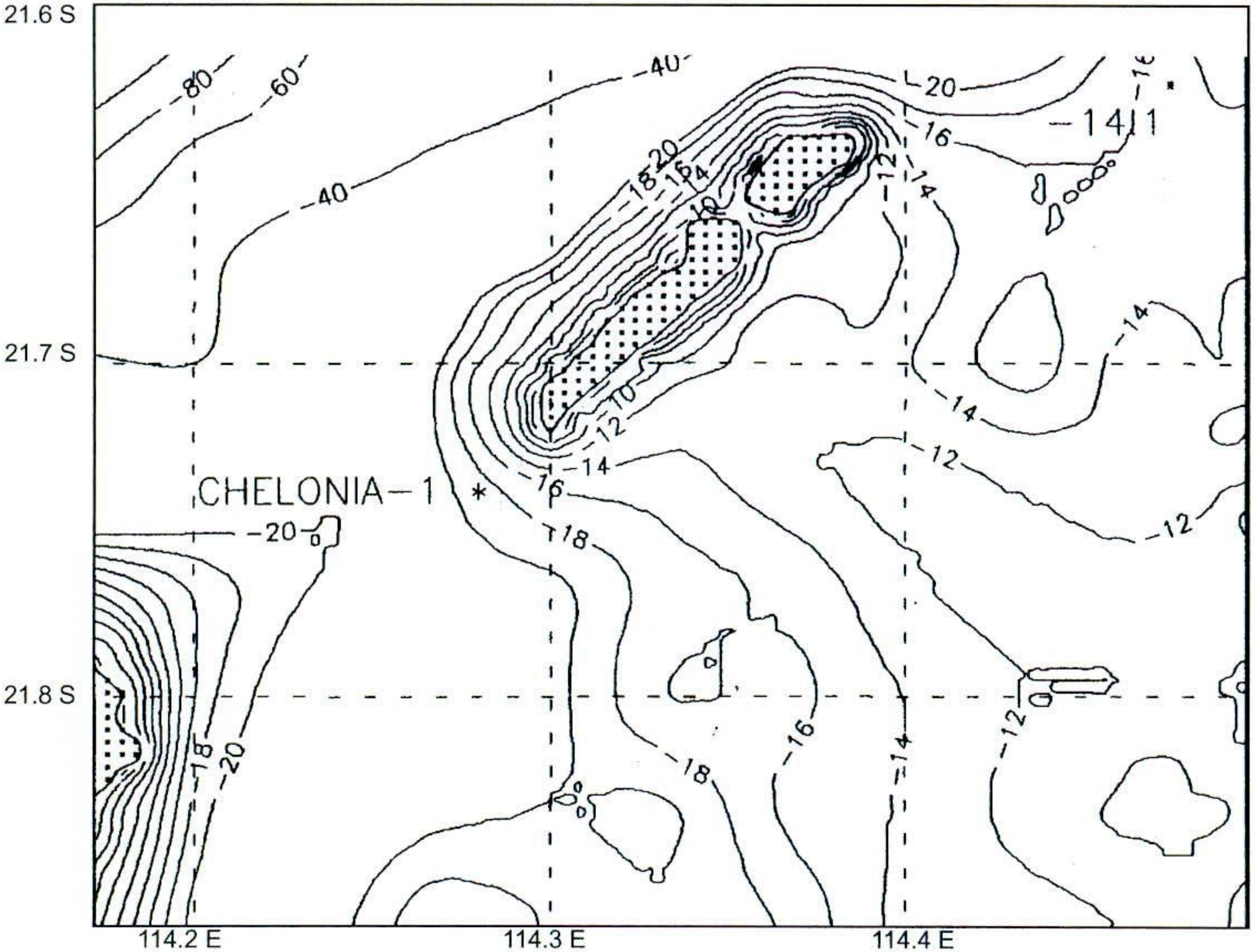
Apache Energy Limited
Chelonia-1,
Vertical Section
RT 0
500
1000
1500
2000
2500
3000
TVD (m)
0
500
1000
1500
2000
2500
3000
Vertical Section (m)
Top Tertiary
Mandu
Cretaceous
Gearle
Muderg
Dingo
Athol
Murat
Mungaroo
30" Shoe @ 74m
36" hole
to 25m BSB
(45m BSL
75m BRT).
Drilled with WBM.
16cum of returns to seabed
17-1/2" hole
to 1128m MD BRT
Final angle 35°.
Azimuth 221.3 °
Drilled with WBM without return of
195cum of cuttings
13-3/8" shoe @ 1090 TVD, 1138m MD
12-1/4" hole
to 3612m MD BRT
Final Angle 61°
Drilled with Petrofree Drilling Fluid.
212cum of cuttings disposed in
13 3/8"/30" annulus
Projection of the NMP
Boundary below surface
9-5/8" shoe @
2393 TVD, 3612m MD
PROPOSAL P 1-2
TARGET from W/Hd 2371m
TARGET TVD (2525 m
8-1/2" hole
to 4089m MD
Final angle 7.5° by TD
Drilled with WBM
25cum cuttings disposed in
13 3/8"/30" annulus

Figure 3



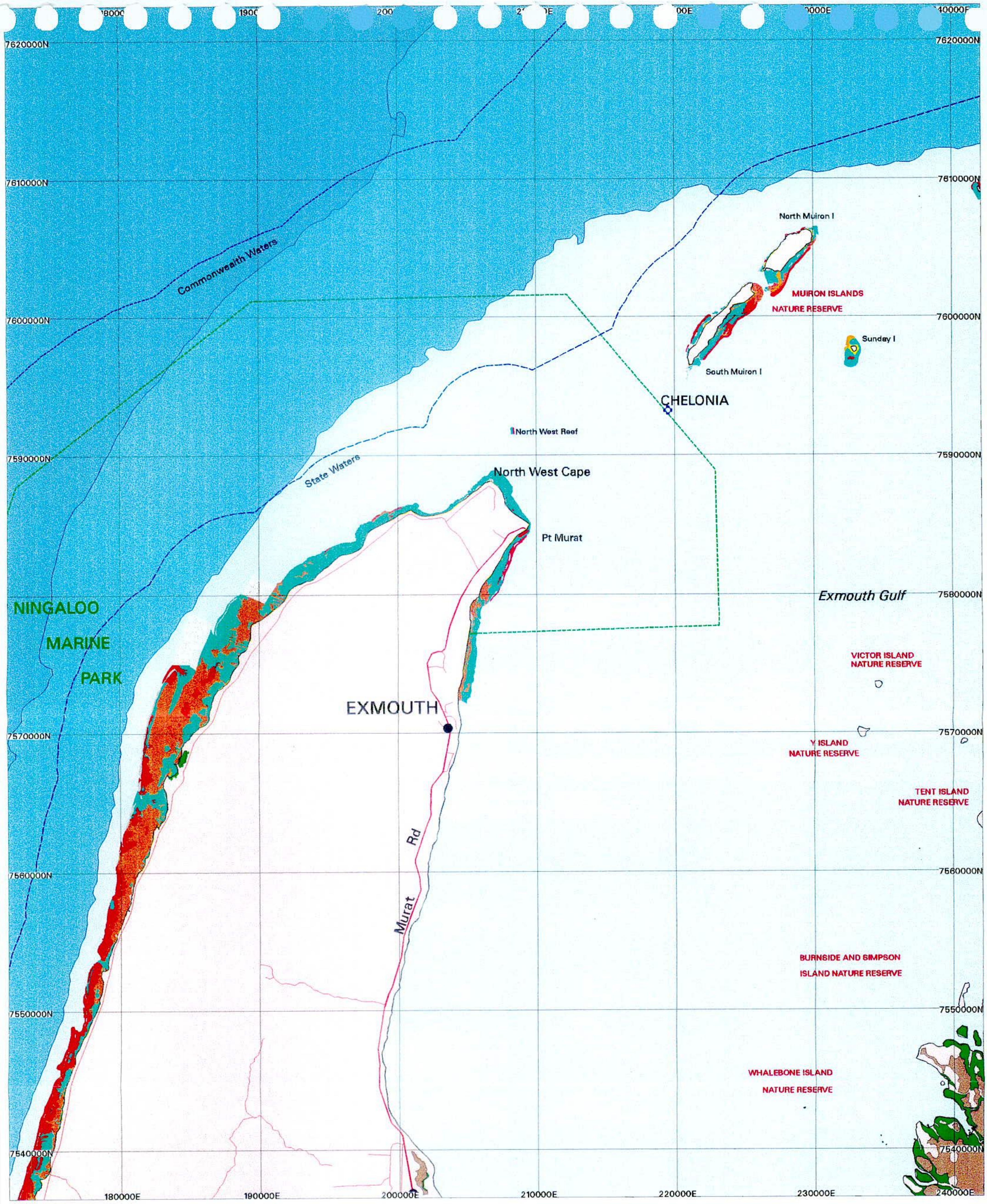
Prepared by Ed Lintott

Figure 4



Bathymetry (m) of the area surrounding Chelonia-1

Figure 5



LEGEND

- Supratidal area
- Sandy beaches
- Intertidal limestone pavements; reef flats; intertidal rubble deposits
- Macroalgal communities; pavement/rubble with macroalgae and seagrass; isolated coral bommies
- Coral communities with high species diversity; Patchy coral reefs, predominantly massives interspaced with large rubble
- Intertidal sand
- Subtidal sand
- Unknown (lack of aerial photography)
- Mangrove
- Mudflat
- Chelonia Exploration Well

Scale:250000

0 2.5 5.0 7.5 10.0

Kilometres

Universal Transverse Mercator Projection

Zone 50

SOURCES
Marine habitats mapped from aerial photography by BBG. Land habitats derived from AUSLIG 1:250000 Geodata.

Drawn by NGIS (Australia) Pty Ltd

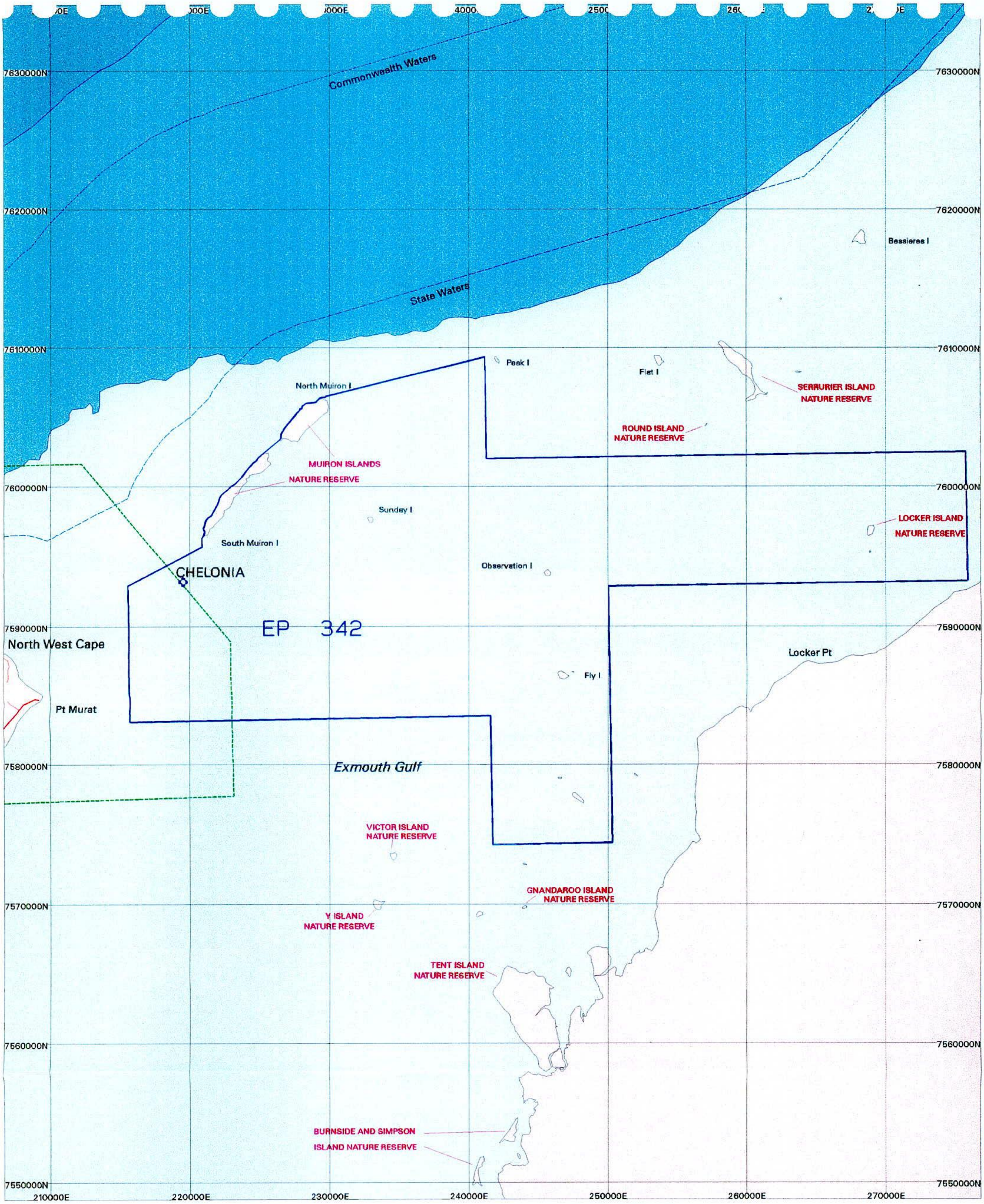
Map ID: BBG016_1

DATE:June 15, 1998

Apache ENERGY

MARINE HABITATS NEAR THE CHELONIA LOCATION

Figure 6



LEGEND

- Chelonia Exploration Well
- Petroleum Exploration Lease EP 342
- Ningaloo Marine Park

Scale:250000

0 2.5 5.0 7.5 10.0

Kilometres

Universal Transverse Mercator Projection

Zone 50

SOURCES
Drill hole and lease locations provided by BBG. Topographic base derived from AUSLIG 1:250000 Geodata.

Drawn by NGIS (Australia) Pty Ltd

Map ID: BBG016_2

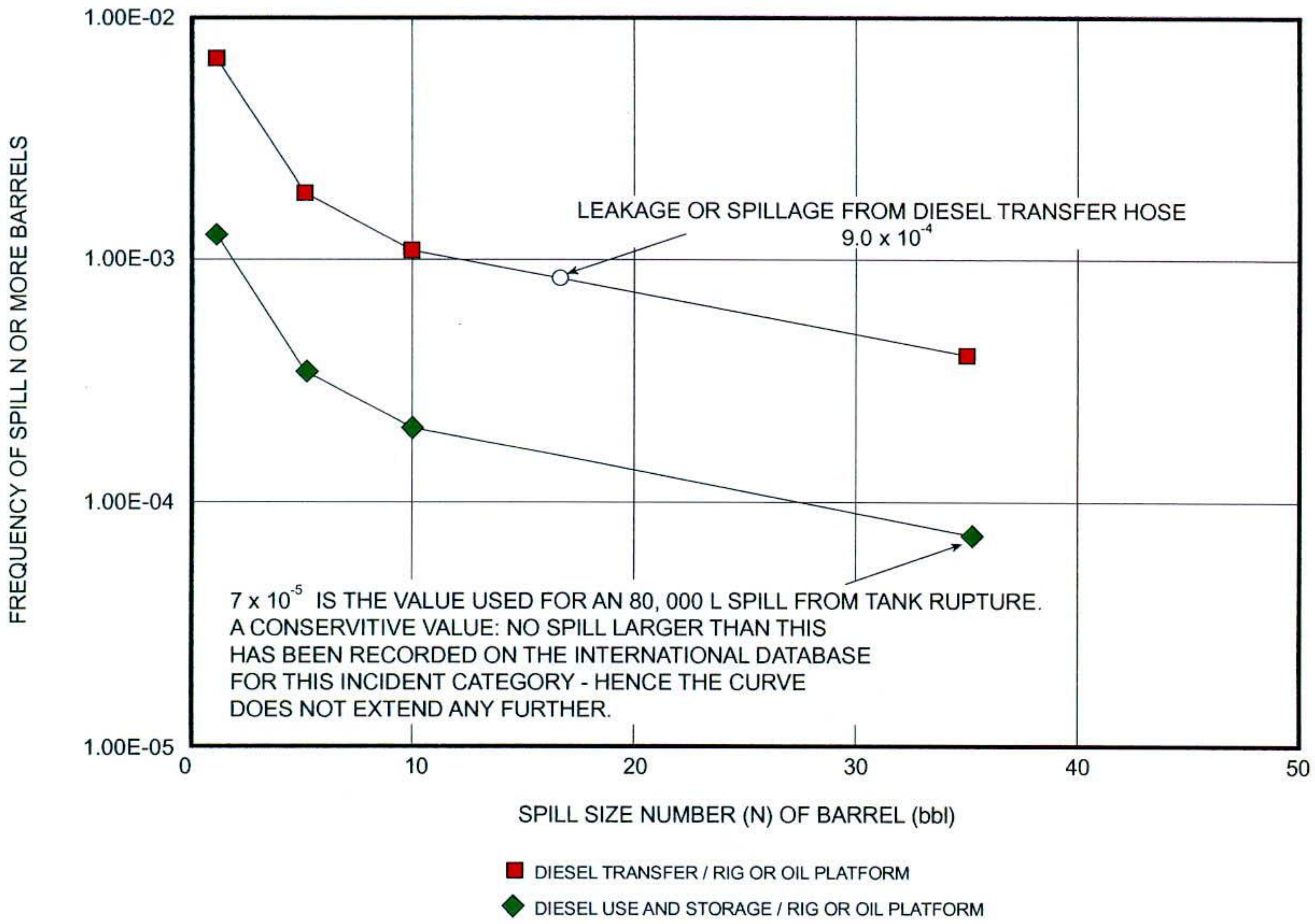
DATE:June 15, 1998

Apache ENERGY

CHELONIA LOCATION DIAGRAM

Figure 7

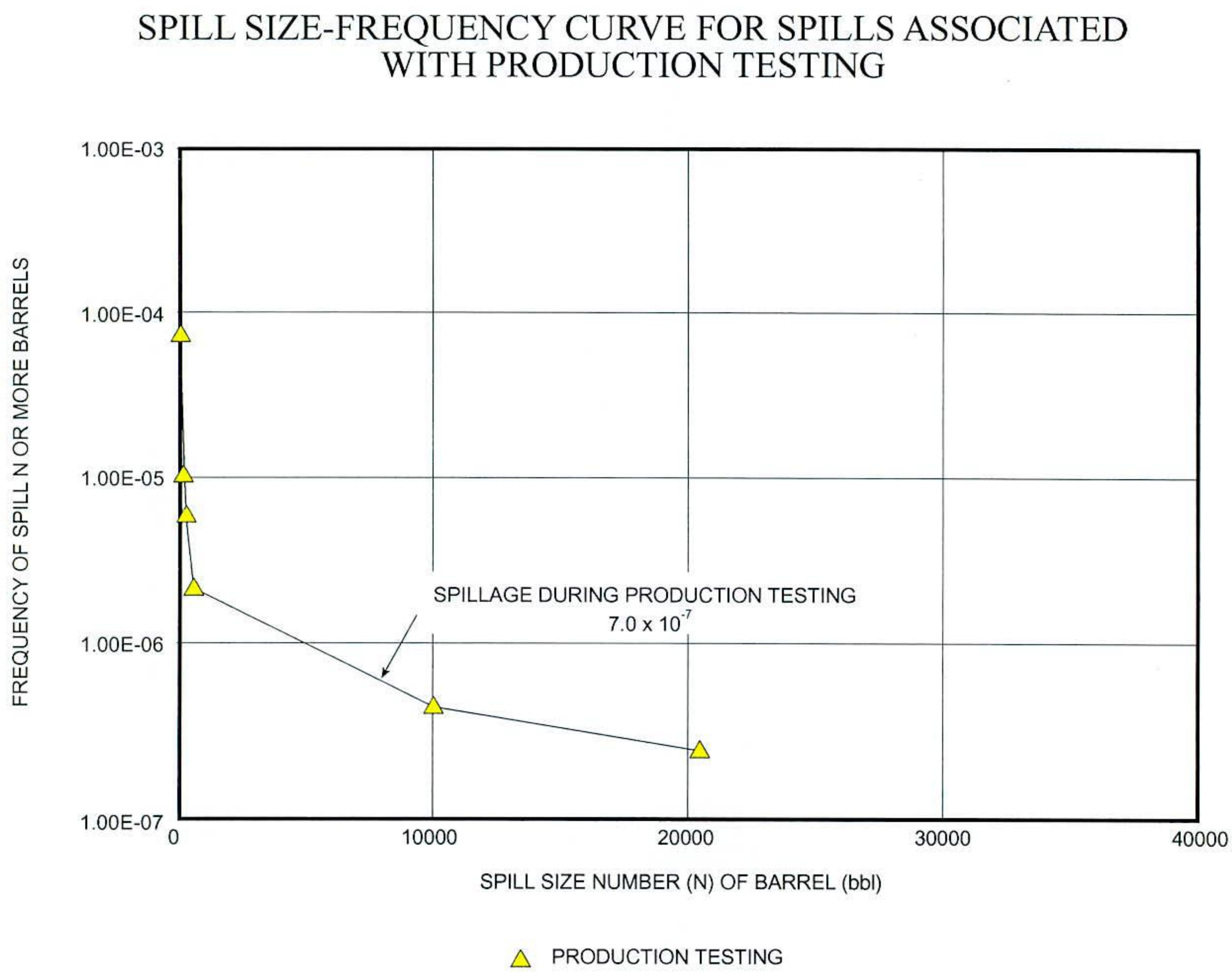
SPILL SIZE-FREQUENCY CURVE FOR SPILLS ASSOCIATED WITH DIESEL HANDLING



SOURCE: DNV ENGINEERING

Figure 8

7 January 1998 SL.m3605

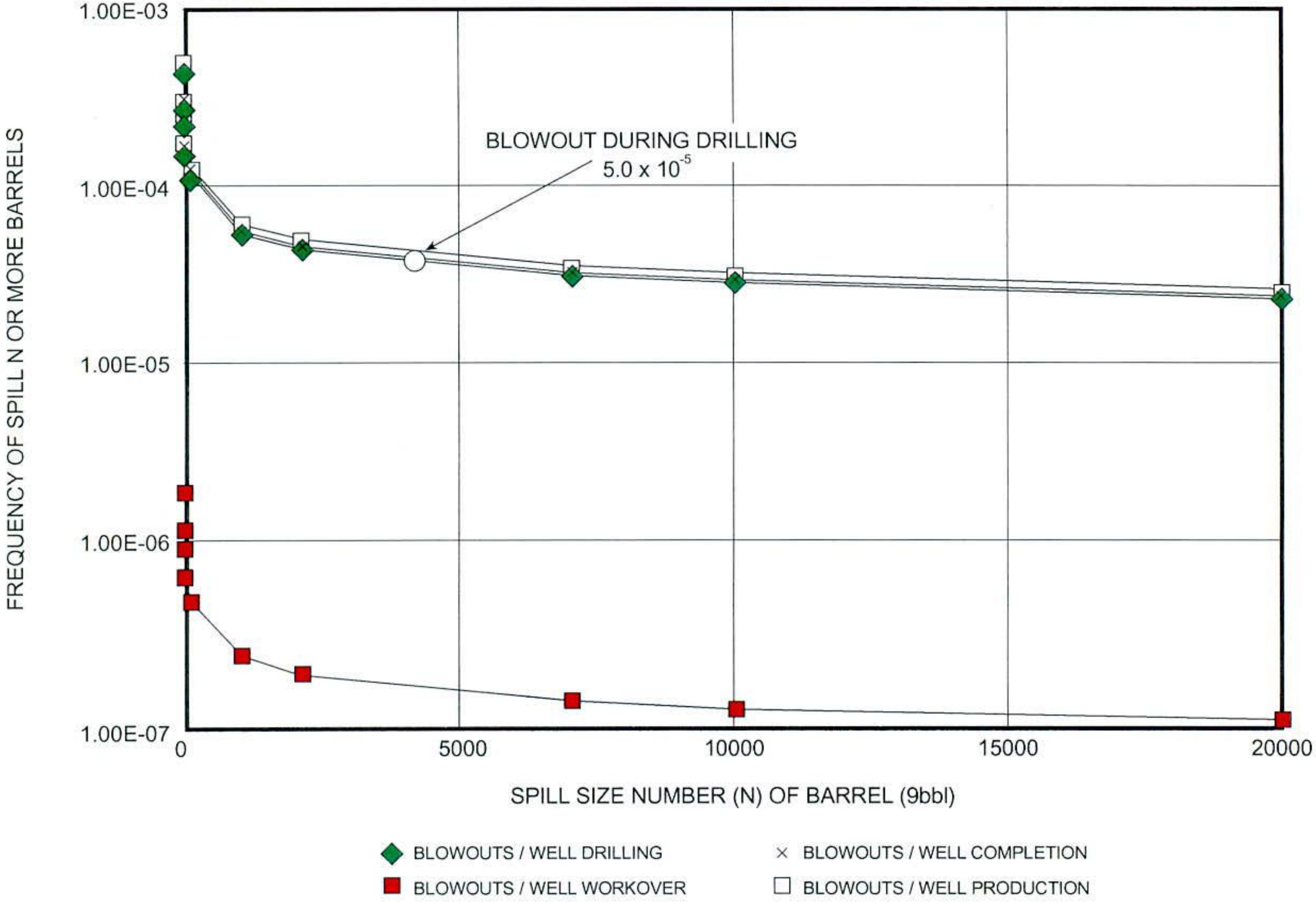


SOURCE: DNV ENGINEERING

7 January 1998 SLm4841

Figure 9

SPILL SIZE-FREQUENCY CURVE FOR SPILLS ASSOCIATED WITH LOSS OF WELL CONTROL

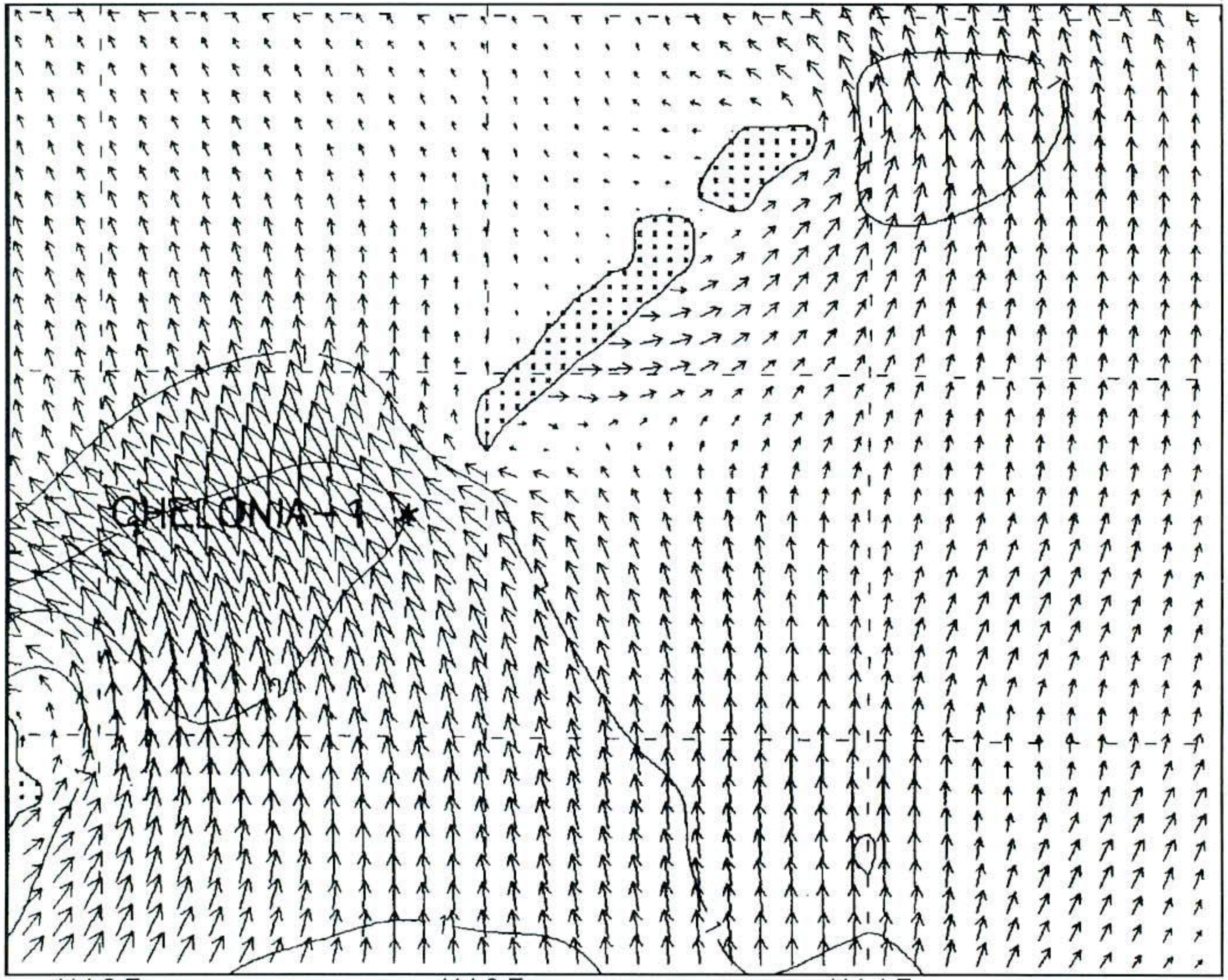


SOURCE: DNV ENGINEERING

7 January 1998 SL.m3622

Figure 10

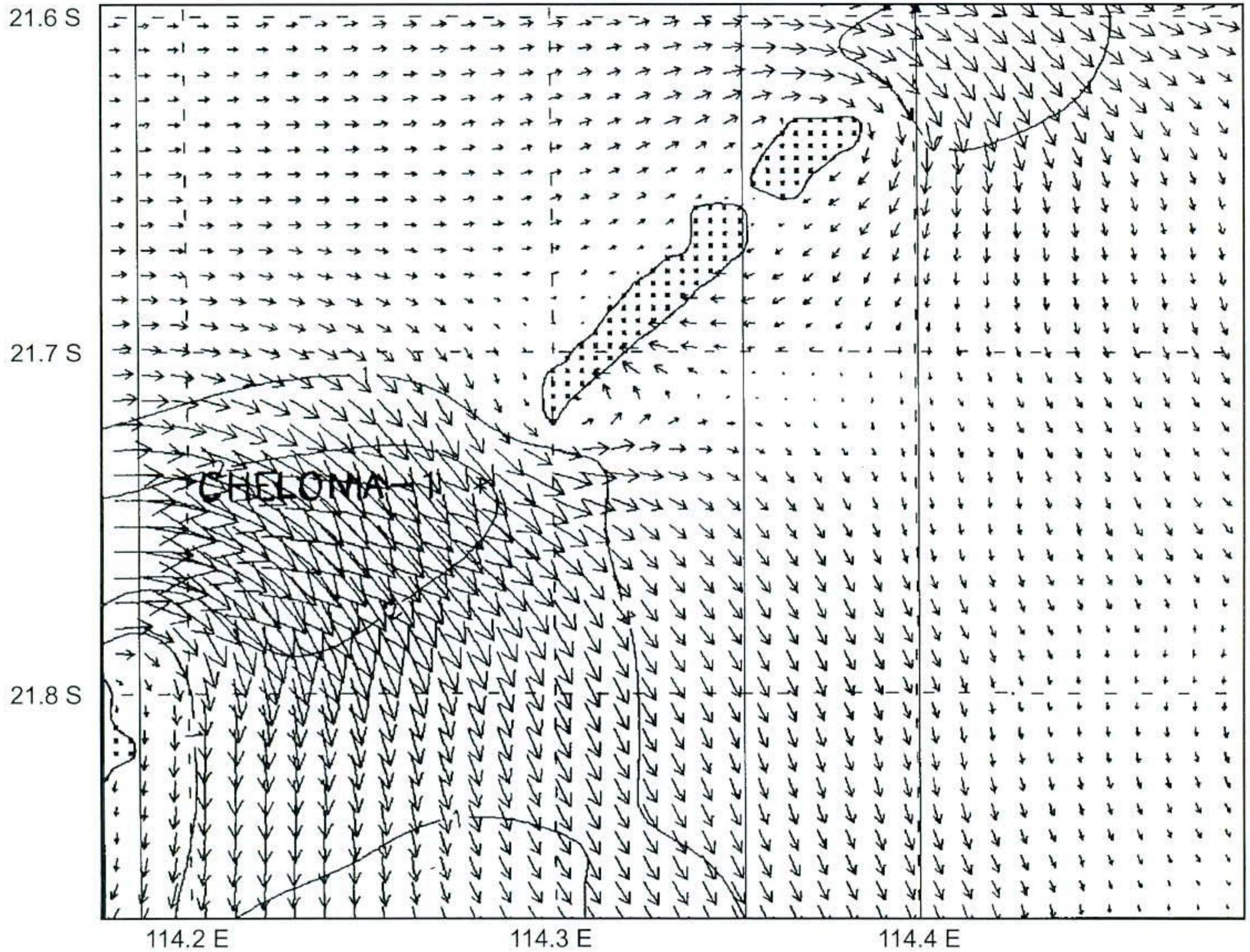
Forecast for 0300 hours on 01 Mar 1995 (UTC + 8.0)



Example of an ebbing tidal current pattern around Chelonia-1 & 2

Figure 13

Forecast for 2100 hours on 28 Feb 1995 (UTC + 8.0)



Example of a flooding tidal current pattern around Chelonia-1 & 2

Figure 14

8 January 1997 IS.m4286a

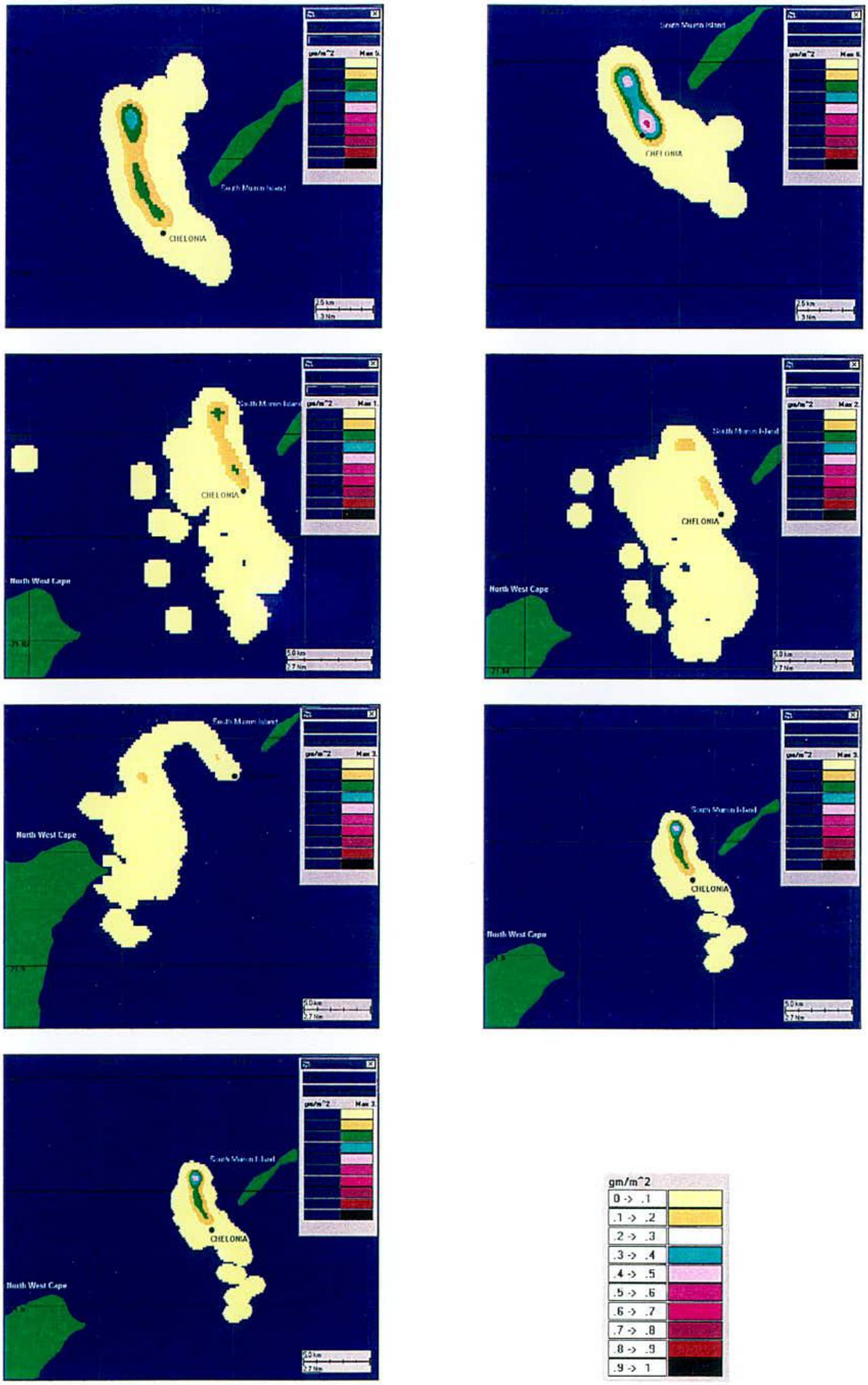


Figure 15: Examples of the predicted concentration of particulates accumulating on the seafloor if 5 m^3 of Petrofree were spilled from the Chelonia drilling location during an ebb tide under winter wind conditions.

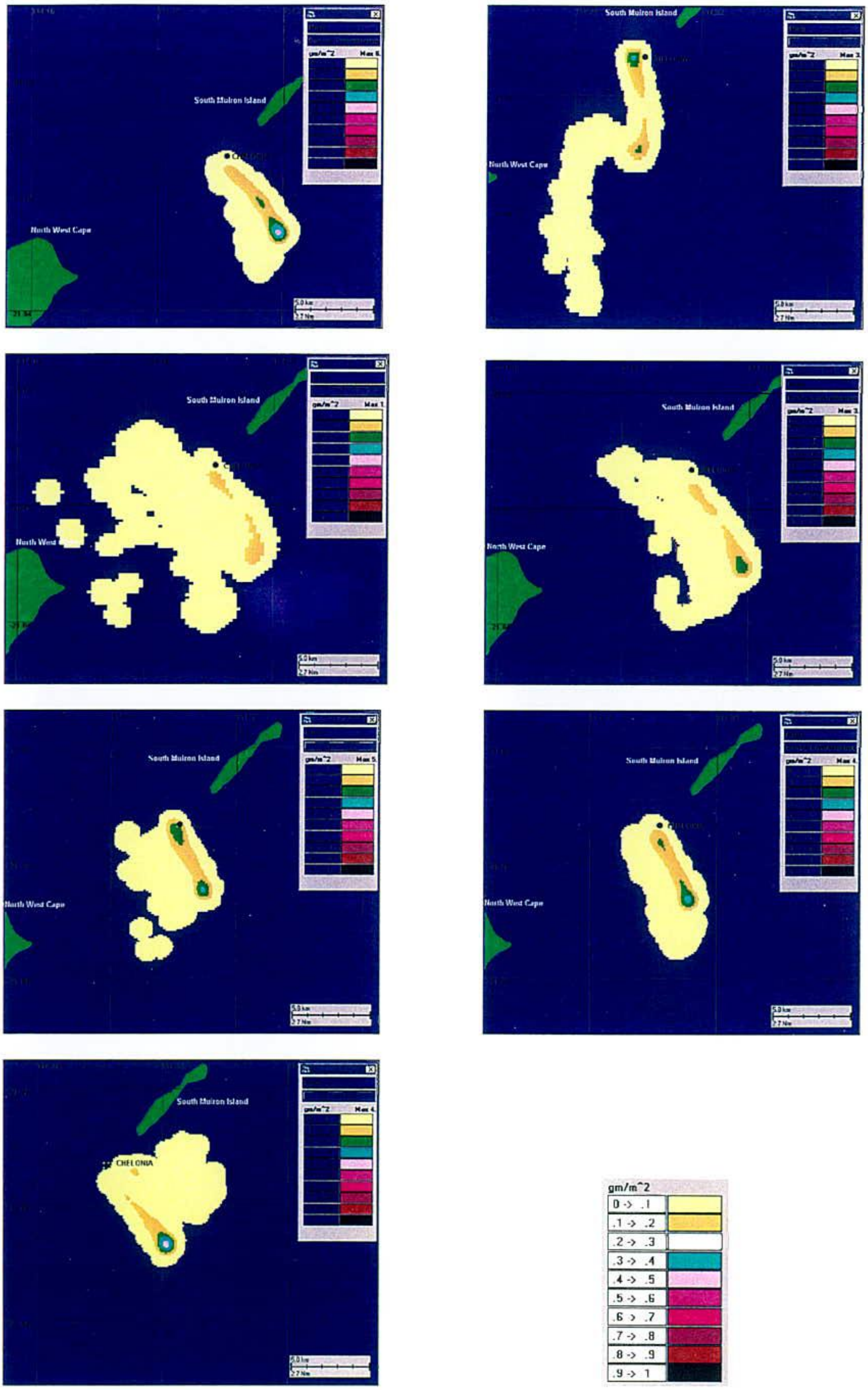


Figure 16: Examples of the predicted concentration of particulates accumulating on the seafloor if 5 m^3 of Petrofree were spilled from the Chelonia drilling location during a flood tide under winter wind conditions.

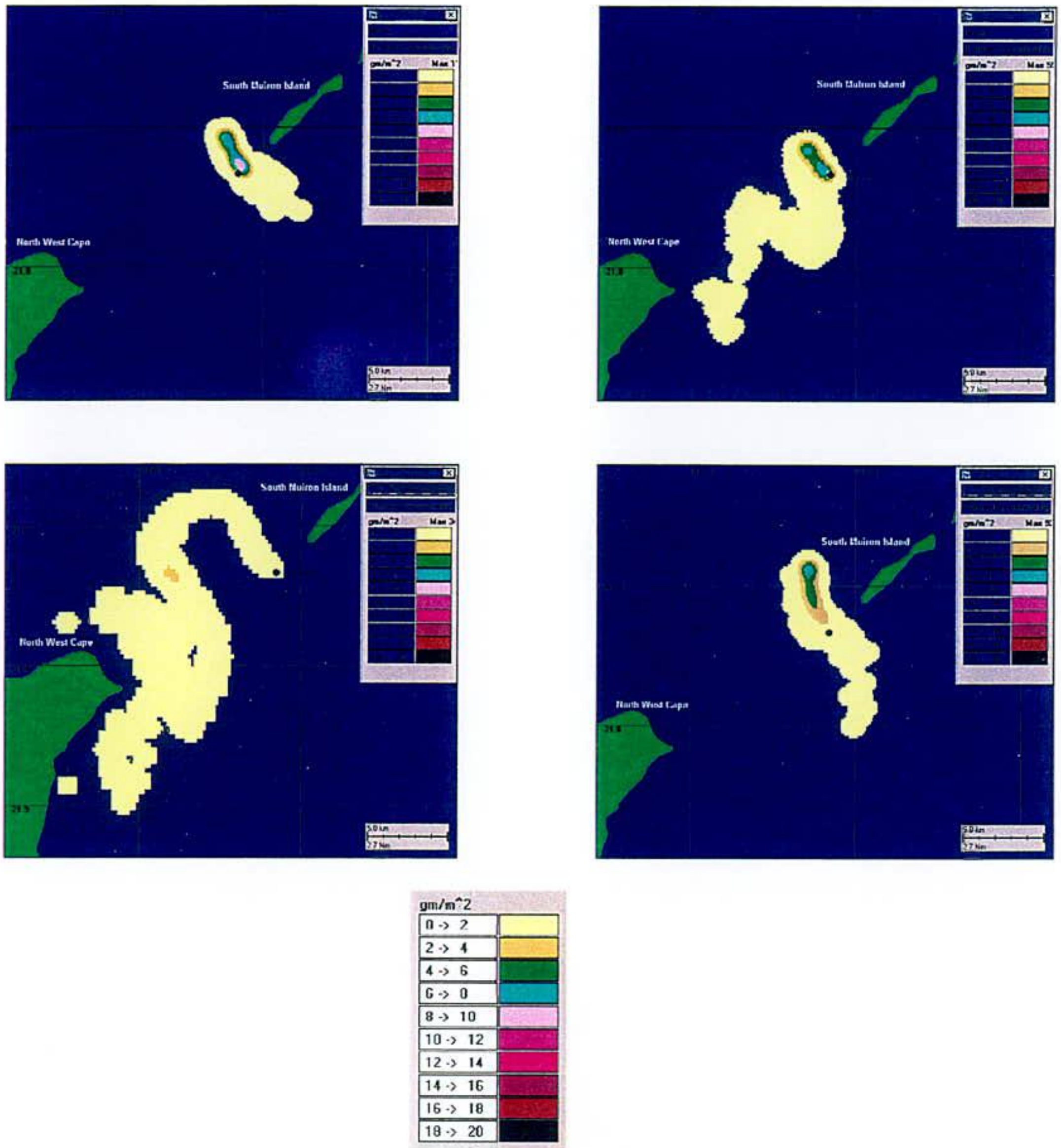


Figure 17: Examples of the predicted concentration of particulates accumulating on the seafloor if 90 m^3 of Petrofree were spilled from the Chelonia drilling location during an ebb tide under winter wind conditions.

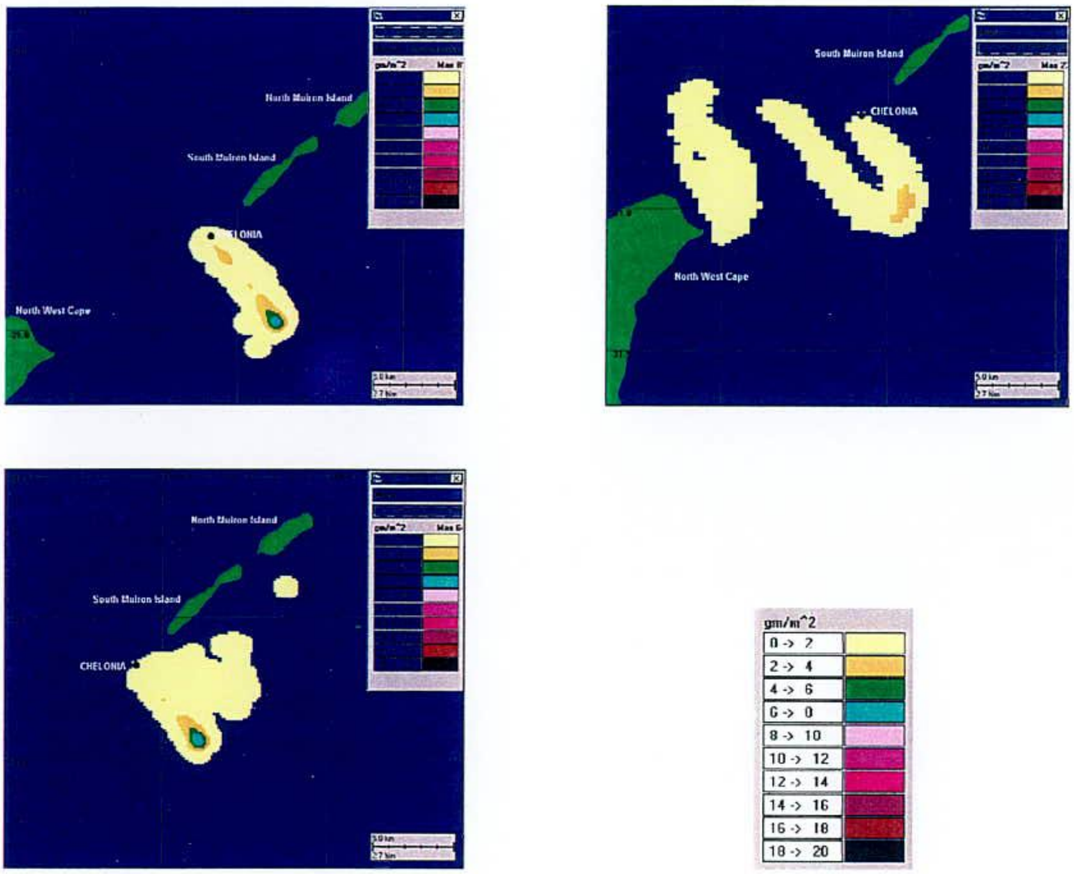


Figure 18: Examples of the predicted concentration of particulates accumulating on the seafloor if 90 m^3 of Petrofree were spilled from the Chelonia drilling location during a flood tide under winter wind conditions.

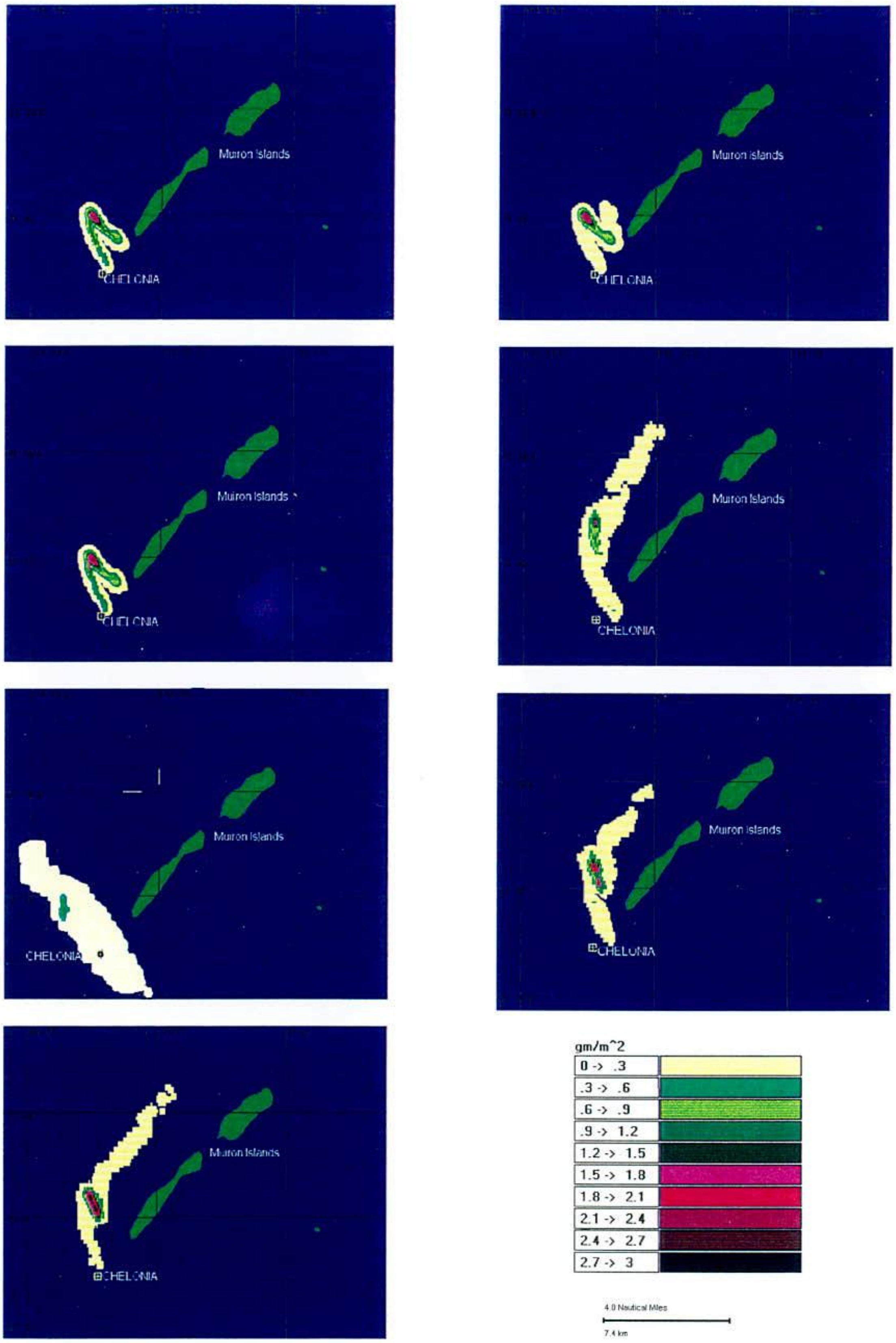


Figure 19: Examples of the predicted concentration of particulates accumulating on the seafloor if 5m[3] of Petrofree were spilled from the Chelonia drilling location during an ebbing tide under summer wind conditions.

5mud95e.doc
15/06/98
S.L.

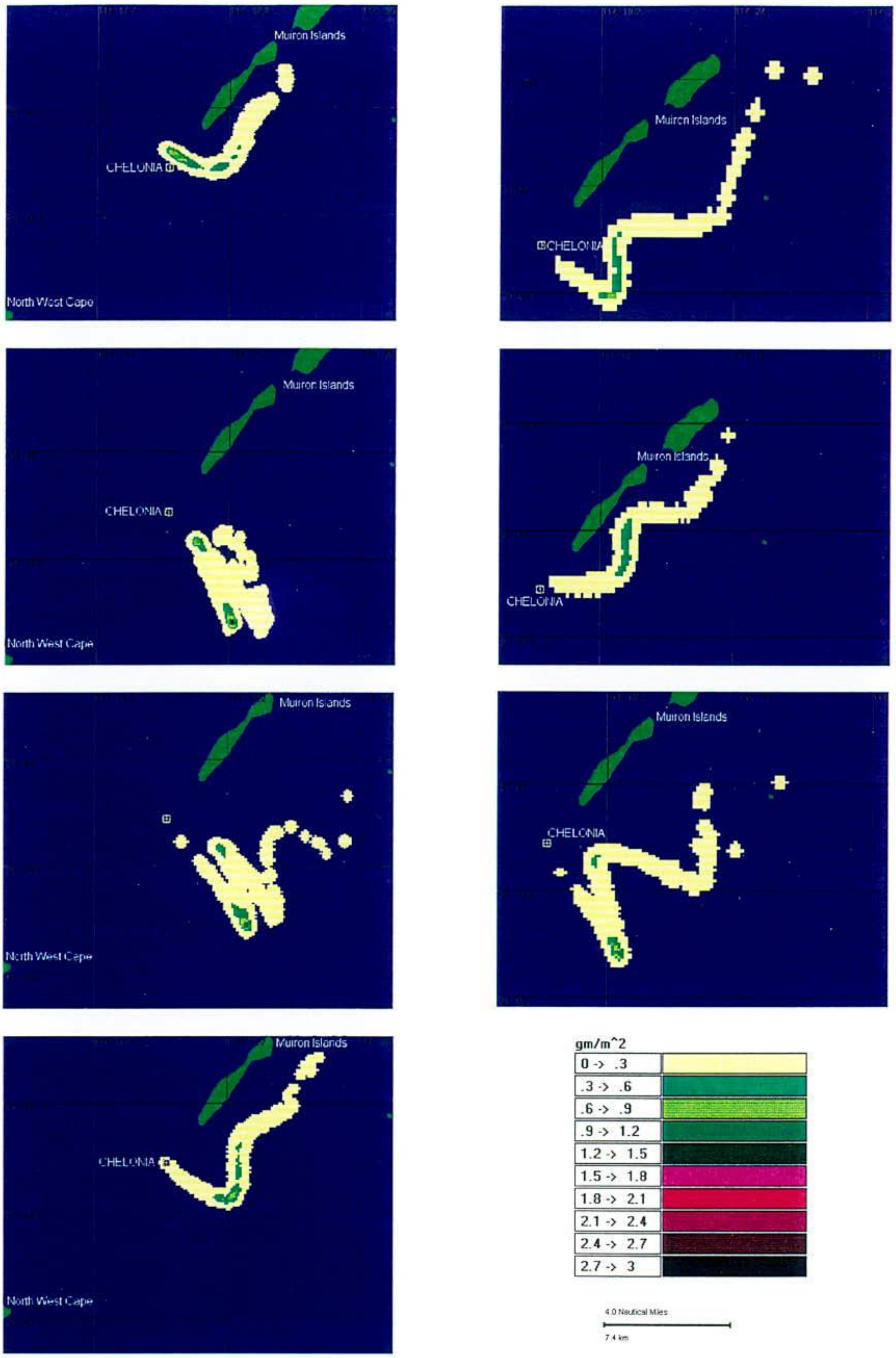


Figure 20: Examples of the predicted concentration of particulates accumulating on the seafloor if 5 m^3 of Petrofree were spilled from the Chelonia drilling location during a flooding tide under summer wind conditions.

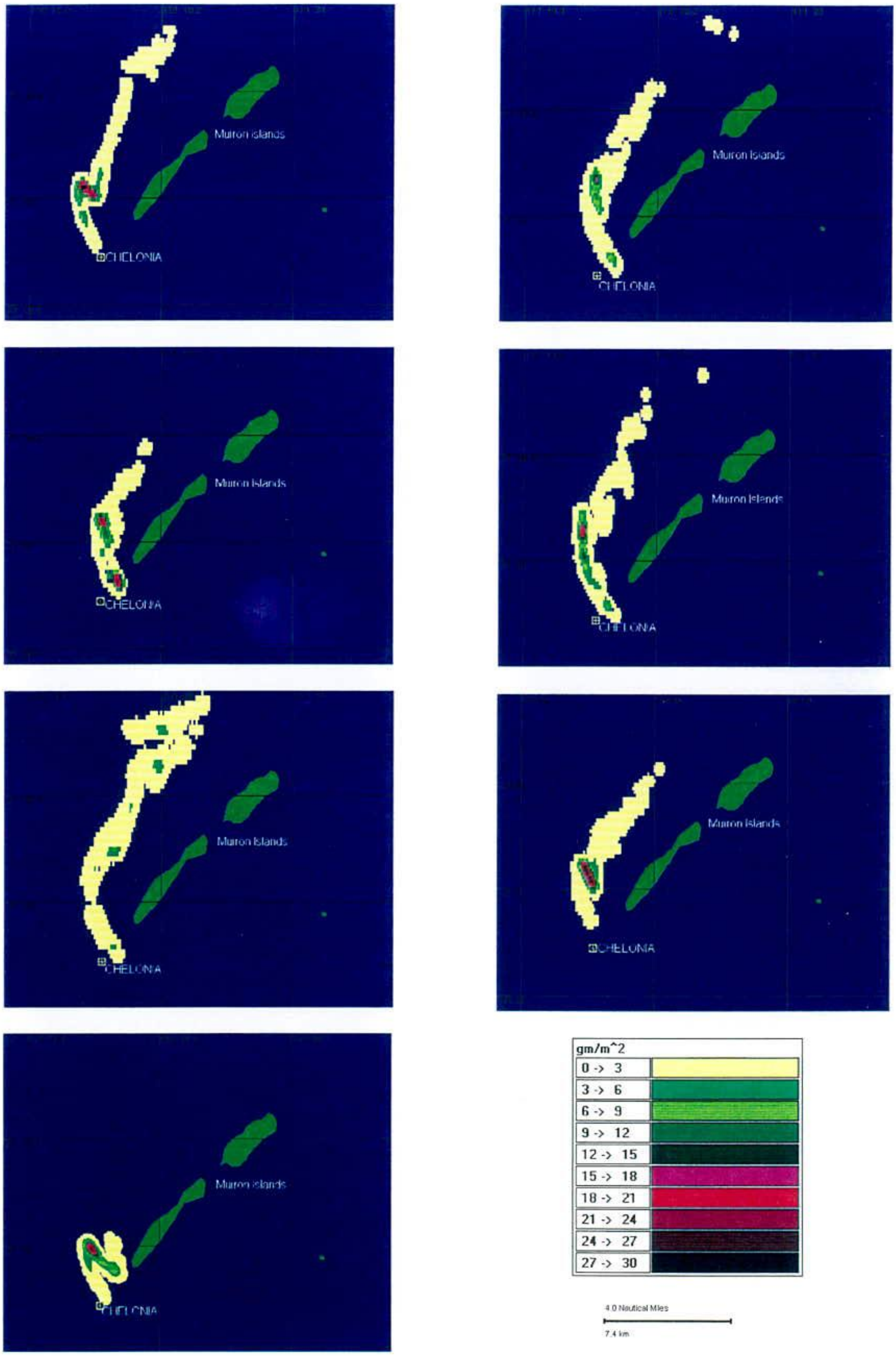


Figure 21: Examples of the predicted concentration of particulates accumulating on the seafloor if 90m^3 of Petrofree were spilled from the Chelonia drilling location during an ebbing tide under summer wind conditions.

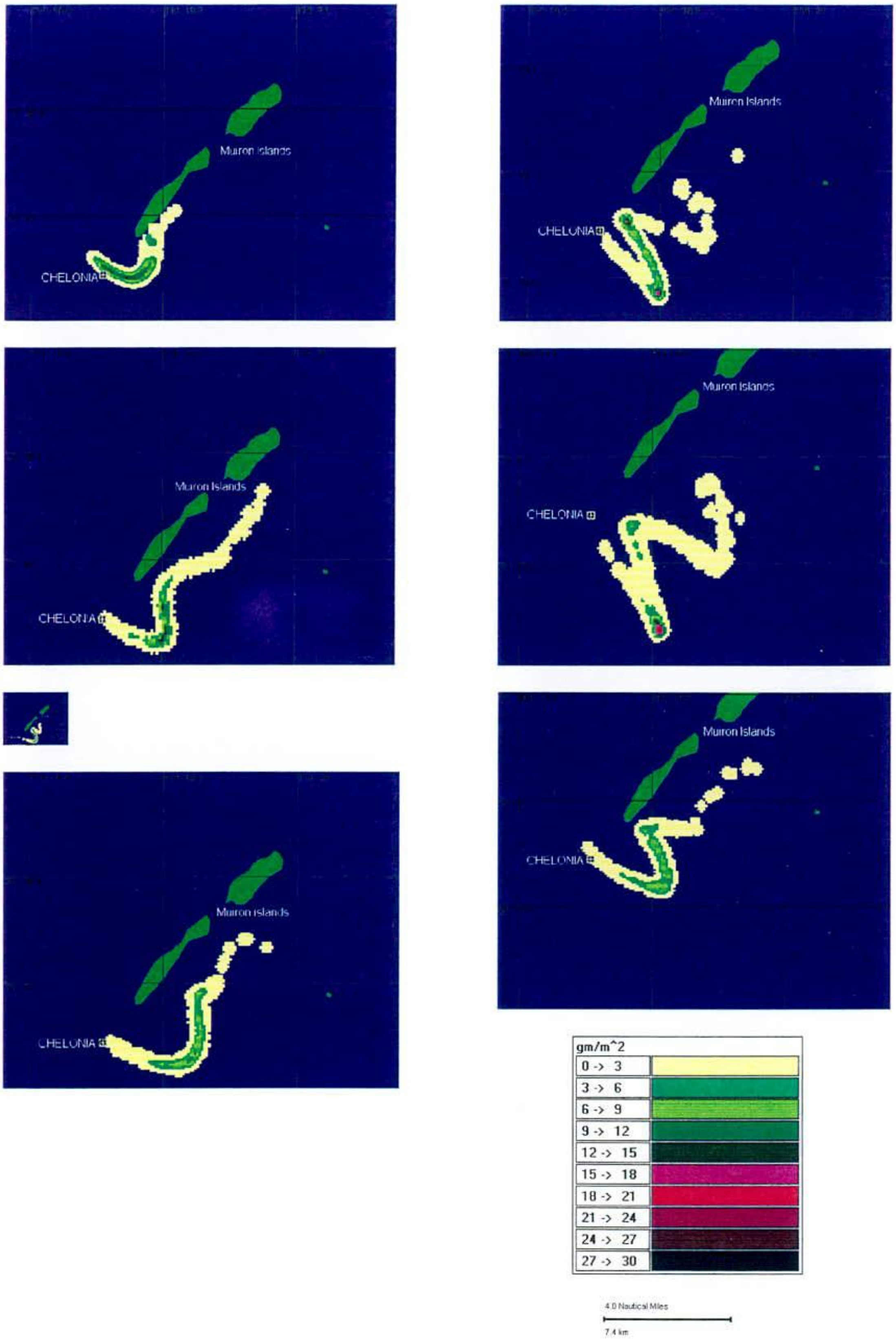


Figure 22: Examples of the predicted concentration of particulates accumulating on the seafloor if 90 m^3 of Petrofree were spilled from the Chelonia drilling location during a flooding tide under summer wind conditions.

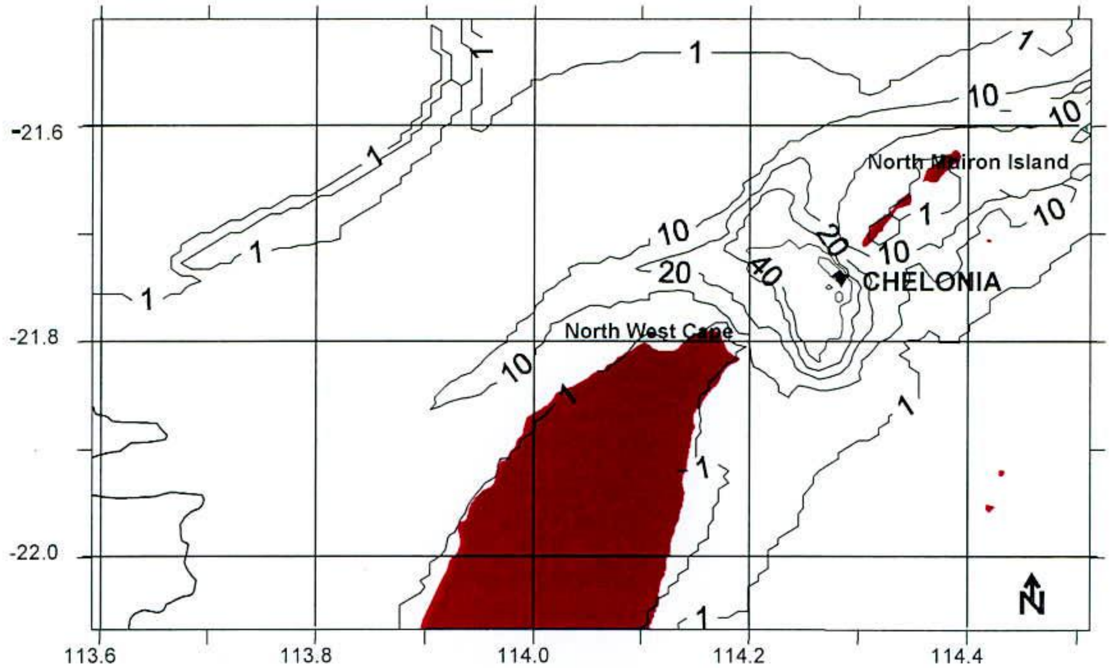


Figure 23 a: Probability contours for a 2,500 L spill of diesel from the Chelonia location under winter conditions

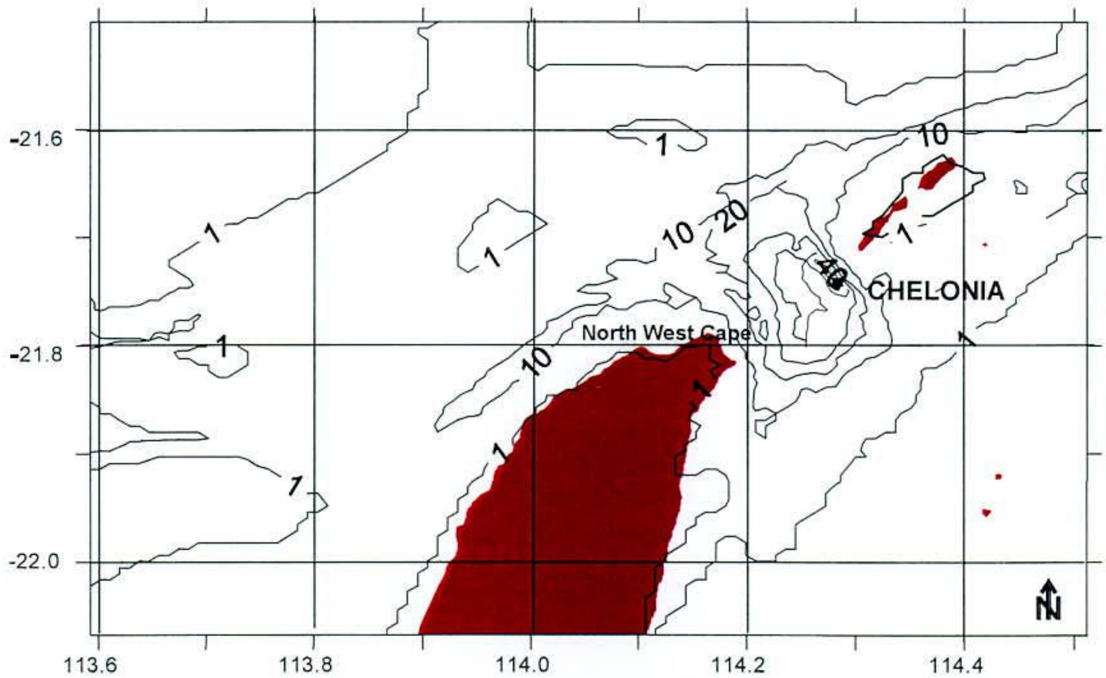


Figure 23 b: Probability contours for an 8,000 L spill of Leatherback crude from the Chelonia location under winter conditions

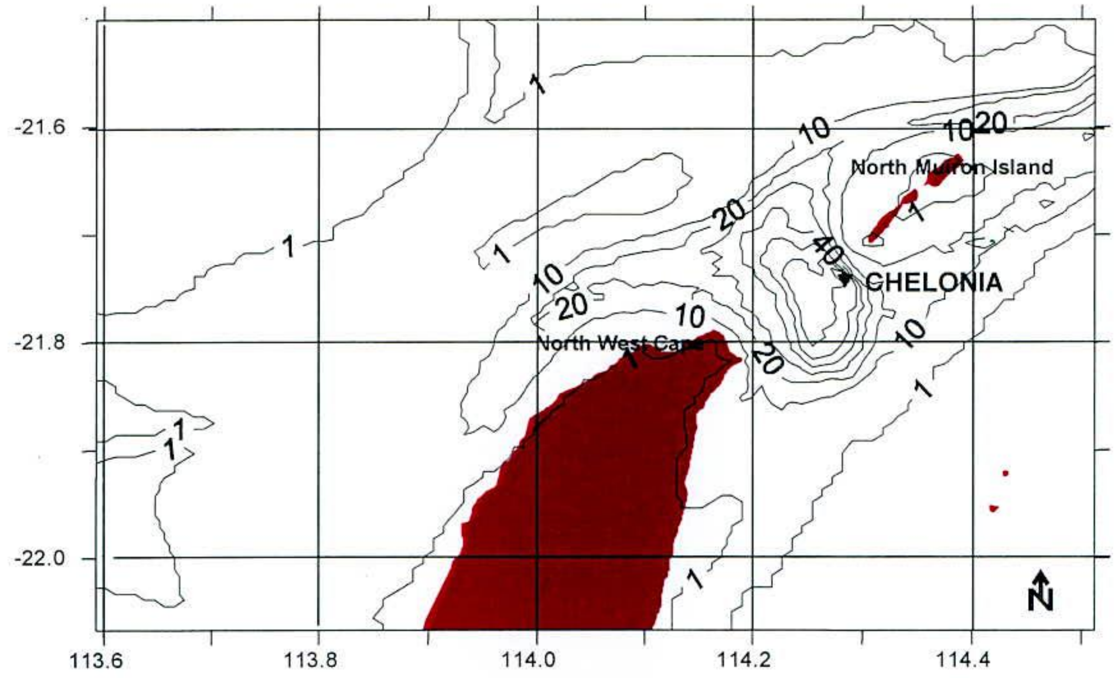


Figure 23 c: Probability contours for an 80,000L spill of diesel from the Chelonia location under winter conditions

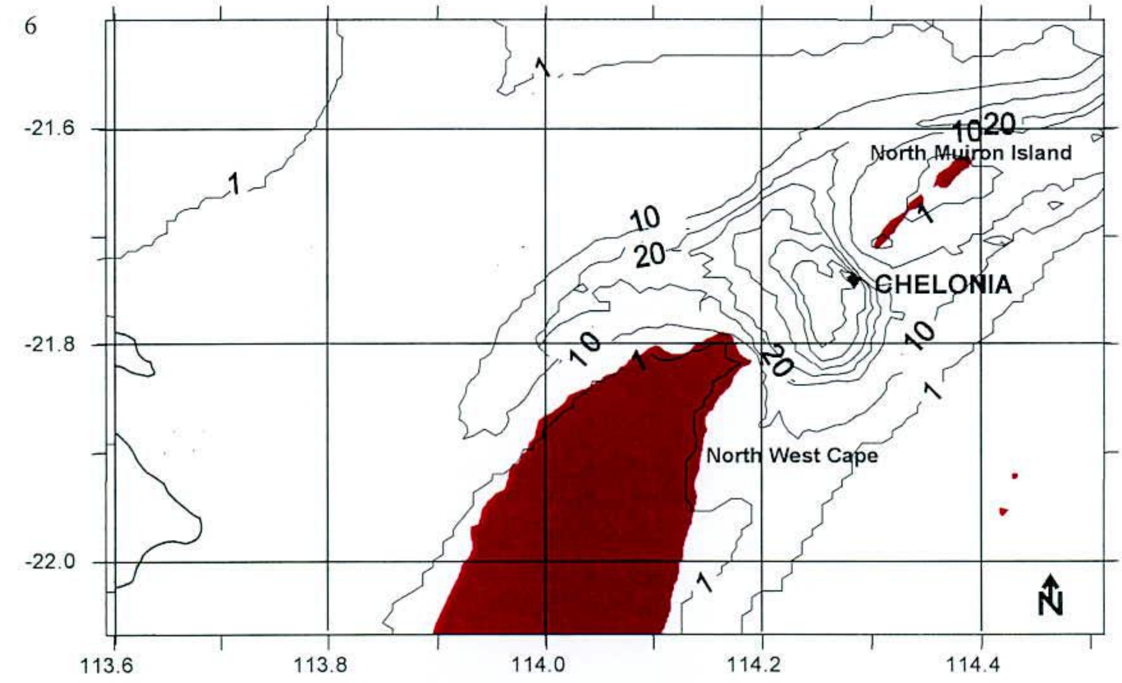


Figure 23 d: Probability contours for a 600,000 L spill of Leatherback crude from the Chelonia location under winter conditions

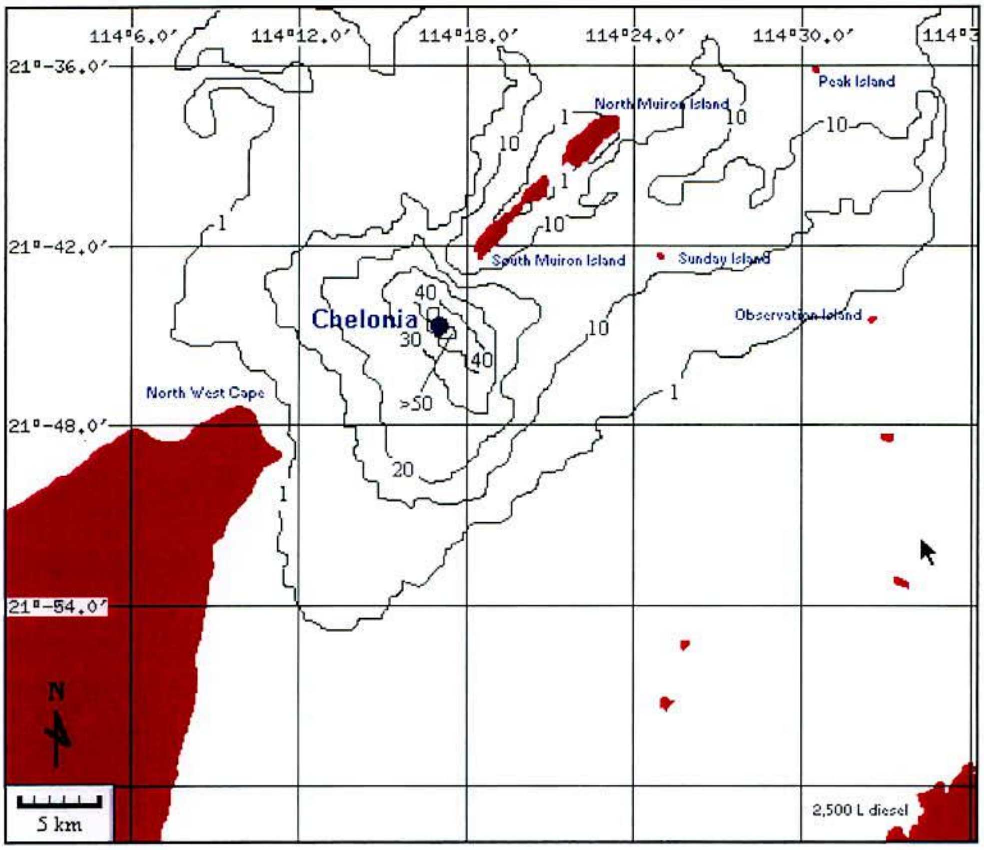


Figure 24a: Probability contours for a 2,500 L spill of diesel from the Chelonia location under summer conditions.

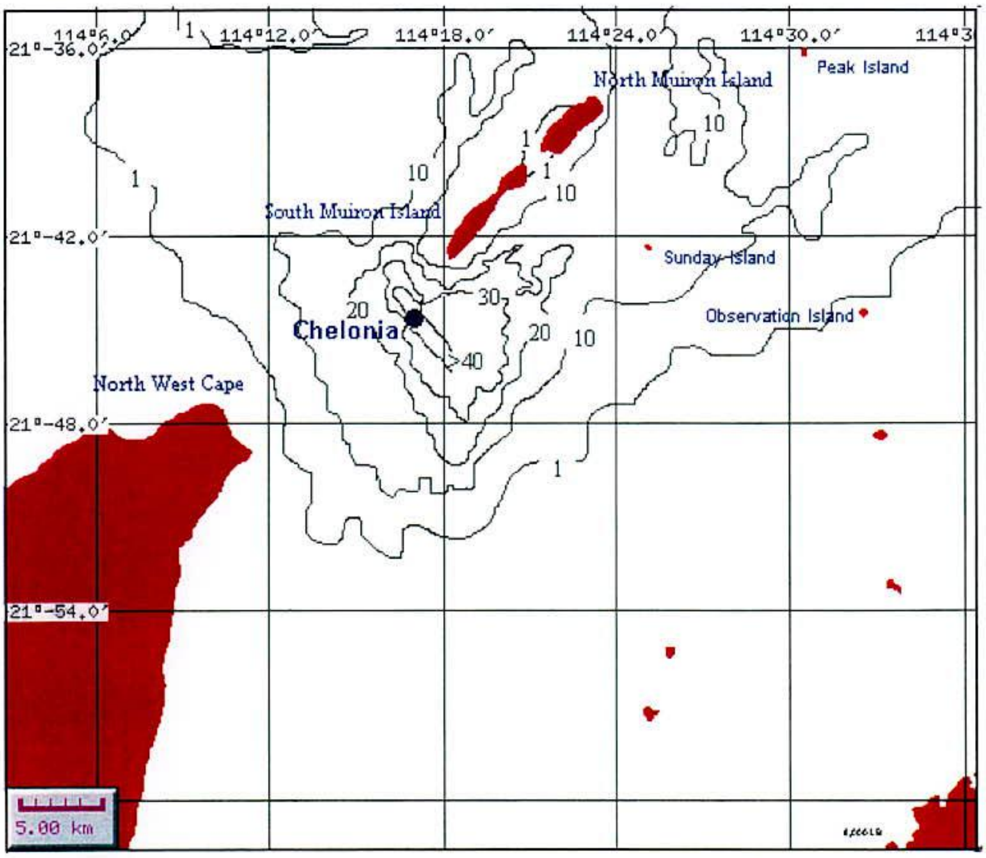


Figure 24b: Probability contours for a 8,000 L spill of light crude from the Chelonia location under summer conditions.

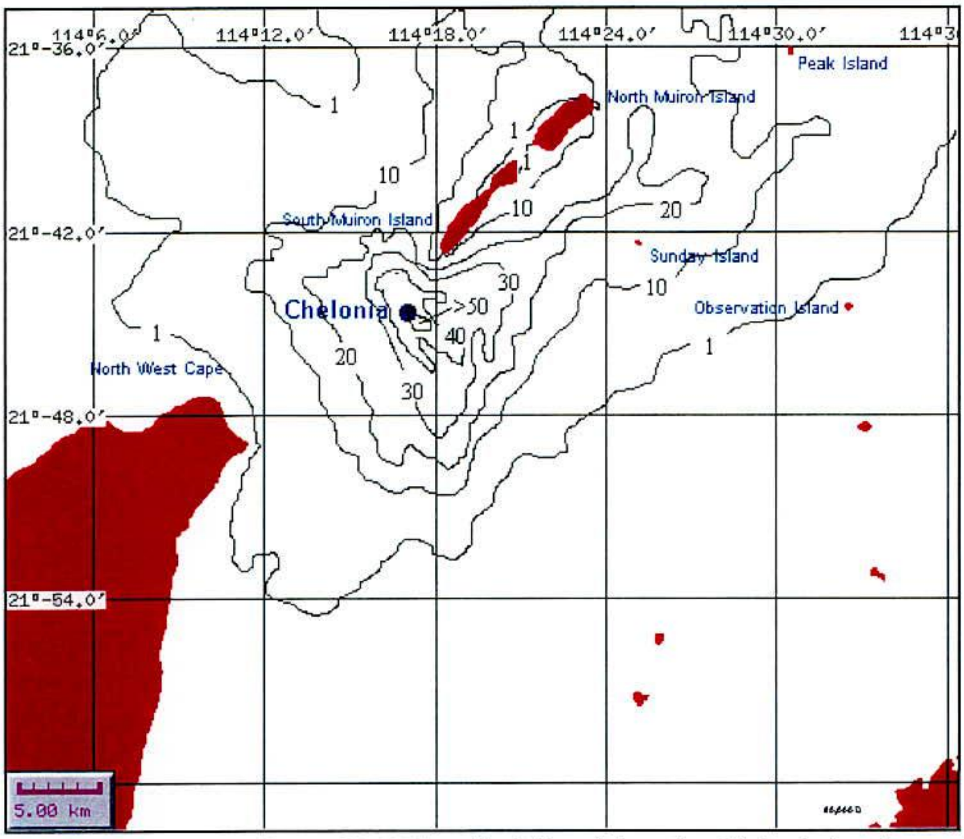


Figure 24c: Probability contours for an 80,000 L spill of diesell from the Chelonia location under summer conditions.

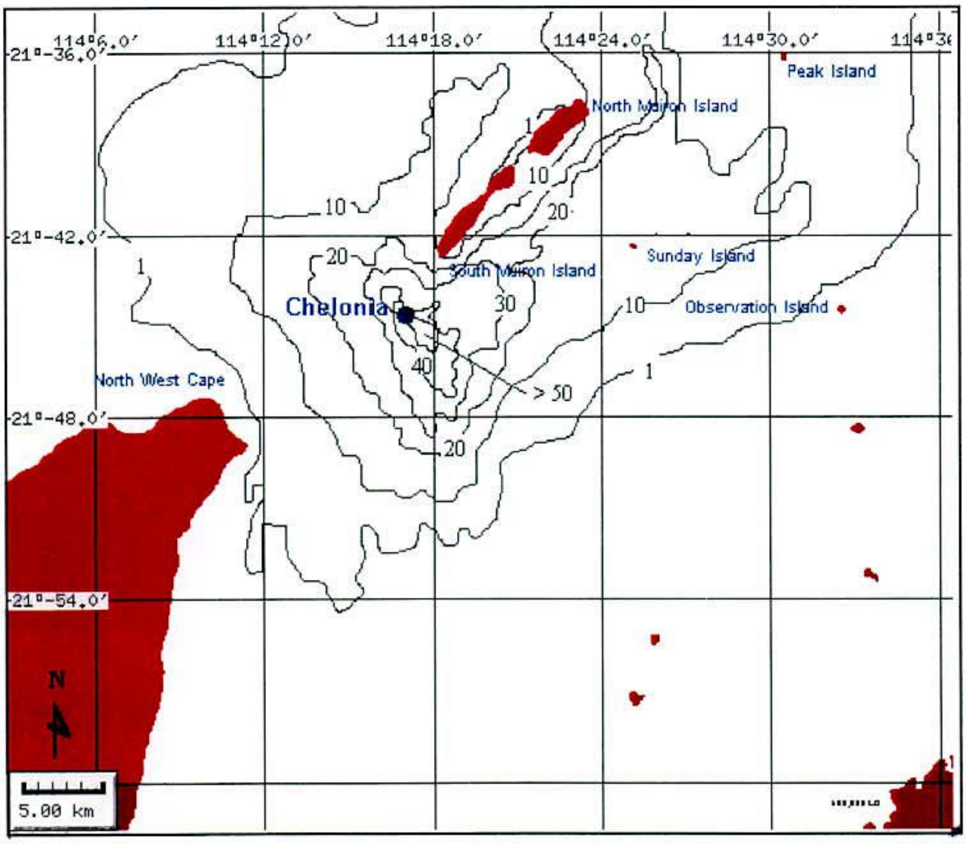


Figure 24d: Probability contours for a 600,000 L spill of light crudel from the Chelonia location under summer conditions.

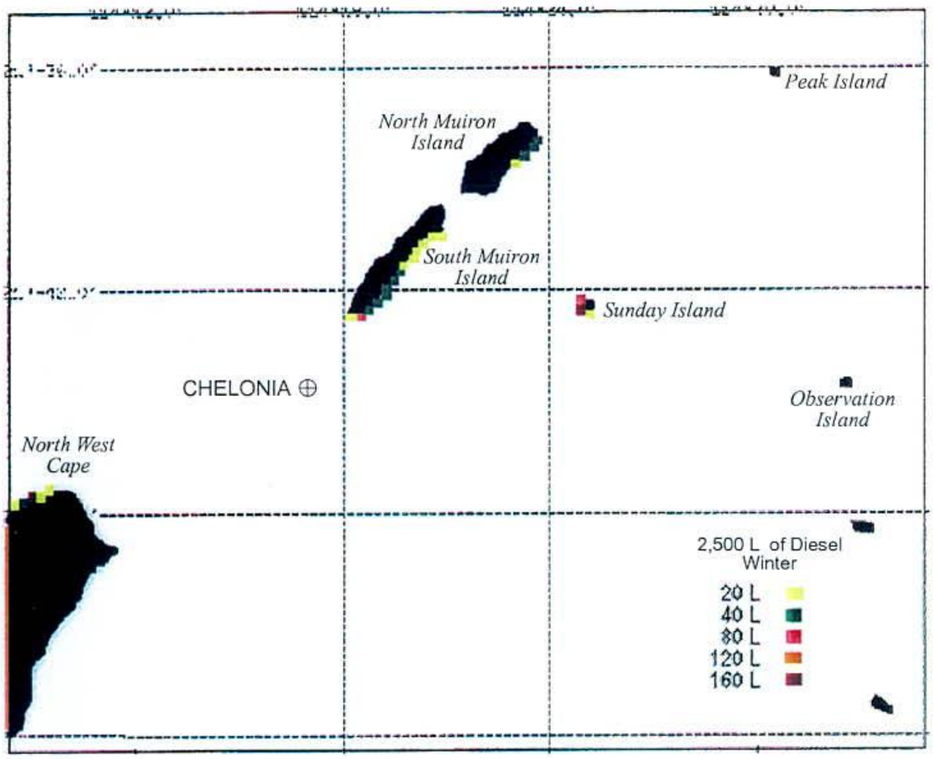


Figure 25a: Predicted volume of diesel which could contact shoreline resources from a 2,500 L spill under winter conditions. Volumes are the worse case scenarios over 100 spills. They do not indicate the volume of oil which would contact shorelines for every tide or wind current.

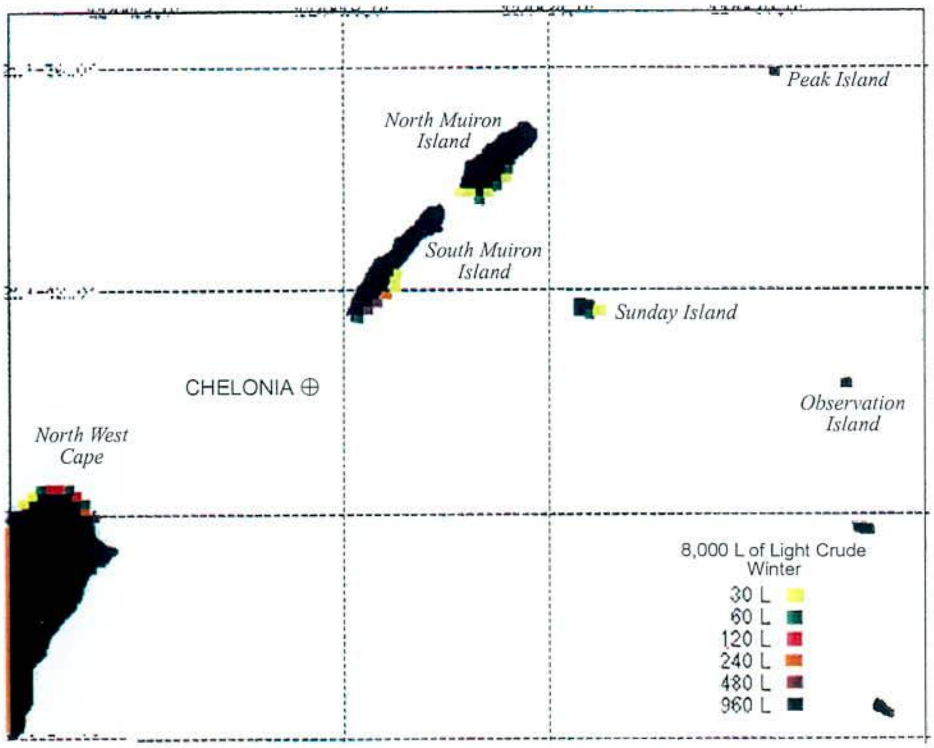


Figure 25b: Predicted volume of light crude which could contact shoreline resources from an 8,000 L spill under winter conditions.

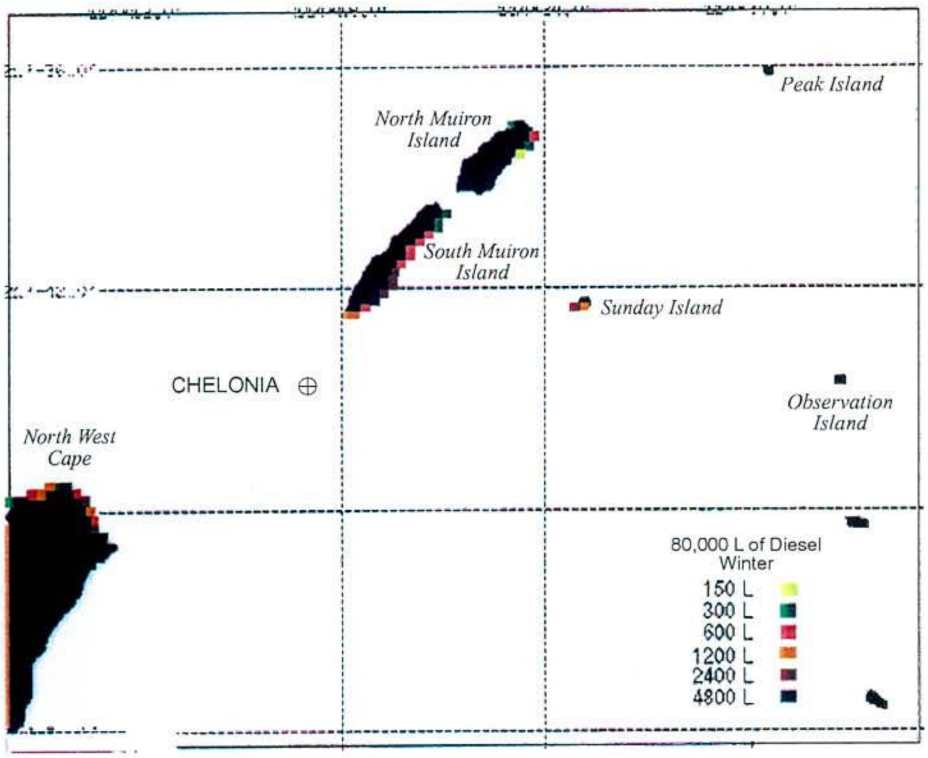


Figure 25c: Predicted volume of diesel which could contact shoreline resources from an 80,000 L spill under winter conditions. Based on the worse case scenarios over 100 spills.

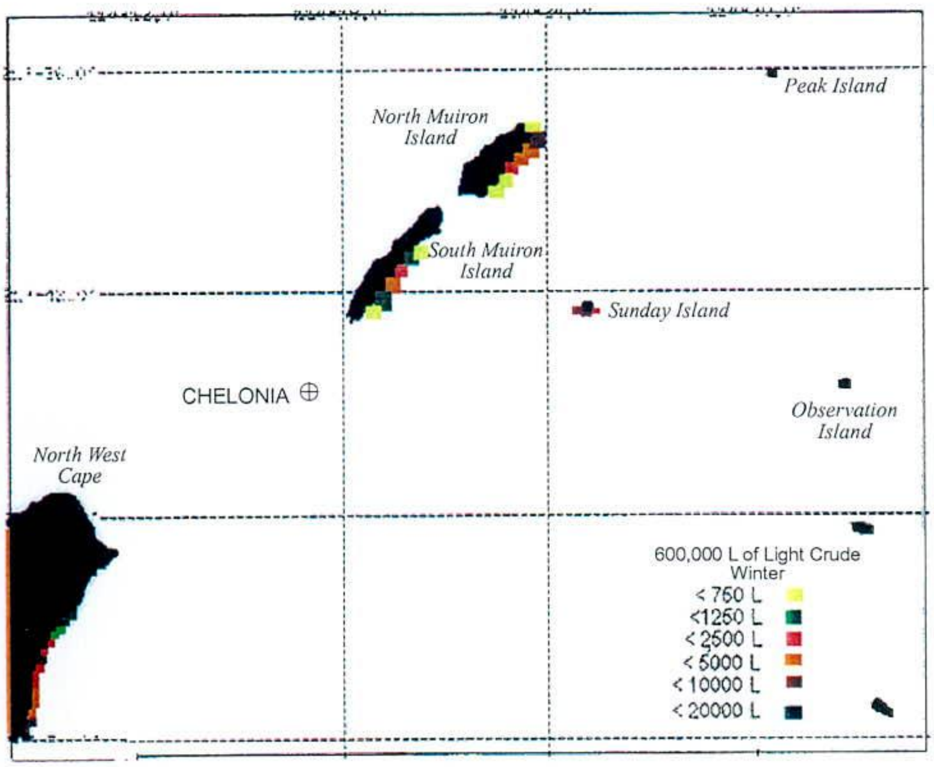


Figure 25d: Predicted volume of light crude which could contact shoreline resources from a 600,000 L spill under winter conditions.

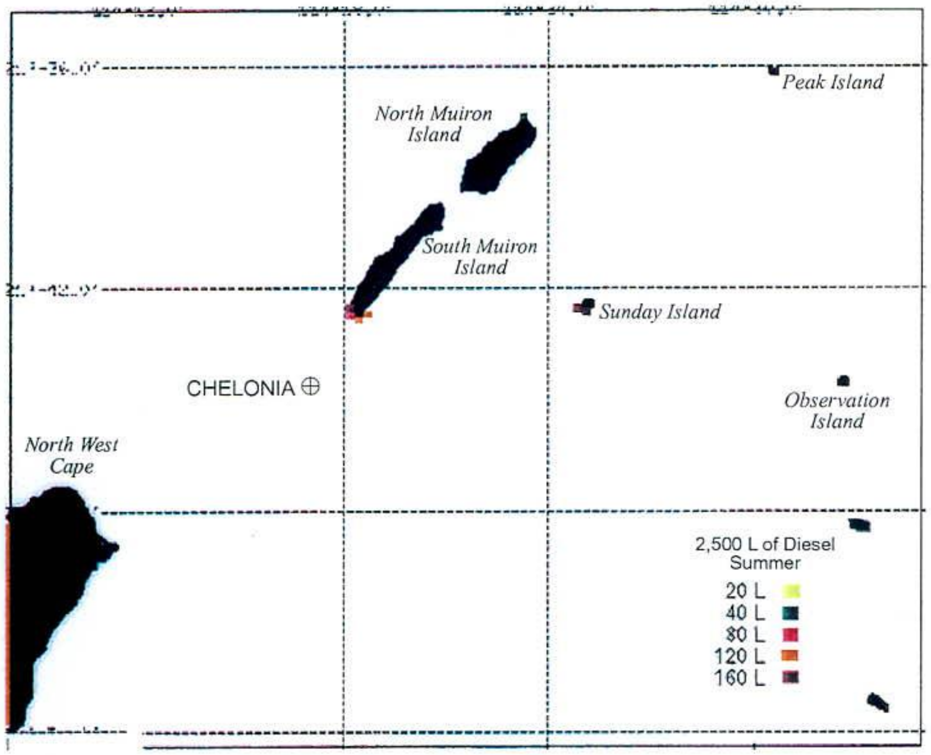


Figure 26a: Predicted volume of diesel which could contact shoreline resources from an 2,500 L spill under summer conditions. Volumes are the worse case scenarios over 100 modelled spills. They do not indicate the volume of oil which would contact shorelines for every tide or wind change.

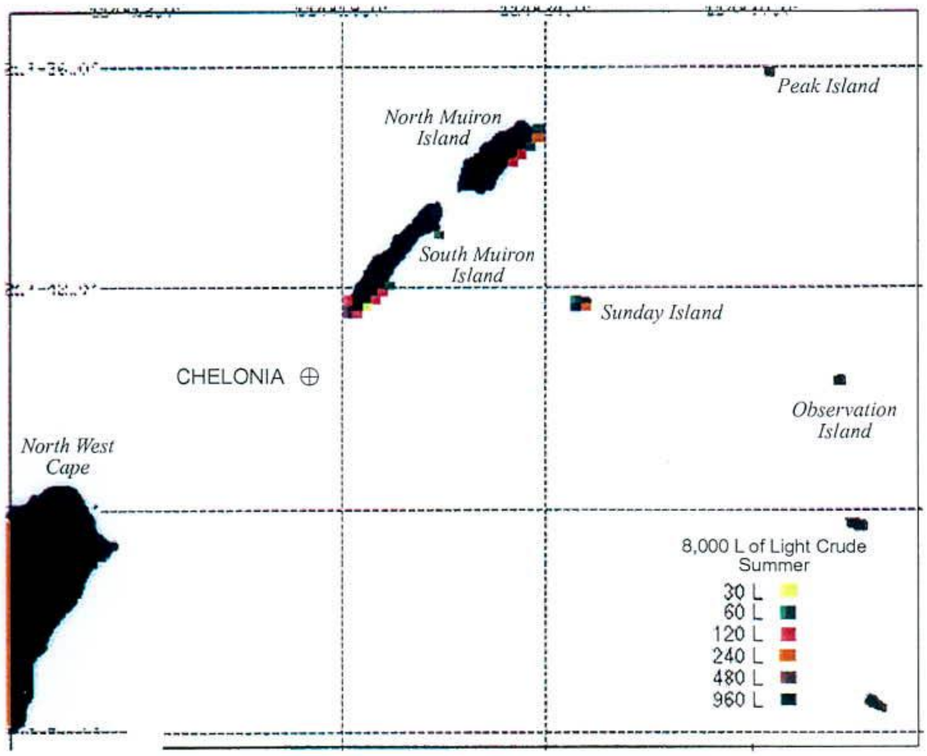


Figure 26b: Predicted volume of light crude which could contact shoreline resources from an 8,000 L spill under summer conditions.

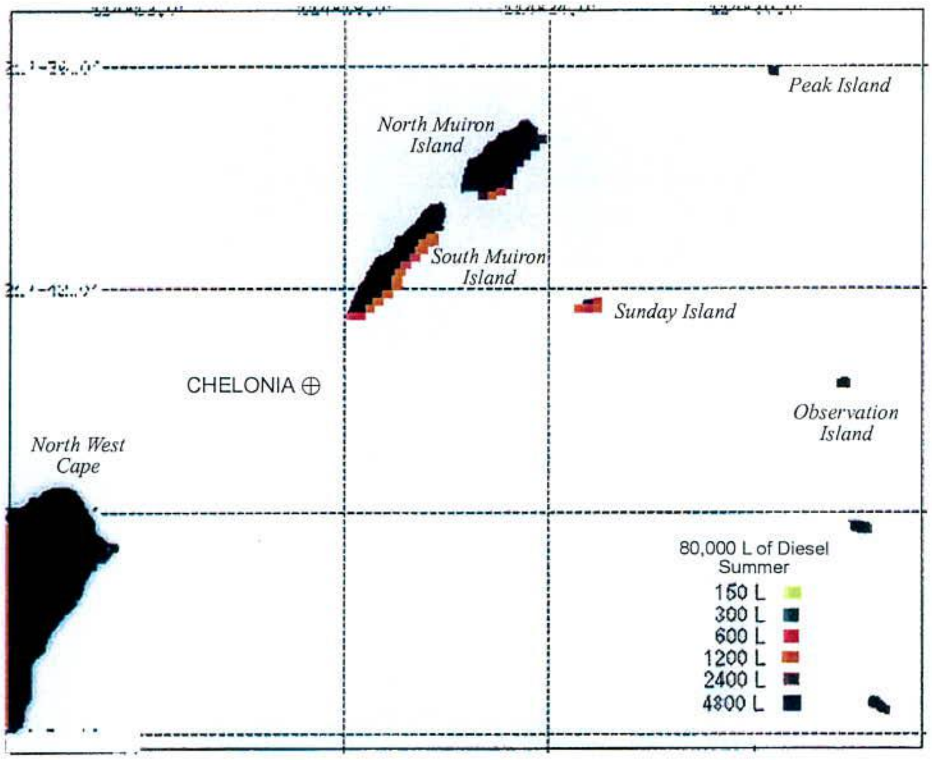


Figure 26c: Predicted volume of diesel which could contact shoreline resources from an 80,000 L spill under summer conditions. Based on the worse case scenarios over 100 modelled spills.

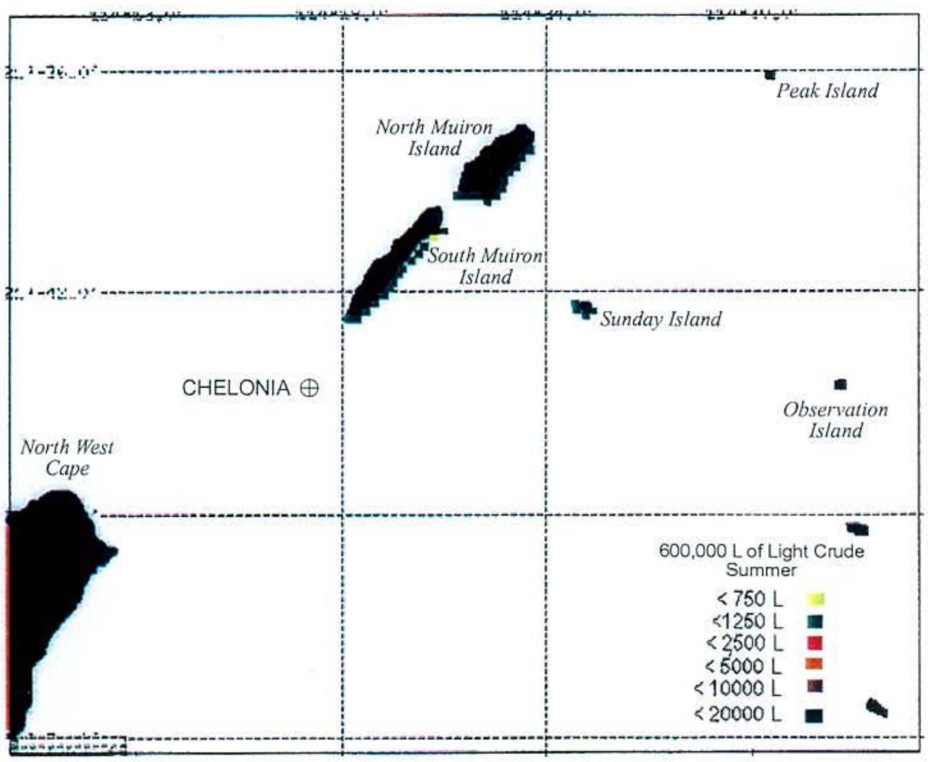
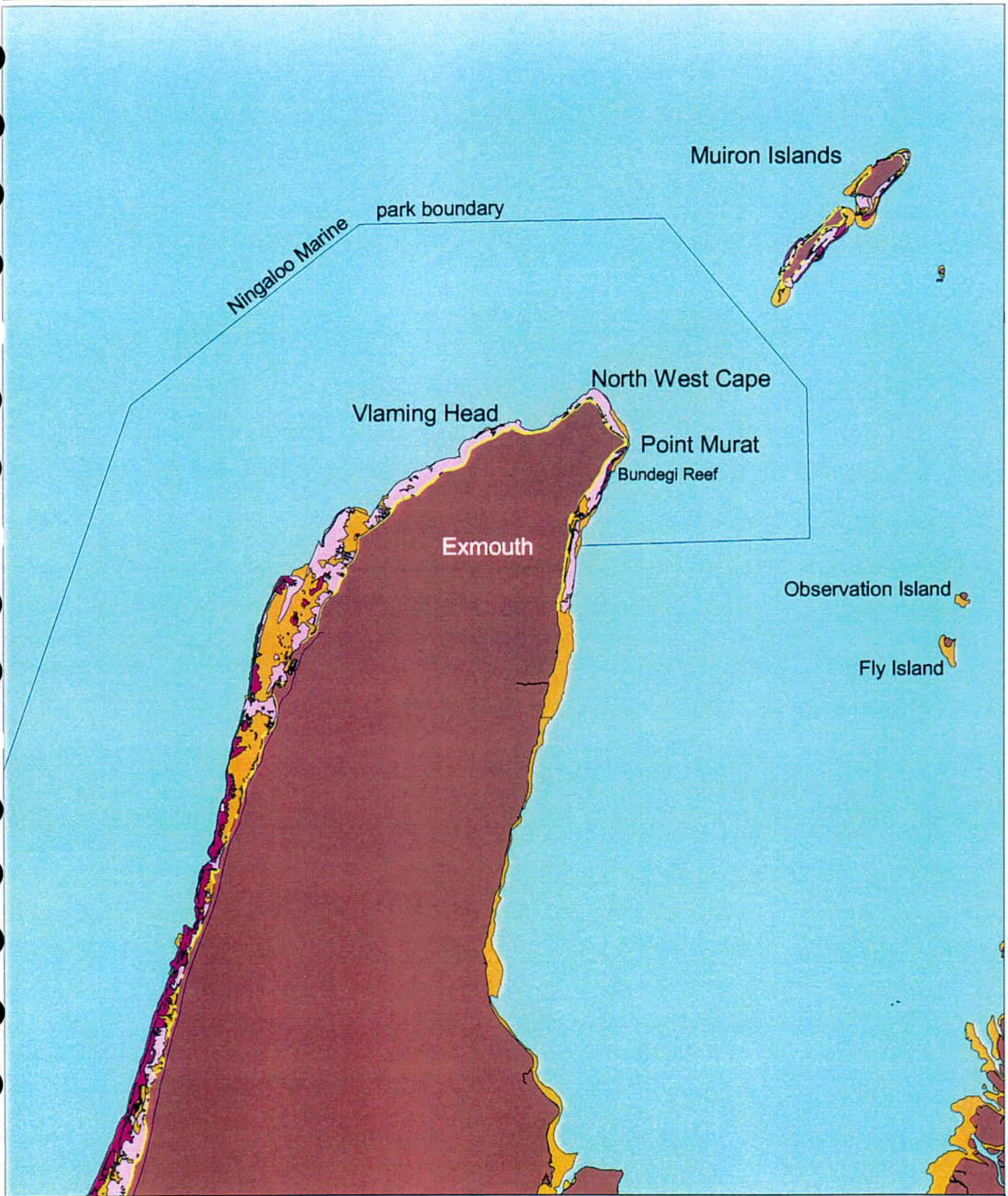


Figure 26d: Predicted volumes of light crude which could contact shoreline resources from a 600,000 L spill under summer conditions.



Marine habitats surrounding North West Cape

N

0 8 16 24 Kilometers

Apache ENERGY

Scale 1:400000

Sandy beaches	Coral communities
Intertidal reef flats	Mangroves
Subtidal pavement with macroalgae	
Intertidal sand	Ningaloo Marine Park boundary
Subtidal sand	
Supratidal	

Author: SKL	Date : 16/6/1998	DRAWING No
Drawn By:		Template/layout 36

Figure 27

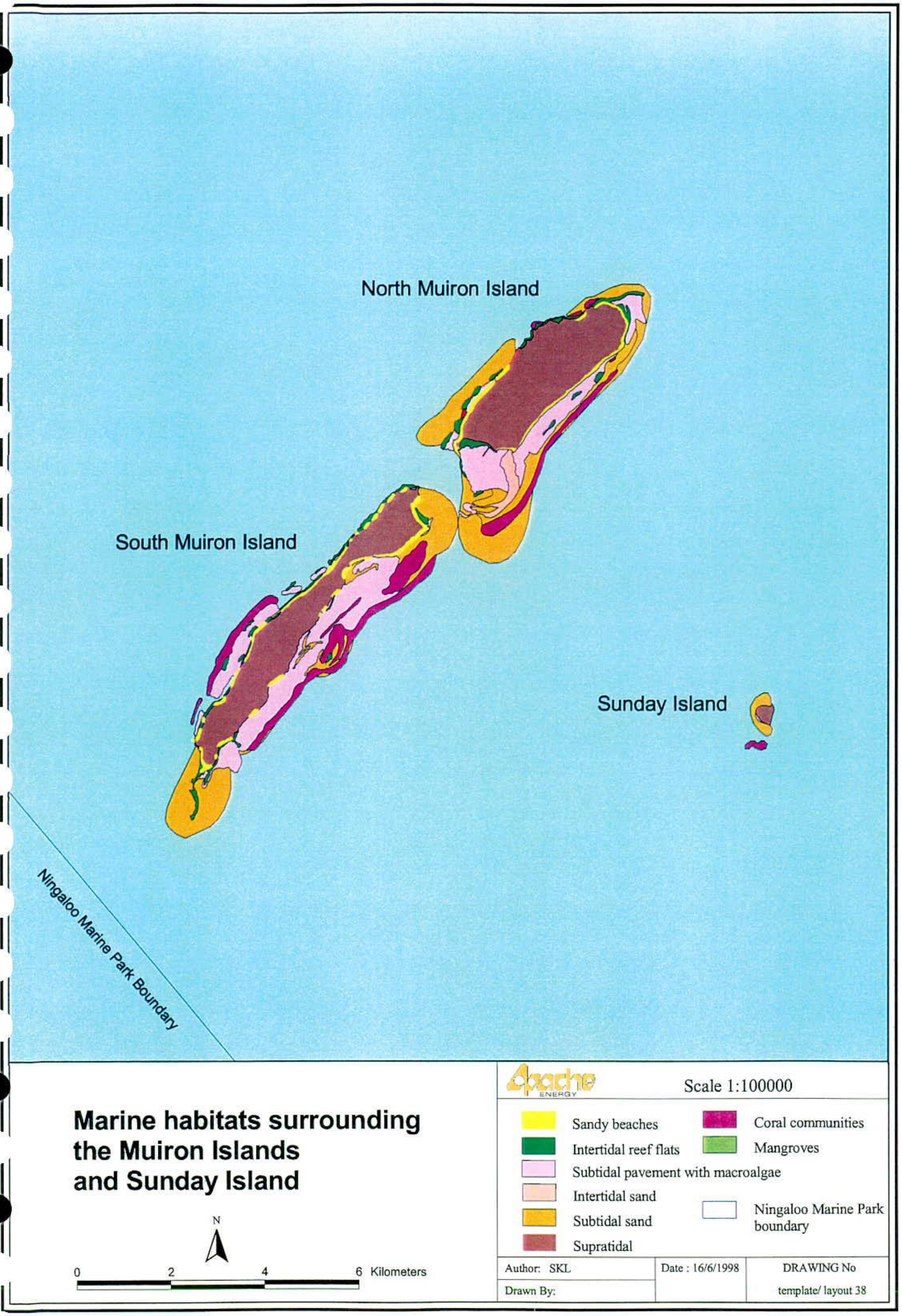
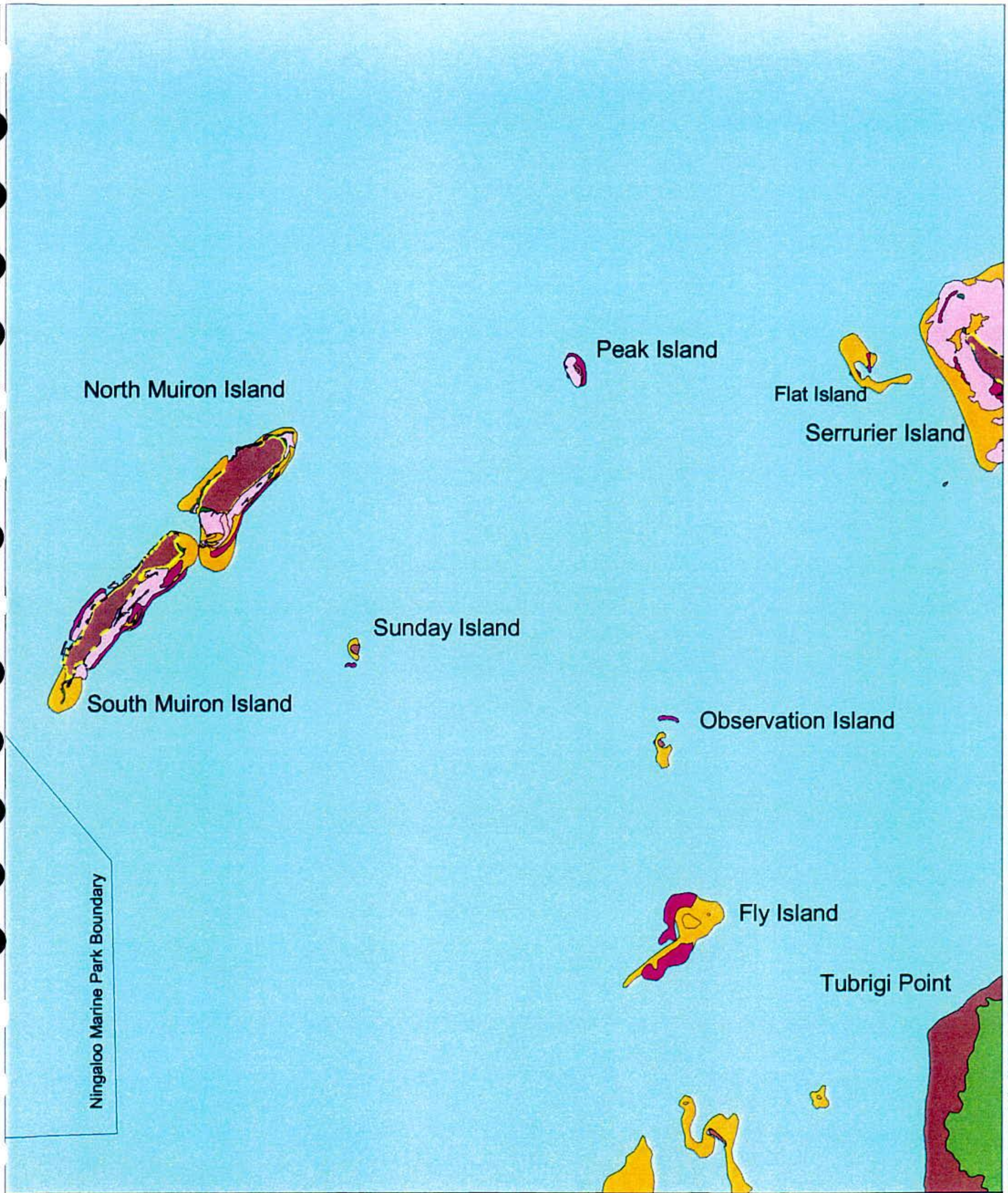

North Muiron Island
South Muiron Island
Sunday Island
Ningaloo Marine Park Boundary
Marine habitats surrounding the Muiron Islands and Sunday Island
N
0
2
4
6 Kilometers
Scale 1:100000
Sandy beaches
Intertidal reef flats
Subtidal pavement with macroalgae
Intertidal sand
Subtidal sand
Supratidal
Coral communities
Mangroves
Ningaloo Marine Park boundary
Author: SKL
Drawn By:
Date : 16/6/1998
DRAWING No
template/ layout 38

Figure 28



Marine habitats surrounding the Muiron Islands, Peak Island, Sunday Island, Observation Island and Serrurier Island

N

0 4 8 12 Kilometers

Apache ENERGY

Scale 1:220000

- Sandy beaches
- Coral communities
- Intertidal reef flats
- Mangroves
- Subtidal pavement with macroalgae
- Intertidal sand
- Subtidal sand
- Supratidal
- Ningaloo Marine Park boundary

Author: SKL	Date : 16/6/1998	DRAWING No
Drawn By:		template/layout 42

Figure 29

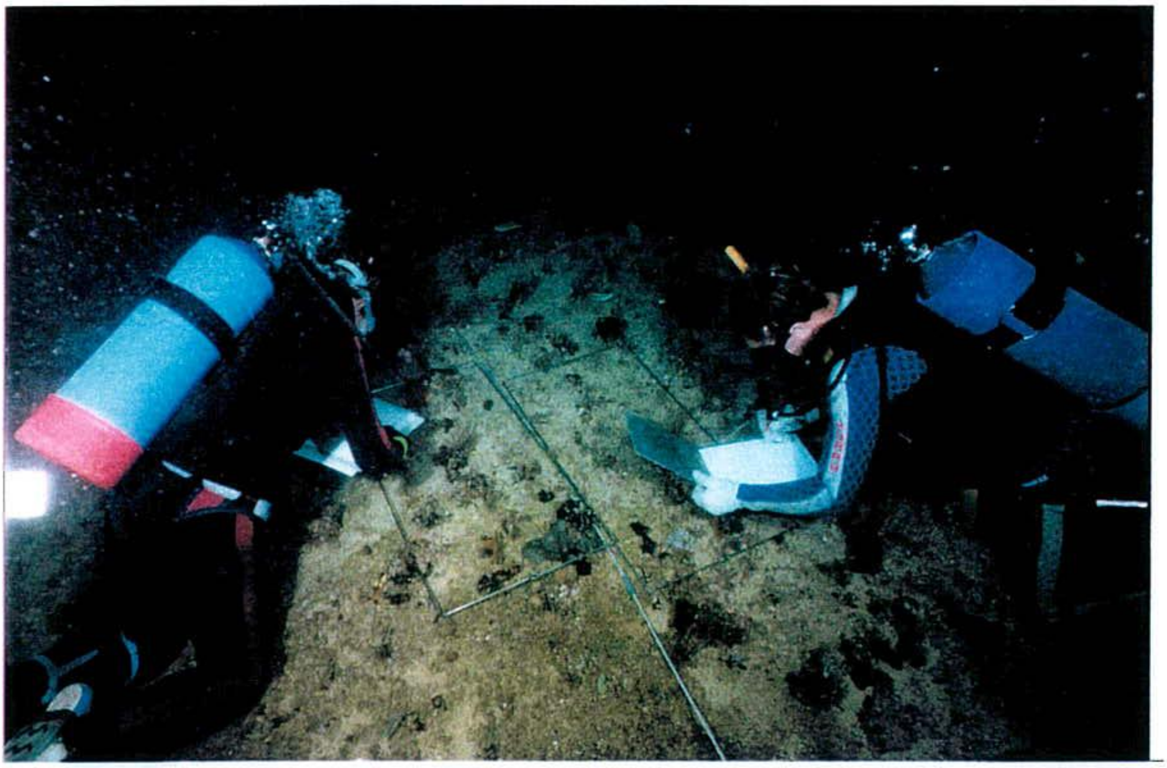


Plate 1: Monitoring of the seabed adjacent to the Loggerhead-1 well location which is about 50m away from the proposed Chelonia location.

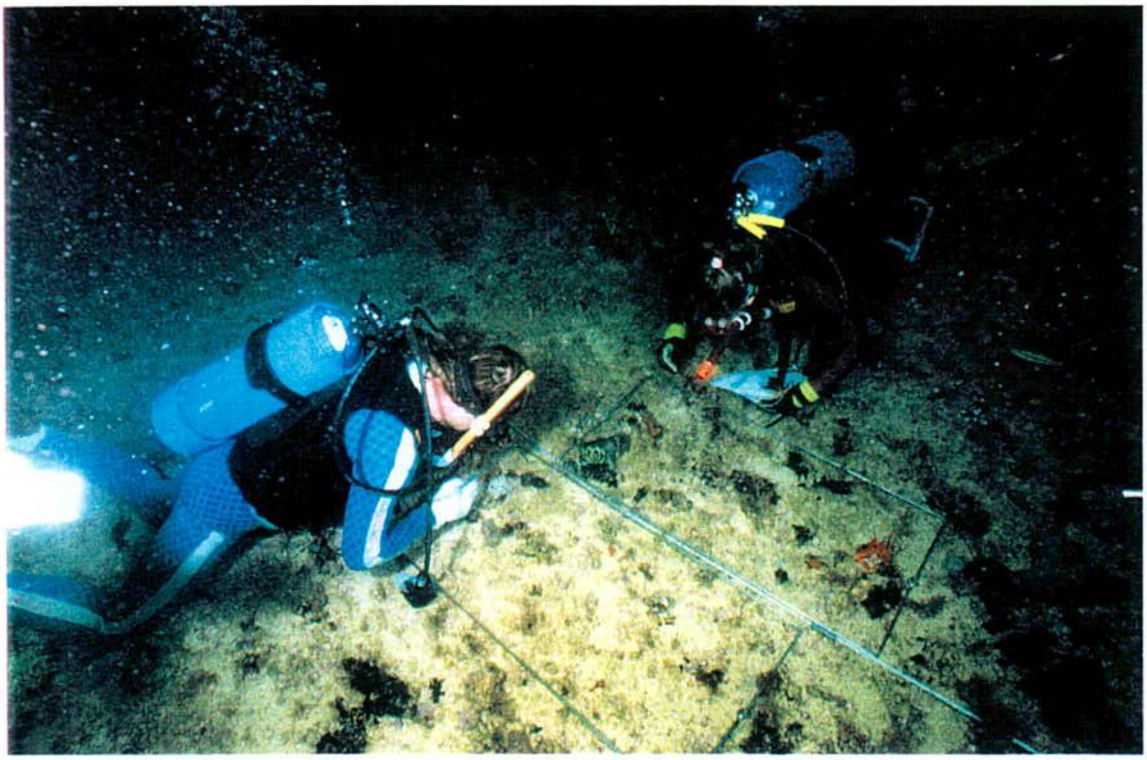


Plate 2: The seabed consists mainly of sparsely distributed filter feeding fauna such as sponges, ascidians and bryozoans on sand veneer limestone.

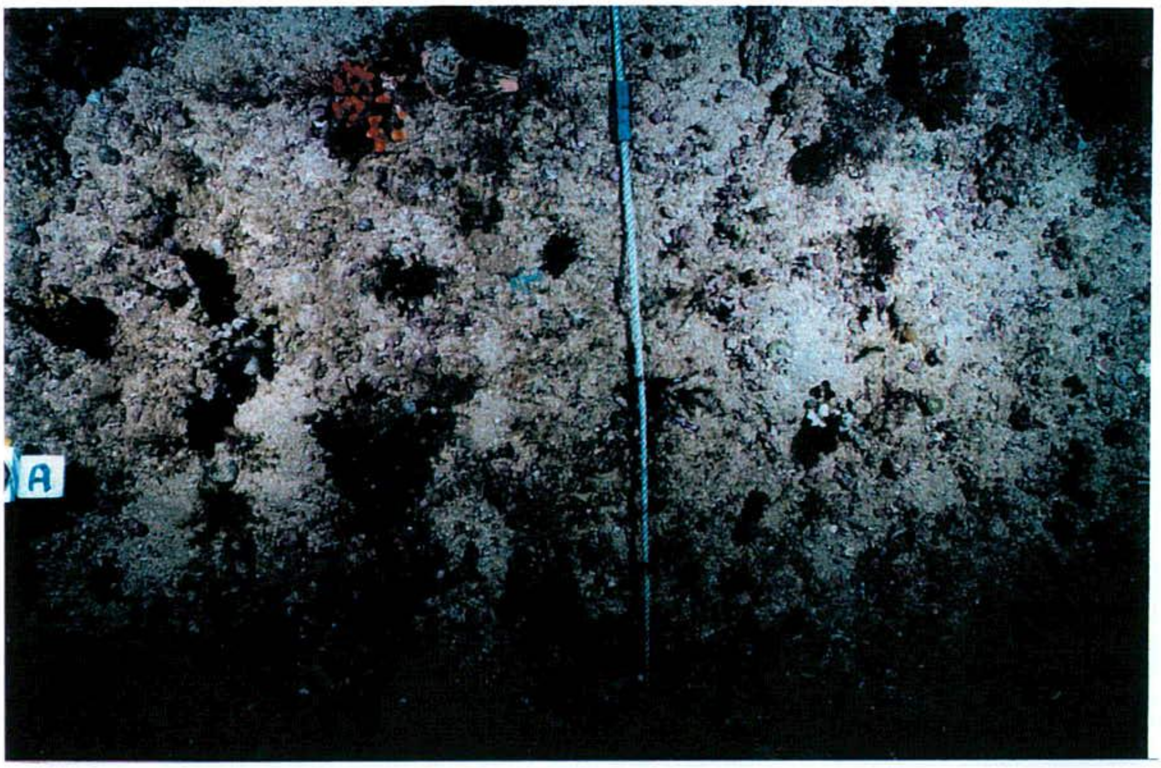


Plate 3: The seabed found around the location of the proposed Chelonia exploration wells.

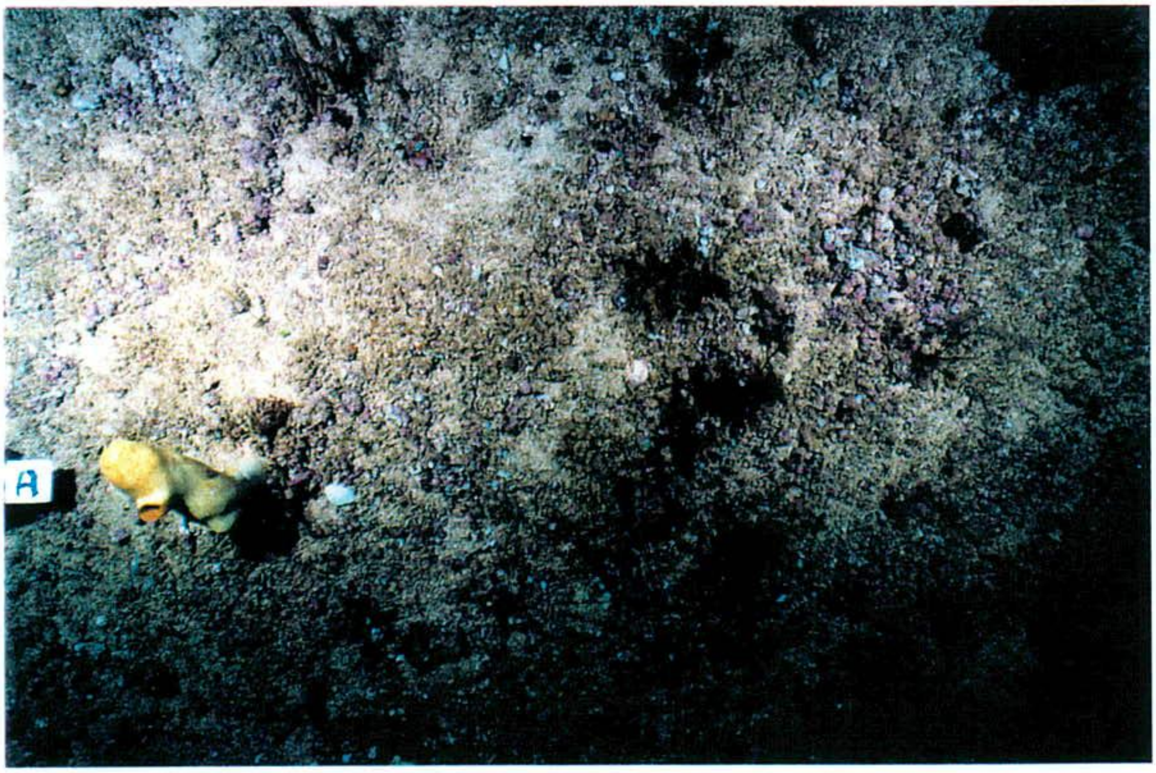


Plate 4: The seabed found around the location of the proposed Chelonia exploration wells.

APPENDIX 1

EPA Guidelines

Environmental Protection Authority

Consultative Environmental Review
Final Guidelines

CHELONIA-1 AND CHELONIA-2 EXPLORATION WELLS
NORTH WEST SHELF

APACHE NORTHWEST PTY LTD

(Assessment Number 1170)

Part A	Specific Guidelines for the preparation of the Consultative Environmental Review
Part B	Generic Guidelines for the preparation of an environmental review document

Attachment 1	Example of the invitation to make a submission
Attachment 2	Advertising the environmental review
Attachment 3	Project location

These guidelines are provided for the preparation of the proponent's environmental review document. The specific environmental factors to be addressed are identified in Part A. The generic guidelines for the format of an environmental review document are provided in Part B.

A key proposal characteristics table and environmental commitments in tabular form as per the examples in Part 'B' of these guidelines <u>must</u> be provided as part of the environmental review document for approval prior to public review.

Part A: Specific Guidelines for the preparation of the Consultative Environmental Review

1. The proposal

Apache Northwest Pty Ltd (the proponent) intends to drill two exploration wells, Chelonia-1 and Chelonia-2, in Permit Area EP342 which is located at the head of Exmouth Gulf approximately 4 km to the SSW of South Muiron Island. The Chelonia-1 well will be drilled initially and, if hydrocarbons are encountered, the drill string will be pulled back and sidetracked to drill the second well, Chelonia-2. The proposed surface location of the wells is illustrated in Attachment 3.

Both wells will be directionally drilled to an estimated vertical depth of 2 582 metres. The wells will have the same surface location, situated approximately 111 metres outside the Ningaloo Marine Park boundary and within 50 metres of the Loggerhead-1 well which was drilled in 1992. The drilling target is located below the Ningaloo Marine Park.

The proposal is for exploration drilling only. The wells will be production tested and, should a resource be discovered in commercial quantities, the wells will be sealed and suspended. The wells will then require additional environmental assessment prior to any further development.

2. Environmental factors relevant to this proposal

At this preliminary stage, the Environmental Protection Authority (EPA) believes the relevant environmental factors, objectives and work required is as detailed in the table below:

CONTENT	SCOPE OF WORK	
Factor	**EPA objective**	**Work required for CER**
BIOPHYSICAL		
Coral reefs	Maintain the abundance, species diversity and geographic distribution of coral reefs.	Provide baseline information on coral reefs in the vicinity of the wells, and on their conservation significance in a local and regional context. Assess potential impacts (direct and indirect) on coral reefs which may occur as a result of the project. Provide details of proposed management measures to meet the objectives.
Seafloor	Maintain the biodiversity of the sea floor and ensure that impacts on locally significant marine flora and fauna communities are avoided.	Provide baseline information on the seafloor in the vicinity of the wells. Assess potential impacts on the seafloor in the vicinity of the wells which may occur as a result of the project. Provide details of proposed management measures to meet the objective

Island shorelines	Maintain the biodiversity, productivity and geographic distribution of the plants and animals of the island shore.	Provide information on the island shorelines in the vicinity of the wells. Assess potential impacts on the island shorelines in the vicinity of the wells which may occur as a result of the project. Provide details of proposed management measures to meet the objective.
Mangroves	Maintain the biodiversity, productivity and geographic distribution of the plants and animals of the mangroves, saltmarshs and mudflats.	Provide baseline information on mangrove communities in the vicinity of the wells, and on their conservation significance in a local and regional context. Assess potential impacts (direct and indirect) on mangrove communities which may occur as a result of the project. Provide details of proposed management measures to meet the objectives.
Marine fauna	To avoid impacts on marine fauna and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	Provide information on the populations of marine fauna which currently utilise the area, including species utilised for commercial purposes (the drill site is located within the Area A Exmouth Gulf Prawn Fishery). Assess potential impacts (direct and indirect) on marine fauna and their habitats which may occur as a result of the project (including any potential impacts on the Exmouth Gulf Prawn Fishery). Provide details of proposed management measures to meet the objective and relevant legislation.
Seabirds	To avoid impacts on seabirds and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	Provide information on the populations of seabirds which currently utilise the area. Assess potential impacts (direct and indirect) on seabirds and their habitats which may occur as a result of the project. Provide details of proposed management measures to meet the objective and relevant legislation.

POLLUTION MANAGEMENT		
Hydrocarbons (from spills)	Ensure that the risk of hydrocarbon spills is extremely low, that actions are taken to reduce identified risks, and that drilling operations and equipment are at the level of international best practice for drilling in environmentally sensitive areas.	Provide information on the probability of hydrocarbon spillage or leakage from the proposed well and associated equipment (including ships), including the risk of leakage after the well is plugged and abandoned. Provide details of proposed management measures to meet the objectives. This should include information on the oil spill contingency plan and site specific best management requirements.
Drilling fluids	Ensure that the probability of spillage is extremely low, that actions are taken to reduce identified risks, and that drilling operations and equipment are at the level of international best practice for drilling in environmentally sensitive areas.	Provide information on the nature and toxicity of drilling fluids to be used, and on the probability of spillage or leakage of drilling fluids. Provide details of proposed management measures to meet the objectives including site specific best practice requirements.
Drilling cuttings	Ensure that drilling cuttings created by drilling do not adversely affect the surrounding environment.	Provide information on the nature, quantity and method of disposal of drilling cuttings that will be created by drilling, and the likely impact these cuttings will have on the surrounding environment. Provide details of proposed management measures to meet the objectives including site specific best practice requirements.
Other operational discharges	Ensure that operational discharges associated with the project do not adversely affect the surrounding environment.	Provide information on the nature and quantity of other operational discharges associated with the project, such as: deck drainage and oily wastes; domestic wastes; and cooling waters. Provide details of proposed management measures to meet the objectives including site specific best practice requirements.
SOCIAL SURROUNDINGS		
Ningaloo Marine Park	Protect the conservation values, biodiversity and ecosystem functions of Ningaloo Marine Park.	Assess potential impacts on the Ningaloo Marine Park which may occur as a result of the project, including the risk of pollution. Provide details of proposed management measures to meet the objectives.

These factors should be addressed within the environmental review document for the public to consider and make comment to the EPA. The EPA expects to address these factors, and others that may arise during the course of the environmental impact assessment process, in its report to the Minister for the Environment.

The EPA expects the proponent to take due care in ensuring any other relevant environmental factors which may be of interest to the public are addressed.

3. Availability of the environmental review

3.1 Copies for distribution free of charge

Supplied to DEP:

	• Library/Information Centre....................9 • EPA members....................6 • Officers of the DEP (Perth)....................6

Distributed by the proponent to:

Government departments	• Department of Minerals and Energy....................3 • Department of Conservation and Land Management....................3 • Marine Parks and Reserves Authority....................1 • WA Tourism Commission....................1 • Fisheries Department....................1 • Department of Transport....................1
Local government authorities	• Shire of Exmouth....................1
Libraries	• J S Battye Library ....3 • The Environment Centre....................2 • Exmouth Library....................2
Other	• Conservation Council of WA ....1 • Ningaloo Action Group....................1 • Cape Conservation Group....................1 • Greenpeace....................1 • Marine and Coastal Community Network 1

3.2 Available for public viewing

- J S Battye Library;
- Exmouth Library; and
- Department of Environmental Protection Library.

Part B: Generic Guidelines for the preparation of an environmental review document

1. Overview

All environmental reviews have the objective of protecting the environment. Environmental impact assessment is deliberately a public process in order to obtain broad ranging advice. The review requires the proponent to describe:

- the proposal;
- receiving environment;
- potential impacts of the proposal on factors of the environment; and
- proposed management strategies to ensure those environmental factors are appropriately protected.

Throughout the assessment process it is the objective of the Environmental Protection Authority (EPA) to help the proponent to improve the proposal so the environment is protected. The DEP will co-ordinate, on behalf of the EPA, relevant government agencies and the public in providing advice about environmental matters during the assessment of the environmental review for this proposal.

The primary purpose of the environmental review is to provide information on the proposal within the local and regional framework to the EPA, with the aim of emphasising how the proposal may impact the relevant environmental factors and how those impacts may be mitigated and managed.

The language used in the body of the environmental review should be kept simple and concise, considering the audience includes non-technical people, and any extensive, technical detail should either be referenced or appended to the environmental review. It should be noted that the environmental review will form the legal basis of the Minister for the Environment's approval of the proposal and therefore the environmental review should include a description of all the main and ancillary components of the proposal, including options where relevant.

Information used to reach conclusions should be properly referenced, including personal communications. Assessments of the significance of an impact should be soundly based rather than unsubstantiated opinion, and each assessment should lead to a discussion of the management of the environmental factor.

2. Objectives of the environmental review

The objectives of the environmental review are to:

- place this proposal in the context of the local and regional environment;
- adequately describe all components of the proposal, so that the Minister for the Environment can consider approval of a well-defined project;
- provide the basis of the proponent's environmental management programme, which shows that the environmental impacts resulting from the proposal, including cumulative impact, can be acceptably managed; and
- communicate clearly with the public (including government agencies), so that the EPA can obtain informed public comment to assist in providing advice to government.

3. Environmental management

The EPA expects the proponent to develop and implement an Environmental Management System appropriate to the proposal consistent with the principles outlined in the AS/NZS ISO 14000 series, including provisions for accountability review and a commitment to continuous improvement.

The key components which should be included in environmental review documentation, depending on the scale of the proposal, are environmental management:

- policy;
- resources budget;
- programme;
- plan(s);
- training programme;
- monitoring programme;
- contingency plan(s); and
- improvement plan(s).

Documentation on the relevant components should be proportional with the scale of the proposal and the potential environmental impacts. If appropriate, the documentation can be incorporated into a formal environmental management system and provision made for periodic performance review. Public accountability is a principle that should be incorporated into the approach on environmental management.

The environmental management programme is the key document that should be appropriately defined in an environmental review. The environmental management programme should provide plans to manage the relevant environmental factors, define the performance objectives, outline the operational procedures and outline the monitoring and reporting procedures which would demonstrate the achievement of the objectives.

4. Format of the environmental review document

The environmental review should be provided to the DEP officer for comment. At this stage the document should have all figures produced in the final format and colours.

Following approval to release the review for public comment, the final document should also be provided to the DEP in an electronic format.

The proponent is requested to supply the project officer with an electronic copy of the environmental review document for use on Macintosh, Microsoft Word Version 6, and any scanned figures. Where possible, figures should be reproducible in a black and white format.

5. Contents of the environmental review document

The contents of the environmental review should include an executive summary, introduction and at least the following:

5.1 The proposal

Justification and alternatives

- justification and objectives for the proposed development;
- the legal framework, including existing zoning and environmental approvals, and decision making authorities and involved agencies; and
- consideration of alternative options.

Key characteristics

The Minister's statement will bind the proponent to implementing the proposal in accordance with any technical specifications and key characteristics[1] in the environmental review document. It is important therefore, that the level of technical detail in the environmental review, while sufficient for environmental assessment, does not bind the proponent in areas where the project is likely to change in ways that have no environmental significance.

Include a description of the components of the proposal, including the nature and extent of works proposed. This information could be presented in the form of a table as follows:

Table 1: Key characteristics (example only)

Element	Description
Life of project (mine production)	55 months
Size of ore body	682 000 tonnes
Area of disturbance	100 hectares
Ore mining rate • maximum • average	 • 200 000 tonnes per year • 160 000 tonnes per year
Background gamma radiation levels • maximum • average	 • 0.52 μGrey per hour • 0.16 m 0.08 μGrey per hour
Water supply • source • maximum hourly requirement • maximum annual requirement	 • Yarloop borefield, shallow aquifer • 180 cubic metres • 1 000 000 cubic metres
Heavy mineral concentrate transport • truck movements (maximum)	 • 75 return truck loads per week

[1] Changes to the key characteristics of the proposal following final approval, would require assessment of the change and can be treated as non-substantial and approved by the Minister, if the environmental impacts are not significant. If the change is significant, it would require assessment under section 38 or section 46. Changes to other aspects of the proposal are generally inconsequential and can be implemented without further assessment. It is prudent to consult with the Department of Environmental Protection about changes to the proposal.

The key characteristics table should be supplemented with figures to ensure that the proposal is clearly explained. Figures that should always be included are:

- a map showing the proposal in the local context - an overlay of the proposal on a base map of the main environmental constraints;
- a map showing the proposal in the regional context;

and, if appropriate:

- a process chart / mass balance diagram showing inputs, outputs and waste streams.

All figures should include a north arrow, a scale bar, a legend, grid co-ordinates, the source of the data, a title and (where applicable) the date of aerial photo.

Other logistics

- timing and staging of project; and
- ownership and liability for waste during transport, disposal operations and long-term disposal (where appropriate to the proposal).

5.2 Environmental factors

The environmental review should focus on the relevant environmental factors for the proposal, and these should be agreed in consultation with the EPA and DEP and relevant public and government agencies. Preliminary environmental factors identified for the proposal are shown in Part A of these guidelines.

Further environmental factors may be identified during the preparation of the environmental review, therefore on-going consultation with the EPA, DEP and other relevant agencies is recommended. The DEP can advise the proponent on the recommended EPA objective for any new environmental factors raised. Minor matters which can be readily managed as part of normal operations for the existing operations or similar projects may be briefly described.

Items that should be discussed under each environmental factor are:

- a clear definition of the area of assessment for this factor;
- the EPA objective for this factor;
- a description of what is being affected - why this factor is relevant to the proposal;
- a description of how this factor is being affected by the proposal - the predicted extent of impact;
- a description of where this factor fits into the broader environmental / ecological context (only if relevant - this may not be applicable to all factors);
- a straightforward description or explanation of any relevant standards / regulations / policy;
- environmental evaluation - does the proposal meet the EPA's objective as defined above;
- if not, environmental management proposed to ensure the EPA's objective is met;
- predicted outcome.

The proponent should provide a summary table of the above information for all environmental factors, under the three categories of biophysical, pollution management and social surroundings:

Table 2: Environmental factors and management (example only)

Environ-mental Factor	EPA Objective	Existing environment	Potential impact	Environ-mental management	Predicted outcome
BIOPHYSICAL					
vegetation community types 3b and 20b	Maintain the abundance, species diversity, geographic distribution and productivity of vegetation community types 3b and 20b	Reserve 34587 contains 45 ha of community type 20b and 34 ha of community type 3b	Proposal avoids all areas of community types 20b and 3b	Surrounding area will be fully rehabilitated following construction	Community types 20b and 3b will remain untouched Area surrounding will be revegetated with seed stock of 20b and 3b community types
POLLUTION MANAGEMENT					
Dust	Ensure that the dust levels generated by the proposal do not adversely impact upon welfare and amenity or cause health problems by meeting statutory requirements and acceptable standards	Light industrial area - three other dust producing industries in close vicinity Nearest residential area is 800 metres	Proposal may generate dust on two days of each working week.	Dust Control Plan will be implemented	Dust can be managed to meet EPA's objective
SOCIAL SURROUNDINGS					
Visual amenity	Visual amenity of the area adjacent to the project should not be unduly affected by the proposal	Area already built-up	This proposal will contribute negligibly to the overall visual amenity of the area	Main building will be in 'forest colours' and screening trees will be planted on road	Proposal will blend well with existing visual amenity and the EPA's objective can be met

5.3 Environmental management commitments

The implementation of the proposal and all commitments made by the proponent become legally enforceable under the conditions of environmental approval issued in the statement by the Minister for the Environment. All the key environmental management commitments should be consolidated in the public review document in a list (usually in an Appendix). This list is attached to the Minister's statement and becomes part of the conditions of approval.

The proponent's compliance with the key environmental management commitments will be audited by the DEP, so they must be expressed in a way which enables them to be audited.

A commitment needs to contain most of the following elements to be auditable:

- who (eg. the proponent)
- will do what (eg. prepare a plan, take action)

- why (to meet an environmental objective)
- where/how (detail the action and where it applies)
- when (in which phase, eg. before construction starts)
- to what standard (recognised standard or agency to be satisfied)
- on advice from (agency to be consulted).

The proponent may make other commitments, which address less significant or non-environmental matters, to show a commitment to good general management of the project. Such commitments would not normally be included in the list appended to the statement. The EPA expects that the proponent will audit these commitments by internal processes. Though the DEP would not subject the less significant environmental commitments to routine audit, it may periodically request that compliance with these commitments be demonstrated, so as to verify satisfactory environmental performance in the proponent's implementation of the proposal.

With the implementation of continuous improvement, the procedures to implement the commitments may need to be changed. These changes can be made in updates to the environmental management plan, whilst ensuring the objective is still achieved.

Once the proposal is approved, changes to the commitments constitute a change to the proposal and should be referred to the DEP.

Examples of the preferred format for typical commitments are shown in the following table:

Table 3: Summary of proponent's commitments (example only)

Commitment (Who/What)	Objective (Why)	Action (How/Where)	Timing (When)	Whose advice	Measurement/ Compliance criteria
1. XYZ Mining will develop a rehabilitation plan	to protect the abundance, species diversity, geographic distribution and productivity of the vegetation community types 3b and 20b	by limiting construction to a small area (10 ha) of Reserve 34587 and rehabilitating the area	before construction	CALM, NPNCA	fences built; species distribution and density consistent with vegetation community types 3b and 20b
2. XYZ Mining will minimise dust generation	to maintain the amenity of nearby land owners	by preparing and implementing a Dust Control Plan which meets EPA Dust Control criteria	before the start of construction phase	preparation: DEP; implementation: Shire	Letter from Shire submitted with Performance and Compliance Report.

Commitments should be written in tabular form, preferably with some specification of ways in which the commitment can be measured, or how compliance can be demonstrated.

Draft commitments which are not in a format that can be audited will not be accepted by project officers for public review documentation. Proponents will be assisted to revise inadequate commitments.

5.4 Public consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the environmental review. It should describe the activities undertaken, the dates, the groups/individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management of the factors which should clearly indicate how community concerns have been addressed. Those concerns which are dealt with outside the EPA process can be noted and referenced.

Attachment 1

The first page of the proponent's environmental review document must be the following invitation to make a submission, with the parts in square brackets amended to apply to each specific proposal. Its purpose is to explain what submissions are used for and to detail why and how to make a submission.

Invitation to make a submission

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

[the proponent] proposes [the rezoning of land and the development of a Marina Complex in the City of Bunbury]. In accordance with the Environmental Protection Act, a [PER] has been prepared which describes this proposal and its likely effects on the environment. The [PER] is available for a public review period of [8] weeks from **[date]** closing on **[date]**.

Comments from government agencies and from the public will help the EPA to prepare an assessment report in which it will make recommendations to government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in the EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the [PER] or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific elements of the [PER]:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the [PER];
- if you discuss different sections of the [PER], keep them distinct and separate, so there is no confusion as to which section you are considering;
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and
- whether you want your submission to be confidential.

The closing date for submissions is: **[date]**

Submissions should be addressed to:

The Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: **[Project Officer name]**

Attachment 2

Advertising the environmental review

The proponent is responsible for advertising the release and arranging the availability of the environmental review document in accordance with the following guidelines:

Format and content

The format and content of the advertisement should be approved by the DEP before appearing in the media. For joint State-Commonwealth assessments, the Commonwealth also has to approve the advertisement. The advertisement should be consistent with the attached example.

Note that the DEP officer's name should appear in the advertisement.

Size

The size of the advertisement should be two newspaper columns (about 10 cm) wide by about 14 cm long. Dimensions less than these would be difficult to read.

Location

The approved advertisement should, for CER's, appear in the news section of the main local newspaper and, for PER's and ERMP's, appear in the news section of the main daily paper's ("The West Australian") Saturday edition, and in the news section of the main local paper at the commencement of the public review period and again two weeks prior to the closure of the public review period.

Timing

Within the guidelines already given, it is the proponent's prerogative to set the time of release, although the DEP should be informed. The advertisement should not go out before the report is actually available, or the review period may need to be extended.

Example of the newspaper advertisement

SCM CHEMICALS LTD

Consultative Environmental Review

EXTENSION TO DALYELLUP RESIDUE DISPOSAL PROGRAMME

(Public Review Period: **[date]** to **[date]**)

SCM Chemicals Ltd is planning to extend the company's existing residue disposal programme at Dalyellup, south of Bunbury, from March 1992 to March 1993.

A Consultative Environmental Review (CER) has been prepared by the company to examine the environmental effects associated with the proposed development, in accordance with Western Australian Government procedures. The CER describes the proposal, examines the likely environmental effects and the proposed environmental management procedures.

SCM has prepared a project summary which is available free of charge from the company's office on Old Coast Road, Australind.

Copies of the CER may be purchased for $5 from:

SCM Chemicals Ltd
Old Coast Road
AUSTRALIND WA 6230
Telephone: (08) 9467 2356

Copies of the complete Consultative Environmental Review will be available for examination at:

- Environmental Protection Authority
  Library Information Centre
  8th Floor, Westralia Square
  38 Mounts Bay Road
  PERTH WA 6000
- Environmental Protection Authority
  65 Wittenoom Street
  BUNBURY WA 6230
- City of Bunbury public libraries
- Shire of Capel libraries
- Shire of Harvey library (Australind)
- Shire of Dardanup (Eaton)

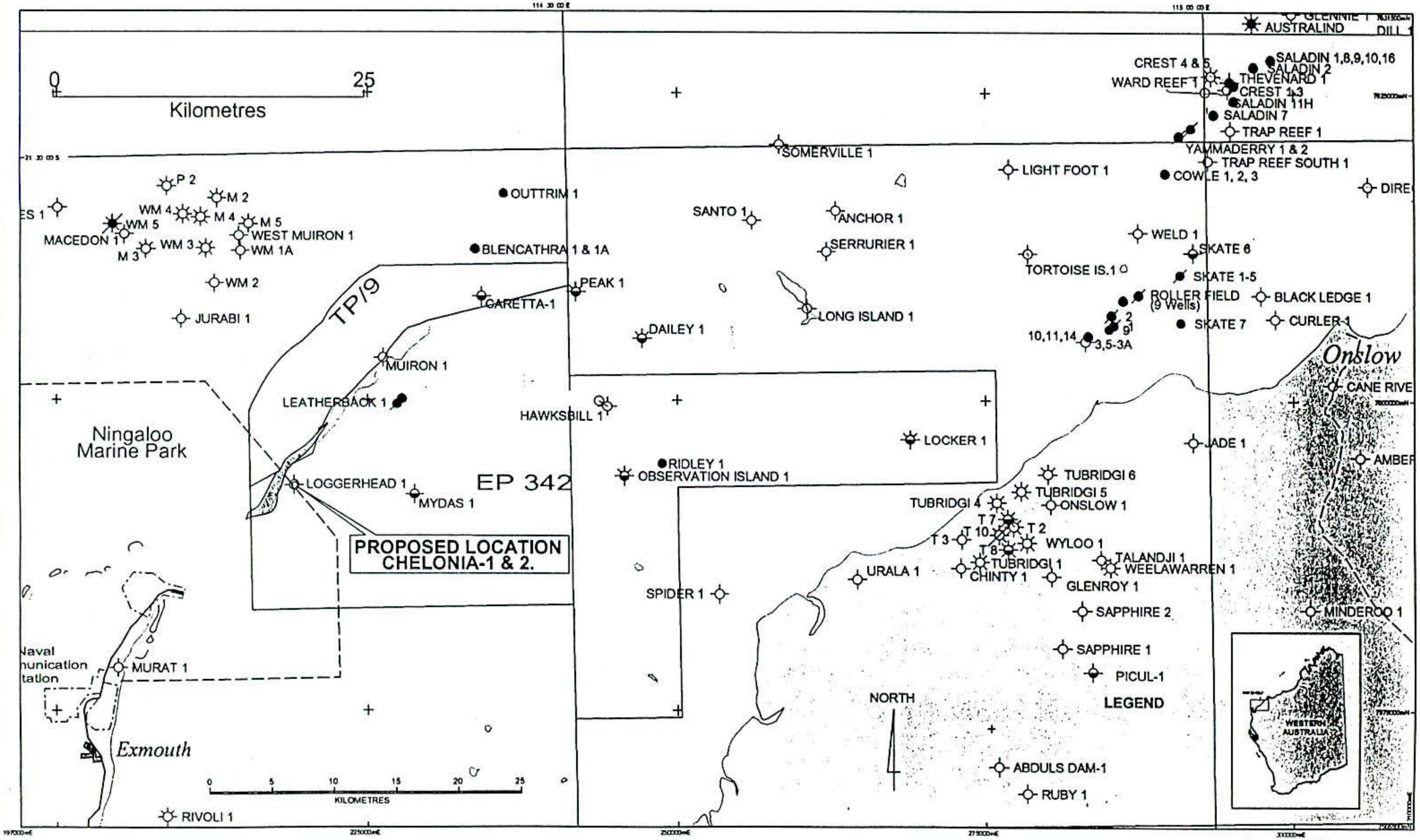
Submissions on this proposal are invited by **[closing date]**. Please address your submission to:

Chairman
Environmental Protection Authority
8th Floor, Westralia Square
38 Mounts Bay Road
PERTH WA 6000
Attention: **[Project Officer name]**

If you have any questions on how to make a submission, please ring the project officer, **[Project Officer name]**, on (08) 9222 7xxx.

EP 342 & TP/9

CHELONIA-1 & 2 DRILLSITE LOCATION MAP



Updated: 30 Sept. 1997 ISu4810

Attachment 3

APPENDIX 2

Communications strategy

EP 342 Drilling Program

Environmental Communications

1.0 Introduction

The purpose of this document is to develop a community relations program for the proposed Chelonia-1 and -2 drilling program in the Exmouth Gulf area.

Exploration and appraisal drilling in and around the Exmouth Gulf will be an emotive issue as the well surface location is adjacent to the Ningaloo Marine Park. The public perception is that offshore drilling is unsafe and unclean resulting in extensive oil spill damage and risk to human life. There is also the widespread community perception that drilling will damage the conservation values of the marine park and will occur on the Ningaloo Reef itself, damage it, and consequently damage the tourism industry.

The actions which will need to be undertaken for the Chelonia communications program include:

- identifying all stakeholders and considering their wants, needs and issues.
- identifying appropriate channels of communication.
- promoting a dialogue that allow free flow of information.
- exploring options which will accommodate community concerns or incorporate any suggestions.
- showing the commitment for environmental protection through excellent performance.

2.0 Background to Drilling in EP342

Nine wells have been drilled in EP342 since 1989. Caretta-1 and Leatherback-1 were drilled in 1991 and intersected oil columns. Caretta-1 was deemed uneconomic and abandoned. Leatherback-1 was tested and suspended as a possible oil producer. Loggerhead-1 was drilled in 1992, and Mydas-1 and Hawksbill-1 were drilled in 1993. These wells did not intersect significant hydrocarbon columns. Ridley-1 was drilled in 1996 and intersected an oil column. Leatherback-2, Sawback-1 and Longneck-1 were drilled in 1997; no hydrocarbons were encountered in any of these wells.

2.1 Proposed drilling program

Two wells are proposed to be drilled in EP342: Chelonia-1 will be drilled initially and if hydrocarbons are encountered, the drill will be pulled back and sidetracked to drill the second well, Chelonia-2.

The Chelonia drilling program has been set at a Consultative Environmental Review (CER) level of assessment.

3.0 Community Issues

The issues of concern to the Exmouth community were determined from two main sources:

- public comments on the Lasmo CER in 1991[1]; and
- comments from the public consultation program and education program carried out by Apache Energy and Hadson Energy (Apache's predecessor) which commenced in 1993.

The main areas of community concern were:

- oil spills
- no economic benefits to the local community
- lack of reasonable notice prior to drilling
- lack of environmental information on the exact drilling site
- need for adequate compensation in the case of environmental damage
- if oil found, then what
- use of dispersants
- management of discharges (drilling fluids, domestic waste).

In addition to the concerns listed above are:

- distrust of the industry in general
- eco-tourism being seen as the economic basis of the region
- oil and gas incompatible with eco-tourism
- distrust in the government being able to regulate the industry.

Apache (ex Hadson) has been carrying out an ongoing, community education and consultation program in Exmouth since 1993. The groups we have focused on so far are:

- Exmouth Council
- prawn fishermen
- Cape Conservation Group
- Ningaloo Action Group
- Exmouth high school
- Exmouth police
- Department of Conservation and Land Management
- dive shops
- private citizens.

4.0 Communications Tasks

Table 1 outlines the various groups which require consultation. Table 2 gives the general tasks needed to be carried out to obtain approval for the drilling program and for the community consultation program.

[1] Bowman Bishaw Gorham (1990). Petroleum Exploration in Permit Areas EP 342 and TP/9, Rowley Shelf, Western Australia. Consulatative Environmental Review. A report for Lasmo Oil (Australia) Ltd. Apache report H24.

Table 1: Specific groups for consultation.

Player	Needs or concerns	How we manage the need
Minister for the Environment Minister for Mines	• awareness of the project • positive media coverage	• communication • ensure due process has been carried out
DME	• ensured compliance	• submit environmental analysis report • collaborate in developing guidelines and procedures • audit report • report incidents immediately
EPA	• assessment process carried out properly • ensured compliance • positive media coverage • no public embarrassment	• ensure due process has been carried out • communication between Apache and other relevant government agencies
DEP	• pollution prevention • ensured compliance	• communication and consultation • audit report • collaborate in developing guidelines and procedures • report incidents immediately • provide detailed environmental analysis report
CALM	• protect natural resources	• communication and consultation • support research • provide environmental analysis report • report incidents immediately
Non government organisations	• protection of the environment • awareness of project	• communication and consultation • provide environmental analysis report • performance standards negotiated • site visit
Media	• selling newspapers	• communication and education
Exmouth council	• pollution prevention • economic benefits • eco-tourism important • awareness of project	• communication and consultation • collaborate on drilling conditions • donations • provide environmental analysis document and audit report • site visit
Prawn fishermen	• no loss of fishing grounds due to pollution • adequate compensation • awareness of project	• communication and consultation • ample insurance
Recreational divers and fishermen	• no loss of diving or fishing area due to pollution • awareness of the project	• communication and consultation • insurance
Tourism	• No damage to livelihood	• communication • insurance
Commonwealth government	• awareness of the project	• communication

Table 2: Communication goals and action items.

Goal		**Action**	**Who**	**When**
1	Obtain the drilling approval in a timely manner.	Pre-submission: • develop approval strategy in conjunction with DME and DEP • preparation of site specific information • meetings with key government agencies DME, DEP, CALM, Ministers for Mines - Env. Post-submission: • submission of document to relevant government and community groups		
2	Maintain an open, 'no-surprises' approach with the government and the community in general, and specific community groups about the drilling program. Determine and consider the issues of concern to the community.	• present overview of program at same time as submission of document State Govt (DME, DEP, CALM, Ministers) Local Govt (Exmouth Shire Council) High school Dive shops, police WAFIC, prawn fishing industry Conservation groups (Exmouth and Perth) • fact sheet for program distribution: library, council offices, school tourism office, CALM office • video footage and stills of proposed sites • article in local community papers • advice on local radio • community visits - Exmouth • close out meetings at end of drilling program		
3	Involve the government and the community in activities which provide them with ownership of the project.	• independent auditor nominated by community		

Goal		Action	Who	When
4	Demonstrate the technological capacity to carry out drilling activities with negligible risk to the environment to ensure no unnecessary, costly requirements are attached to the drilling program.	• Risk assessment carried out • Actions to manage risk		
5	Provide acceptable concessions to the government and the local community for the right to drill.	• insurance • measurable attributes developed in conjunction with govt, conservation groups and Exmouth Shire • donation? • local research support via Calm		
6	Manage the direction of media coverage, and respond to any coverage effectively and expediently.	• develop media strategy		

APPENDIX 3

Petrofree handling procedure

8. Workboat And Rig Preparation For PETROFREE

The Workboat tanks should be cleaned by high pressure water jetting and by blowing out all circulating and transfer lines with air followed by flushing with water. Steam clean if possible. Drain excess water. Detergents for washing the tanks are not usually used. If so, it must be ascertained that all detergent residue is removed prior to mixing the mud.

Rig hoses for loading and offloading PETROFREE ester and mud should be changed if necessary or thoroughly flushed out with water and drained. Rig hoses must be suitable for oil service and pressure rated for the mud density and pump pressures required, typically 300 psi.

The rig hose should be fitted with a Avery-Hardol type non-return valve at the workboat end. This fitting must be removed before backloading PETROFREE to the workboat. All PETROFREE transfer hoses should be integrity tested with air before use.

Rig mud pits should be cleaned using high pressure water jetting and abundant flushing with seawater. Allow to drain completely. Detergents are usually not required if water-based fluids have been in use.

The rig mixing and transfer lines should be flushed out with seawater until all residual mud is removed and then drained completely.

All pits should be entered and inspected. All dump valve seals should be inspected and replaced if necessary with recommended elastomer seals. Similarly, all suction and discharge mud valves should be inspected and replaced if necessary with suitable elastomer inserts.

The BOP must use elastomer elements that have been tested to be compatible with PETROFREE ester. All other elastomers liable to come into contact with PETROFREE, eg, down-hole motor stators, mud pump swabs, standpipe hoses etc., must be compatible with PETROFREE.

The rig ester storage tank should be cleaned, flushed out, drained and dried as above.

A thorough rig audit should be carried out well in advance to determine what rig modifications and additions are required. A Rig Audit Checklist For PETROFREE Use follows.

RIG AUDIT CHECKLIST FOR USE OF PETROFREE

A. RIG FLOOR & RIG FLOOR DRAINAGE

1	Mud saver valve installed	YES/NO
2	Mud bucket	YES/NO
3	Condition of mud bucket seals	GOOD/POOR
4	Spare mud bucket seals available	YES/NO
5.	Condition of mud bucket drain line	GOOD/POOR
6	Mud bucket drain line diameter	4" / 6"
7	Mud bucket drain line properly secured	YES/NO
8	Individual shaker running lights in view of driller	YES/NO
9	Drip tray under rig floor	YES/NO
10	Drip tray drained to pits	YES/NO
11	All drains from rig floor into collection tank	YES/NO
12	Alarm on collection tank	YES/NO
13	Facility to pump tank contents to pit	YES/NO
14	Mousehole piped to collection tank	YES/NO
15	Rathole piped to collection tank	YES/NO
16	Pipe wipers available for use when tripping	YES/NO
17	Standpipe drain line	YES/NO

B. TRIP TANK

1	Capacity :	
2	Bund surrounding trip tank pump	YES/NO
3	Type of gland packings	MECHANICAL/PRESSURISED
4	Condition of gland packings	GOOD/POOR
5	Overflow line fitted to trip tank	YES/NO
6	Trip tank dump valve lockable	YES/NO
7	Trip tank dump valve type	GATE/KNIFE/BUTTERFLY
8	Drains within bunds	OPEN/SEALED

C. FLOWLINE

1	Open sections	YES/NO
2	Splash guards fitted to open sections	YES/NO

D. SOLIDS CONTROL PITS

1	Dump valve type	SCREW/KNIFE
2	Dump valves lockable	YES/NO
3	Common drain line	YES/NO
4	Master dump valve in common drain line	YES/NO
5	Suction lines recessed onto bottom of solids control pits	YES/NO
6	Facility to circulate sand traps over shakers	YES/NO
7	Solids control pits can be completely emptied without discharge to the sea	YES/NO

E. SHAKER HOUSE

1	Shaker type and number :	
2	Header box capacity :	
3	Header box configured to allow even distribution of flow over shakers	YES/NO
4	Jetting facility in header box	YES/NO
5	High pressure shaker washdown system	YES/NO
6	Cuttings retaining wall	YES/NO
7	Shaker house floor drains	OPEN/SEALED
8	Shaker house floor drains to common collection tank	YES/NO
9	Shaker house ventilation	ADEQUATE/INADEQUATE
10	Mud cleaner type and number :	
11	Bunds around centrifugal pumps for mud cleaners	YES/NO
12	Pump gland packings	MECHANICAL/PRESSURISED
13	Pump gland packing condition	GOOD/POOR
14	Centrifuge type and number :	
15	Bunds around centrifugal pumps for centrifuge	YES/NO
16	Pump gland packings	MECHANICAL/PRESSURISED
17	Pump gland packing condition	GOOD/POOR
18	Drains within bunded area	YES/NO
19	Drains to common collection tank	YES/NO

F. MUD PITS

1	Number and capacity :	
2	Pit level indicators fitted to active pits	YES/NO
3	Graduated volume indicators fitted in all pits	YES/NO
4	Agitators in all pits	YES/NO
5	Mud guns installed in all pits	YES/NO
6	Lockable dump valves to all pits	YES/NO
7	Condition of dump valves	GOOD/POOR
8	Common drain from dump valves	YES/NO
9	Master dump valve in common drain	YES/NO
10	Suction lines recessed into bottom of pits	YES/NO
11	Mud pits can be completely emptied on backloading without discharge to the sea	YES/NO

G. PUMPS

1	Mud pump type :	
2	Bunds surround all mixing and charge pumps	YES/NO
3	Centrifugal pump gland packings	MECHANICAL/PRESSURISED
4	Condition of pump gland packings	GOOD/POOR
5	Drains in bunded areas	YES/NO
6	Drains in common collection tank	YES/NO
7	Drains	OPEN/SEALED
8	Condition of lines to cement unit	GOOD/POOR

H. MIXING AREA

1	Hoppers surrounded by bunds	YES/NO
2	Drains in bunded areas	YES/NO
3	Drains	OPEN/SEALED
4	Drains to collection tank	YES/NO

I. BASE OIL/ESTER STORAGE

1	Accurate base fluid storage volume indicator installed	YES/NO
2	Metering system for base fluid movements	YES/NO

J. LOADING HOSES

1	Dedicated hoses for loading/backloading oil/ester based mud	YES/NO
2	Dedicated hoses for loading/backloading oil/ester base fluid	YES/NO
3	Date of last pressure test of hoses :	
4	Check valve at boat end of loading hose to prevent backflow of base oil/ester (Avery Hardoll or similar)	YES/NO
5	Manual check valve at boat end of loading hose to prevent backflow of oil/ester based mud	YES/NO

K. MUD VACUUM UNITS

1	Number and type of mud vacuum units onboard :	
2	Condition of mud vacuum hoses and couplings	GOOD/POOR
3	Lengths of mud vacuum hoses sufficient to access areas to use	YES/NO

L. PROCEDURES FOR HANDLING OIL/ESTER BASED MUD

Written procedures in place to cover :

1	Integrity testing of tanks and valves prior to the loading of oil/ester based mud	YES/NO
2	Loading/backloading of either oil/ester based mud or base oil/ester to or from a supply vessel	YES/NO
3	Loading/backloading of oil/ester based mud or base oil/ester controlled by a Permit to Work system	YES/NO
4	Transfer of base oil/ester and oil/ester based mud from pontoon storage (where applicable) to the mud pits	YES/NO
5	Cleaning of pits on completion of the use of oil/ester based mud	YES/NO
6	Use of mud vacuum units/air diaphragm pumps	YES/NO
7	Displacement of oil/ester based mud to or from the well	YES/NO
8	Displacement of the riser on a semi-submersible from oil/ester based mud to seawater and vice versa	YES/NO
9	Pre-circulation checks	YES/NO
10	Loss of oil/ester based mud at the shakers whilst circulating	YES/NO
11	Operation of dump valves	YES/NO
12	Operation of dump valves controlled by Permit to Work System	YES/NO
13	Displacement of oil/ester based mud during cementing operations	YES/NO
14	Handling of cement contaminated oil/ester based mud	YES/NO

8.2 PETROFREE Handling Procedures

8.2.1 Prior To Taking PETROFREE On Board

Mud Engineer and Derrickman

Fill all the mud pits, sand traps, solids control pits and trip tank with seawater in order to check the integrity of all the dump valves at the end of any lines that discharge directly overboard, eg. on some rigs the trip tank and skimmer tank overflow directly overboard.

Check the integrity of all suction and equalisation valves in order to eliminate possible communication between mud pits.

Check that all dump valves are properly seated after dumping the seawater and cleaning the mud pits.

Chain and lock all dump valves in the mud pits, sand traps, solids control pits and trip tank in the closed position. Lock all dump gates or valves at the shale shakers in the closed position. The keys will be kept in the Drilling Supervisor's office.

Derrickman or Assistant Driller

Check all mixing pump packings and replace if necessary.

Barge Engineer or Crane Operator

Visual check of integrity of bulk hoses and connections.

Pressure test hose with rig air. Hold 80 psi on hose for 10 minutes.

A Male "Avery-Hardol" or equivalent valve should be fitted to the end of the mud hose which is given to the boat. A crossover Female Avery-Hardol or equivalent should be fitted to a "Cam-Lock" conventional or equivalent connector. This crossover ie Female "Avery-Hardol" and Cam-Lock connector should be kept on the rig and used for boats which do not have a Female "Avery-Hardol" connection on their mud or base ester discharge line.

8.2.2 Receiving / Backloading PETROFREE Mud, Base Ester And Brine At The Rig

Chief Engineer on Boat

Check that the transfer hose is securely connected on the boat and that the manifold on the boat is correctly lined up. This is especially important when the boat has more than one fluid onboard.

Advise the rig of volume pumped or received periodically throughout, and upon completion of the fluid transfer to the rig.

Barge Engineer or Crane Operator

Check that all responsible crew members are issued with VHF Radios to ensure that a good communication system is established between the rig and the boat. VHF Radios must be issued to the Derrickman in the mud pit room and the Observer on the deck.

A pre-job safety meeting must be held with all personnel involved in the loading or backloading operation.

Check that the transfer hose is securely connected on the rig and that the manifold on the rig is correctly lined up.

Assign a responsible deck crew member to be stationed on deck throughout the transfer to observe and immediately report any leaks in the transfer hose. This includes any leaks from the submerged section of the transfer hose. PETROFREE mud losses would be seen as a discoloration in the sea around the submerged transfer hose section. Brine losses would not be obvious from the submerged transfer hose section. Consequently checks on volume and rate of transfer take on even greater significance.

Derrickman or Assistant Driller

Line up and check all lines and mud pits.

Remain in the immediate vicinity of the mud pit or tank throughout the fluid transfer.

When backloading mud, a diaphragm pump must be utilised to transfer all PETROFREE volumes left below the mud pit suctions to the slug pit. By this method "dead volume" can be minimised.

Mud Logging Unit

Monitor all the mud pits during the fluid transfers.

Mud Engineer

Establish a rate of fluid transfer and immediately report any change in that rate so that the fluid transfer can be shut down to check for losses.

Correlate the volume pumped and the volume received periodically throughout, and upon completion of fluid transfer.

Co-ordinate and support the efforts of the responsible crew members throughout the fluid transfer.

Ensure that all the above procedures are complied with during the fluid transfer.

Report any lack of co-ordination between responsible crew members to the Drilling Supervisor so that action can be taken to rectify the situation with Toolpusher and/or the Boat's Master.

8.2.3 Tripping Out Of The Hole

Driller

Ensure that all the following procedures for the Derrickman or Assistant Driller are complied with prior to tripping out of the hole.

Derrickman or Assistant Driller

Check that fluid transfers from the active pit to the trip tank are correctly lined up and check the integrity of lines/valves during all fluid transfers to the trip tank.

Check that at least one shale shaker is running throughout the trip out of the hole and that the gates to the inoperative shale shakers are closed.

Check that all rig floor drains are lined up to the flowline or the skimmer tank.

Function test the cut off switch on the trip tank fill up pump (if present).

Check the integrity of the seals on the mud bucket and the return line from the mud bucket to the flowline or trip tank in the event of a wet trip.

Check and ensure that the Mud Logging Unit personnel are aware of all fluid transfers and a responsible crew member is at each end of the transfer i.e., Transferring mud from a pit in the mud pit room to the trip tank would require the Assistant Driller or Derrickman in the mud pit room and a responsible crew member or the Mud Engineer stationed at the trip tank.

Ensure that a "Pipe Wiper" is available and properly installed.

Mud Logging Unit

Comply with all requirements with regard to maintaining and completing "Trip Reports". This reconciles actual trip volumes against calculated trip volumes. Any discrepancy should be immediately reported to the Driller and the Mud Engineer.

Mud Engineer

Periodically check that the Trip Report is being correctly maintained.

Must periodically check the shale shakers and trip tank.

8.2.4 Tripping Into The Hole

Driller

Ensure that all the following procedures for the Derrickman or Assistant Driller are complied with prior to tripping into the hole.

Derrickman or Assistant Driller

Check that fluid returns from the hole are correctly lined up to the trip tank or the active pit and check the integrity of lines/valves during all fluid transfers from the trip tank.

Check that at least two shale shakers are running throughout the trip into the hole and that the gates to the inoperative shale shakers are closed.

Check that the shale shakers are running prior to circulating to test that MWD and/or Mud Motor. Must ensure that the Shaker Hand or a responsible person is at the shale shakers while circulating.

Check and ensure that the Logging Unit personnel are aware of all fluid transfers and a responsible crew member is at each end of the transfer. ie: Transferring mud from a trip tank to the active pit would require the Assistant Driller or Derrickman in the mud pit room and a responsible crew member or the Mud Engineer stationed at the trip tank.

Mud Logging Unit

Comply with all requirements with regard to maintaining and completing a Trip Report. This report reconciles actual trip volumes against calculated trip volumes, any discrepancy should be immediately reported to the Driller and the Mud Engineer.

Mud Engineer

Periodically check that the Trip Report is being correctly maintained.

Periodically check the shale shakers and trip tank.

Turn in the completed Trip Report to the Drilling Supervisor.

8.2.5 Running And Cementing Casing

Driller

Ensure that all the following procedures for the Derrickman or Assistant Driller are complied with prior to running casing into the hole.

Derrickman or Assistant Driller

Check that fluid returns from the hole are correctly lined up to the trip tank or the active pit and check the integrity of lines/valves during all fluid transfers from the trip tank.

Check that at least two shale shakers are running throughout the period that casing is being run into the hole and that the gates to the inoperative shale shakers are closed.

Check that the shale shakers are running prior to circulating through the casing in the event of having to wash the casing to bottom. Ensure that the Shaker Hand or a responsible person is at the shale shakers whilst circulating.

Supervise the mixing of the cement mix water and cement spacer and ensure that the pits used for this purpose are isolated from pits containing Petrofree.

Remain in the immediate vicinity of the mud pits whilst pumping the cement spacer or transferring the cement mix-water to the cement pump unit.

Check and ensure that the Mud Logging Unit personnel are aware of all fluid transfers and a responsible crew member is at each end of the transfer. ie: Transferring mud from a pit in the mud pit room to the trip tank would require the Assistant Driller or Derrickman in the mud pit room and a responsible crew member or the Mud Engineer stationed at the trip tank.

Mud Logging Unit

Comply with all requirements with regard to maintaining and completing the Operators Trip Report. This report can be used for running casing and reconciles actual volume displaced against calculated volume displaced. Any discrepancy should be immediately reported to the Driller and the Mud Engineer.

Mud Engineer

Calculate volume gains due to casing displacement, cement and cement spacer displacements and initiate a mud pit management procedure prior to running casing.

Ensure that mud pits used for cement mix-water and cement spacers are thoroughly cleaned.

Supervise with the Assistant Driller or Derrickman the mixing of the cement mix water and cement spacer and ensure that these particular mud pits are isolated.

8.2.6 During Drilling And Circulating

Assistant Driller and Mud Engineer

Check that the flowline valves and/or gates are correctly lined up to the shale shakers.

Check that all the shale shakers are running and ensure that the Shaker Hand is aware of his responsibilities.

Check that the dump gates at the shale shakers are closed and locked.

Ensure the trip tank is not dumped into the active system whilst circulating, as losses may result if the shale shakers could not handle the resultant additional flow.

Check that all the rig floor drains are lined up to the flowline or the skimmer tank.

Assistant Driller or Derrickman

Check and ensure that the Logging Unit personnel are aware of all fluid transfers and that a responsible crew member is at each end of any liquid transfers.

Derrickman

Check that pits into which pop-off lines and pressure bleed off lines discharge are never too full to accept this fluid discharge.

Check that mud pump drain valves from the piston chambers and strainer boxes are closed. When necessary this fluid must be drained into a bucket and returned to the mud pits.

Shaker Hand

Constantly monitor the shale shakers during connections to clean screens and check for screen damage. This will ensure efficient primary solids separation and maximise screen life.

Function check the shale shaker wash-down unit prior to drilling or circulating. This unit must be functioning to help prevent fluid losses at the shale shakers. This is especially important when the PETROFREE is cold.

Maintain communication with the Derrickman and/or the Motorman when Ester is being transferred to the wash-down unit reservoir from the Ester storage tank. Good communication is essential in order to avoid overfilling this reservoir.

Mud Logging Unit

Establish with the Mud Engineer an average rate of losses whilst drilling and closely monitor and record this rate. The Driller and the Mud Engineer should be immediately informed of a change in the average rate of losses. It is especially important to re-establish the rate of losses when the centrifuges are being utilised.

Mud Engineer

Perform and record an accurate volume reconciliation every six hours whilst drilling or circulating. This in conjunction with data from the Mud Logging Unit will establish current losses per foot and will indicate any abnormal trends which must be immediately investigated.

Regularly check the shale shakers for excess fluid losses associated with the drilled cuttings.

Regularly check the centrifuges for excess fluid losses associated with the centrifuge discharge.

Regularly check the integrity of the Bell Nipple and Flowline (and Slip Joint on floating rigs). Any leaks or losses should be immediately reported to the Driller and Toolpusher.

8.2.7 Loading / Backloading PETROFREE Or Brine At Shore Base

Mud Company Representative and Vessel Representative

Inspect all loading hoses and lines from vessel to storage facility for splits, kinks etc.

Connect flexible hoses to vessel and inspect Weco threads. Make up Weco connections firmly with a hammer.

Check all valves are lined up correctly for the required transfer.

Mud company representative must be positioned on top of the storage tanks to ensure transfer is into or from the correct tank. Another mud company representative must be positioned by the mud plant pump when transferring to the boat. Visual contact must be maintained between the two representatives at all times.

Visual contact between the mud company representative and the boats skipper or mate must be maintained at all times while pumping from the boat to the storage facility. This will ensure immediate shut down of the pump can be effected should spills or overflows occur.

After completion of transfer, the hoses must be blown clear of fluid with compressed air, end caps fitted and all hoses rolled up and stored away.

On completion of transfer, all valves must be closed and checked for leaks. Any leaks must be confined and cleaned up immediately.

8.2.8 Recommendations

In order to successfully introduce all the aforementioned procedures it will be necessary to supply and or install the following:

Supply

Sufficient VHF Radios for improved communication during loading and backloading of Petrofree.

Supply "Trip Report" pads for use by the Mud Logging Unit.

Supply and Install

Pit level monitors on all mud pits (including the solids control pits, sand trap and trip tank) so that the Mud Logging Unit can monitor all volumes at all times.

Flood lights at both loading points to ensure good observation of the transfer hose from the deck of the rig. This is especially important with regard to the submerged transfer hose section.

Rig Modifications

All overboard lines should be checked and traced to their origin. If any of these lines can result in drilling fluid losses to the sea, a valve with a locking facility should be installed.

All drain lines originating from the rig floor should be checked and traced. All these drains should be capable of returning fluid to the flowline or the skimmer tank.

Shale shaker dump gates or valves should be modified so that a locking facility can be installed.

All dump valves and the associated dump lines should lead to a common line which has a master dump valve installed with a locking facility.

8.2.9 Conclusions

If all of these procedures and modifications are followed, accidental and unnecessary losses of PETROFREE Mud, Base Ester and Brine to the environment will be significantly reduced.

It is especially important that the Drilling Supervisor introduces and emphasises the importance of these procedures to the Drilling Contractor and the Service Company personnel concerned. These procedures can then be implemented by the Mud Engineer with the support and backing of the Drilling Supervisor and the Drilling Contractor's Toolpusher.

The Mud Engineers WILL NOT TOUCH ANY VALVES in the mud pit room or be involved in any transfers of PETROFREE, unless in an emergency. The responsibility for opening and closing valves, and mixing and transferring Petrofree volumes WILL BE THE EXCLUSIVE RESPONSIBILITY OF EITHER THE ASSISTANT DRILLER, DERRICKMAN OR ASSISTANT DERRICKMAN.

This will ensure that one person and one person only, ie Assistant Driller, Derrickman or Assistant Derrickman are responsible for any mud loss resulting from these activities. This will rule out traditional misunderstandings arising between the Mud Engineer and the Drilling Crew that frequently result in serious overboard mud loss.

These procedures have been specifically structured around identifying who will be responsible for what functions, thus reducing the incidences of misunderstandings or neglect resulting in overboard spills.

Baroid is committed to minimising overboard spills to our environment and their consequent impact on the environment and well costs.

APPENDIX 4

Characteristics of Petrofree

PROPERTIES OF PETROFREE

1. Introduction

In hydrocarbon exploration and development, drilling fluid performs a number of functions including: carrying cuttings to the surface; providing hydraulic power to the drill bit; exerting hydrostatic head to prevent caving or sloughing of the formation, preventing the flow of formation fluids into the borehole (kicks and blowouts); and suspending cuttings and weight materials such as barite when circulation is interrupted - as when adding a new joint of drill-pipe.

Until recently, there were two broad classes of drilling fluids: oil-based and water based. Within the last few years, a new class of fluids has been developed which are formulated using a variety of synthetic organic based fluids. These fluids possess the performance properties of oil based and water based fluids, but avoid most of the environmental problems associated with the water and oil based fluids.

The synthetic ester-based drilling fluid, Petrofree ™ will be used for the Wonnich gas development wells.

2. Petrofree

Petrofree ™ is a biodegradable invert emulsion system (i.e. the ester based is emulsified within water) which is derived from vegetable oil and alcohol. It contains no aromatic hydrocarbons, is readily degradable under aerobic and anaerobic conditions and exhibits low toxicity. It also possesses no health risk to workers under normal conditions of exposure.

Biodegradation

Petrofree ™ has undergone testing both in Australia and overseas to determine its biodegradability and toxicity to marine life. Test results have been supplied by the manufacturers, Baroid, Australia Proprietary Limited. These results are summarised below.

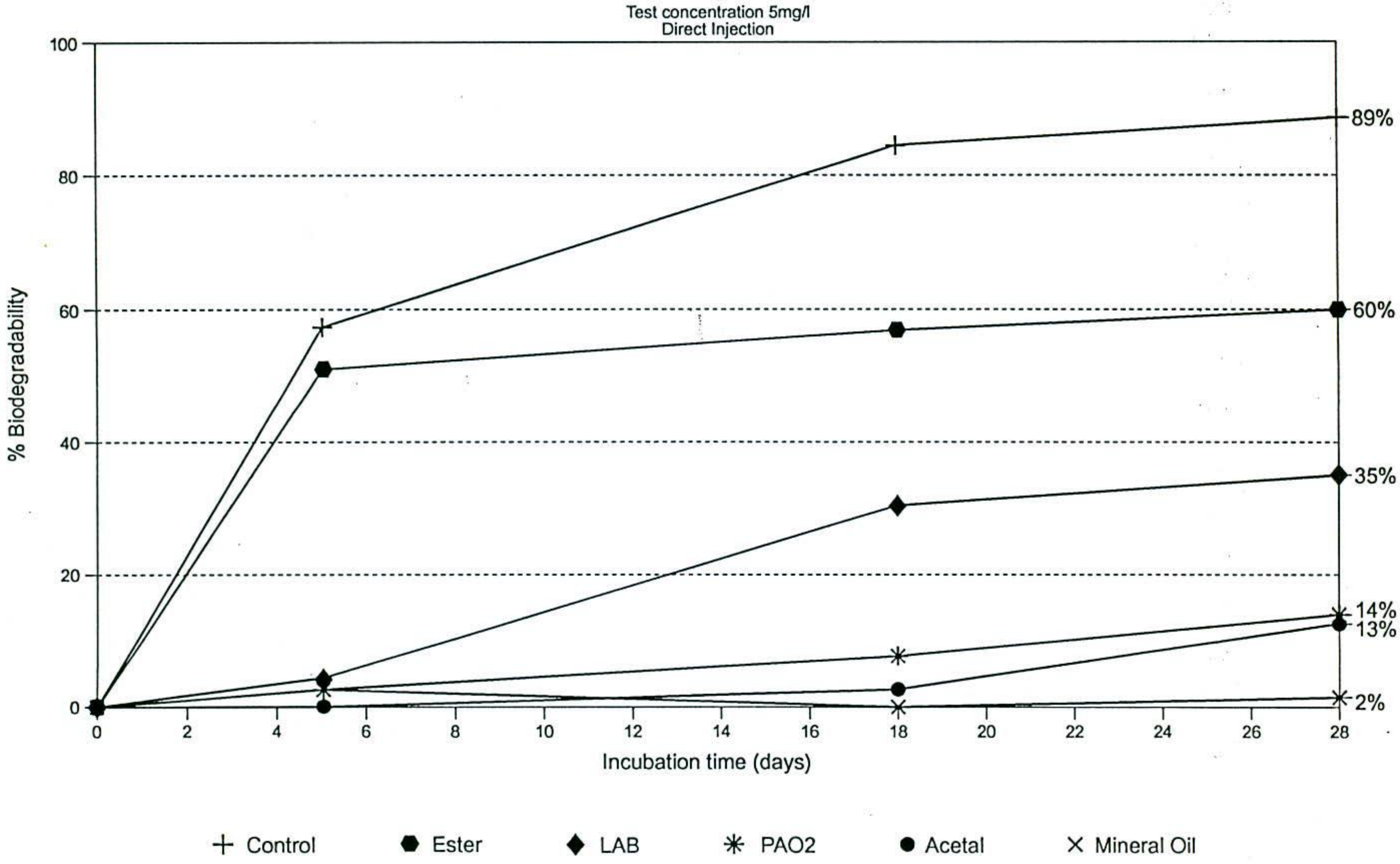
The anaerobic biodegradability of vegetable oil esters was found to be 82.5 (± 13.9)% of organic carbon over a period of 35 days (Table 4.1). This may be compared to the result for a mineral oil which produced a degradation figure of 3.9 (± 11.0)% (European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC) No. 28 screening test (Figure 4.1).

Aerobic biodegradability, was found to be 89% over a 28 day period, with 57% degradation occurring in the first five days (US EPA 40 CFR 796.3200 protocol) (Figure 4.1).

Toxicity

Toxicity testing on Petrofree ™ has been carried out in the United States, at the centre for Petroleum Engineering, University of New South Wales and Curtin University, Perth. The results of testing conducted to date indicate that Petrofree ™ has a very low toxicity to subtropical and tropical marine organisms, including species found on the North West Shelf of Western Australia, as shown in Table 4.2, and Figures 4.2 and 4.3.

BIODEGRADABILITY OF SYNTHETIC BASE FLUIDS
AEROBIC METHOD 28 DAY TEST



Updated 24 October 1996 IS.m4034

Figure 4.1

Table 4.1: Anaerobic biodegradability of Chemicals Examined in the ECETOC No. 28 Screening Test

Test Chemical	Test duration (days)	Degradation in the ECETOC test (% of organic carbon)		
		Net gas production	Net DIC production	Extent of ultimate degradation *
Vegetable oil ester	35	63.3	19.2	82.5 ± 13.9
Acetal-derivative (Ether II)	70	3.7	8.9	12.6 ± 19.2
Polyalphaolefin (PAO) I	70	4.4	10.0	14.4 ± 20.3
PAO II	50	-1.6	2.2	0.6 ± 16.0
Alkylbenzene (LAB)	50	0.9	-2.4	-1.5 ± 12.0
Mineral oil	35	0.7	3.2	3.9 ± 11.0

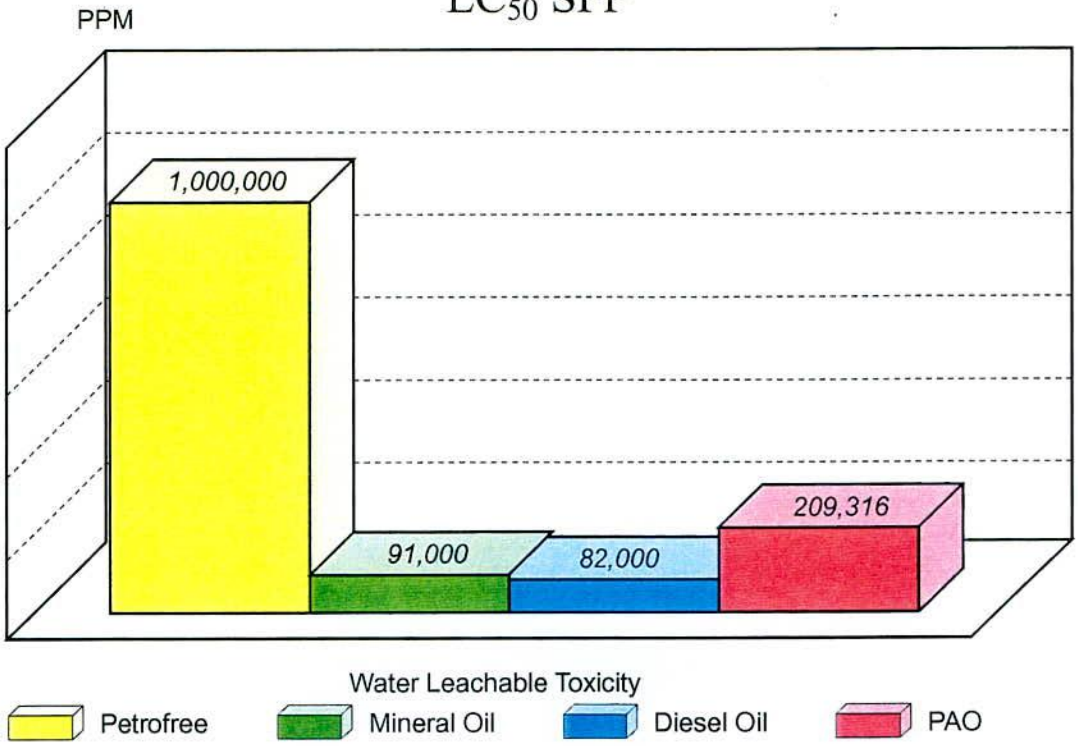
(DIC - dissolved inorganic carbon)
* mean value (from 5 replicates) and its 95% - confidence interval.

Table 4.2: Toxicity of Petrofree to Various Marine Organisms

SPECIES NAME	COMMON NAME	TEST	RESULTS mg/L
Penaeus monodon	prawn (juvenile)	96 hr LC_{50}	>256,000
Isochrysis sp.	algae	96 hr IC_{50}	177,000
Mysidopsis bahia	mysid shrimp	96 hr LC_{50}	>1,000,000
Allorchestes compressa	amphipod	96 hr LC_{50} (solid phase)	691,000

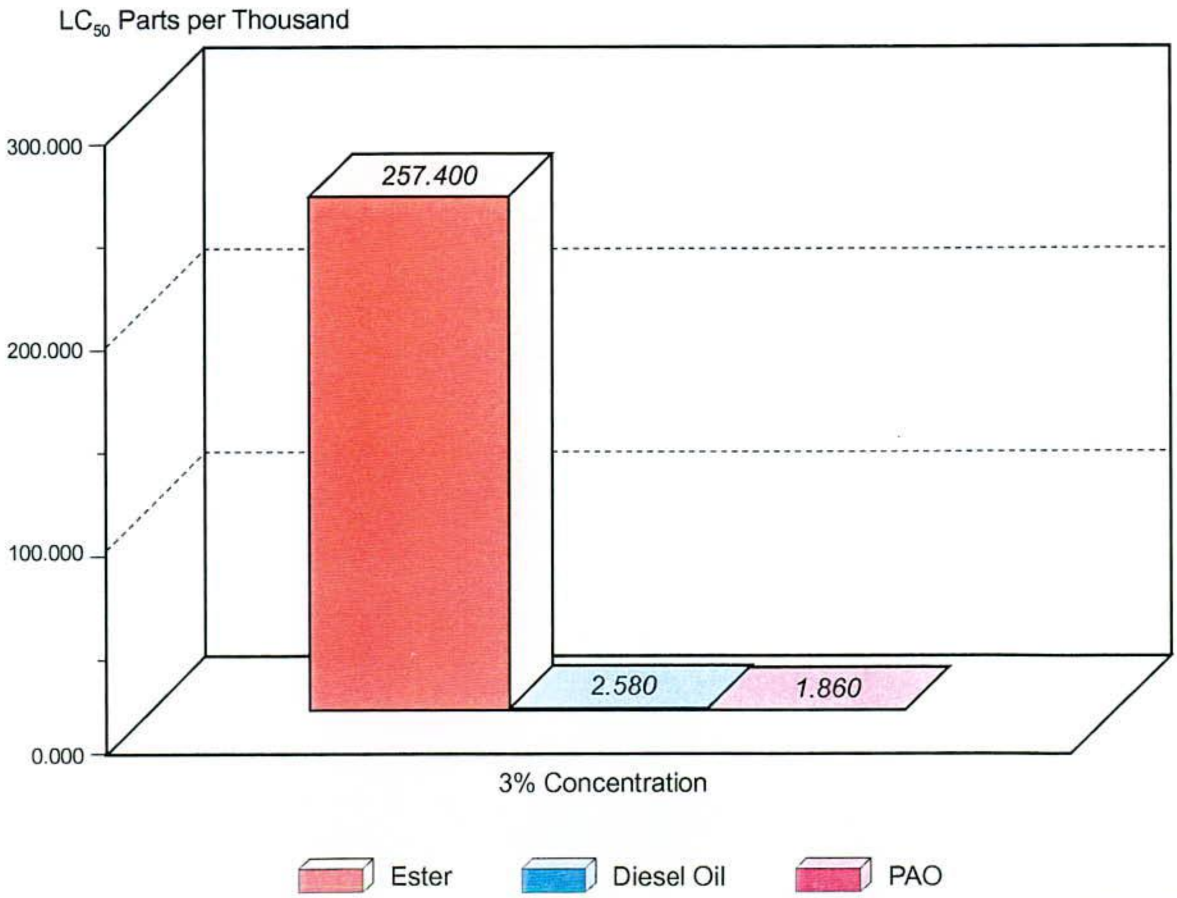
DRILLING FLUID TOXICITY COMPARISON

LC_{50} SPP



BASE FLUID TOXICITY COMPARISON

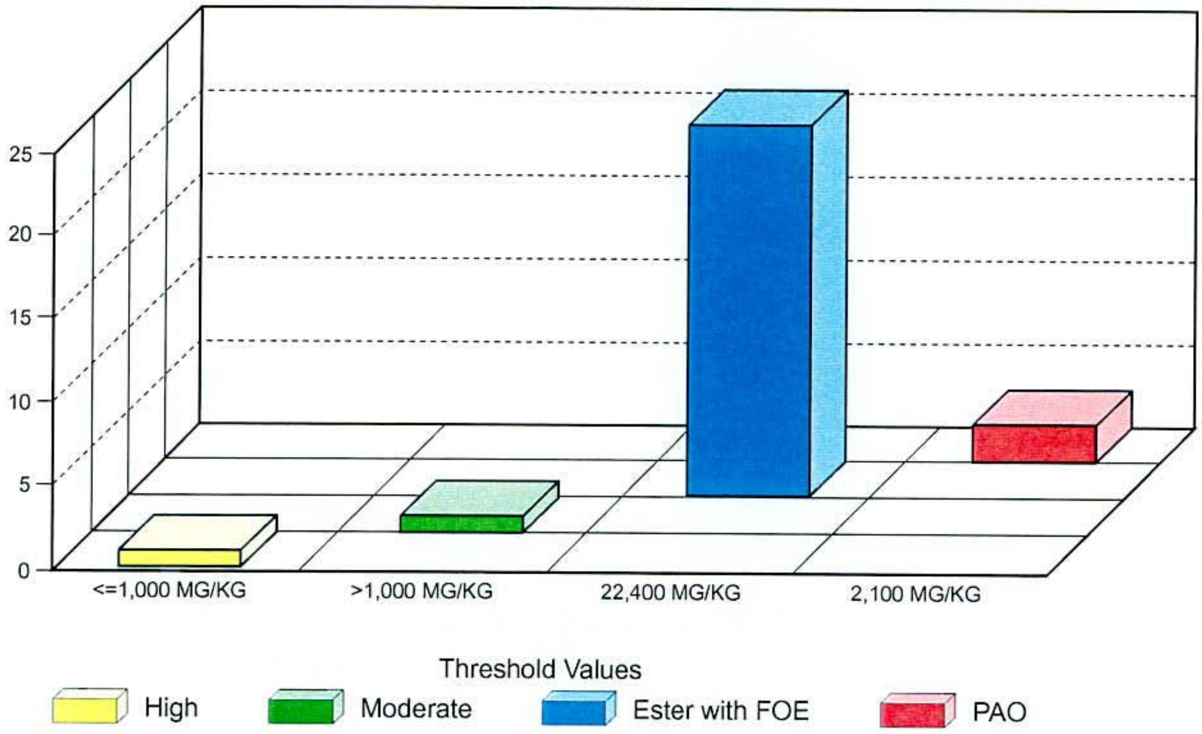
LC_{50} TEST IN A GEN#7 MUD SYSTEM



Dated: 18 October 1996 IS.m4032

Figure 4.2

TOXICITY TO *SKELETONEMA COSTATUM*
EC_{50} VALUES



PETROFREE TOXICITY

TEST	PETROFREE ESTER
Acute Oral Toxicity Water Rate OECD Guideline #401	LC 50 > 2,000 mg/l
Acute Dermal Toxicity OECD #402	'Slight Irritant'
Primary Eye Irritation (Rabbit) J. Am. Coll. Tox. 1/2 13-35 (1982) OECD #405	'Slight Irritant'
Skin Sensitization - Dermal OECD #408	Negative
Mutagenicity - Ames bacterial OECD #471	Not Mutagenic
Dermal Study Dermatological 129-37-46 (1964)	Not Irritant
Dermatological Test - Burckhardt Test - Closed epicutanious	 - no reaction - very good skin compatibility
Pre-Manufacture Notification	Not Mutagenic

Dated: 18 October 1996 IS.m4033

Figure 4.3

APPENDIX 5

Oiltrak and Oilmap system Validation

1.0 Introduction

Predictions for the behaviour of drilling fluid and oil spills that were described in the Chelonia CER made use of a suite of linked modelling systems: MUDMAP, OILMAP and GCOM3D (or OILTRAK). Following are details of these models.

2.0 Model descriptions

MUDMAP is a computer modelling system, developed by Applied Science Associates (ASA), which predicts the near and far-field dispersion of particulate or water-soluble discharges (Spaulding 1994, Kolloru and Spaulding 1993). The model considers three independent but integrated stages in the transport of a discharge plume. The stages are:

Stage 1: The dynamic convective descent or ascent phase, which predicts the initial dilution and spreading of the discharge as it is released.

Stage 2: The dynamic collapse phase, which estimates the growth and dilution of the released cloud as it either impacts the surface or bottom or becomes entrapped by a density gradient in the water column.

Stage 3: The dispersive phase, where the model predicts the transport and dispersion of discharged material by local water currents.

Governing equations used to predict the dispersion of material in MUDMAP were developed from formulations of Koh and Chang (1973), and extended by Brandsma and Sauer (1983), Brandsma and Smith (1995) and Smith *et al.* (1994).

OILMAP is a computer modelling system, also developed by ASA, which models the fate and transport of surface-bound hydrocarbon slicks. The model system combines a suite of oil spill behaviour models which have been derived from empirical studies and tested against historical oil spills world-wide (Kolloru *et. al.* 1993, Spaulding 1988, Spaulding *et. al.* 1992a, 1992b, 1993, 1994,). OILMAP also incorporates a geographical information system (GIS) which is used to provide information on the location of environmental resources. OILMAP uses information on the physical and chemical characteristics of each particular oil, together with environmental conditions (sea and air temperatures, wind speeds, surface currents) that are prevailing during a spill episode, to predict how a slick will weather and migrate. Factors considered within the model include the propensity of the oil to evaporate, form an oil-in water emulsion, become entrained within the water column, or to interact with shorelines of various types (e.g. mud, sand, and rock). As a spill simulation progresses, the model continuously partitions the mass balance of the oil between the sea surface, sub-sea surface, shorelines, and atmosphere.

A stochastic function within OILMAP provides a facility for running a large number of model simulations for the same oil type and spill volume under a random selection of different environmental conditions that represent a season or other period of interest. The combined results of these multiple spill trajectories can then be analysed to quantify the risks to particular resources, should there be a spill in the first place. Risks can be quantified in terms of the probability that particular resources will be affected (from their rate of contact), the time that may lapse before contact (such as the shortest time for any of the spills), and the quantity that may arrive (such as the largest volume for any of the spills).

While the behaviour models within both MUDMAP and OILMAP have been well validated, both models must be provided with reliable information on the prevailing water currents to accurately predict the transport of spills. In open water areas where water flows are uniform, this information can be approximated using limited point-source measurements of water currents. However in coastal areas with any topographical complexity (i.e. islands, channels etc.), point source data becomes inadequate due to spatial variation within the observed current fields (King and McAllister 1997). A high-definition hydrodynamic model is required in these locations to reliably predict water currents.

GCOM3D is a fully three-dimensional hydrodynamic model that has been developed by Global Environmental Modelling Systems (GEMS) in Melbourne, Victoria, to study and predict ocean currents on or near continental shelves (Hubbert 1993). GCOM3D includes terms to drive water masses due to wind stress, atmospheric pressure gradients, astronomical tides, quadratic bottom friction and ocean thermal structure. Being a three-dimensional model, GCOM3D can simulate both the vertical and horizontal variation in ocean currents. The model is relocatable over any part of the Northwest Shelf and both the vertical and horizontal resolution can be adjusted to suit the complexity of the particular region to be modelled. Surface ocean currents from GCOM3D can be used for modelling transport of surface-bound material or objects, and the full three-dimensional current field can be used for plume dispersion modelling. Basic input data to GCOM3D includes:

- High resolution bathymetric data (to describe the shape of the seafloor);
- Tidal amplitudes and phases of the major tidal constituents (to predict sea heights, and hence the speed and direction of tidal currents); and,
- Time-linked forecasts or observations of wind speed and direction (to predict wind-induced surface currents).

Predictions of the GCOM3D model, and combined predictions of this model operating with MUDMAP and OILMAP, have undergone validation at a number of locations on the Northwest Shelf. The GCOM3D model is designed to be completely relocatable from one region to another, and uses generic formulations to predict the transport of water based on the supplied wind forecasts, bathymetric data, tidal information and coastal map for the given geographic area of interest. Verification of the generic formulations has been provided by a number of field experiments conducted on the Northwest Shelf. Specific verification of the model predictions have also been undertaken within and around Exmouth Gulf.

3.0 Model verifications

3.1 Verification within Exmouth Gulf

The GCOM3D model has been validated against several mat tracking exercises and a current measurement exercise within Exmouth Gulf. These are summarised in Tables 1 and 2 and are described below.

Case 1

Two mat tracks were conducted on successive days (16th and 17th) in April 1992 between Onslow and Barrow Island (towards the northern boundary of the model region used in this study). One mat was released at the start of an ebbing tide (16^{th}) and the other during the flood (17^{th}). GCOM3D was set up on a 2 km horizontal grid and with 8 vertical levels (with a surface layer 4m thick). GCOM3D was driven by winds observed during the deployments and by seven tidal constituents to simulate the trajectories of the two mats. The observed and predicted tracks for each of the two days are shown in Figures 5.1 to 5.4.

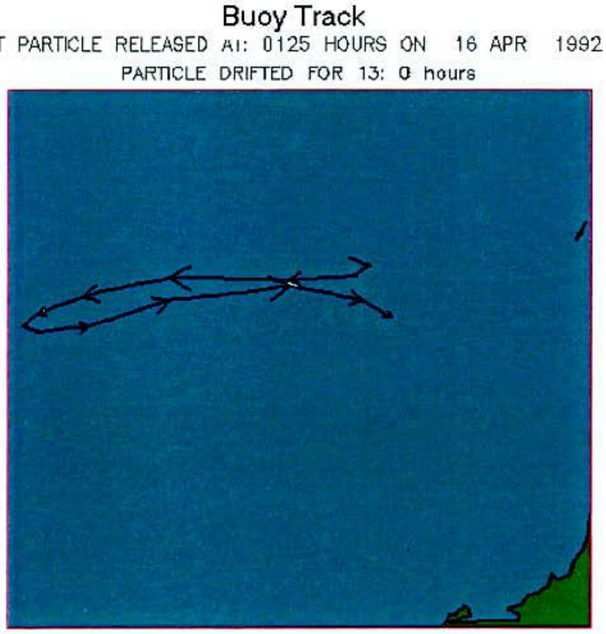


Figure 5.1: Track of a fibre mat released on 16th April 1992 between Onslow and Barrow Island at the start of an ebbing tide during a neap-tide cycle.

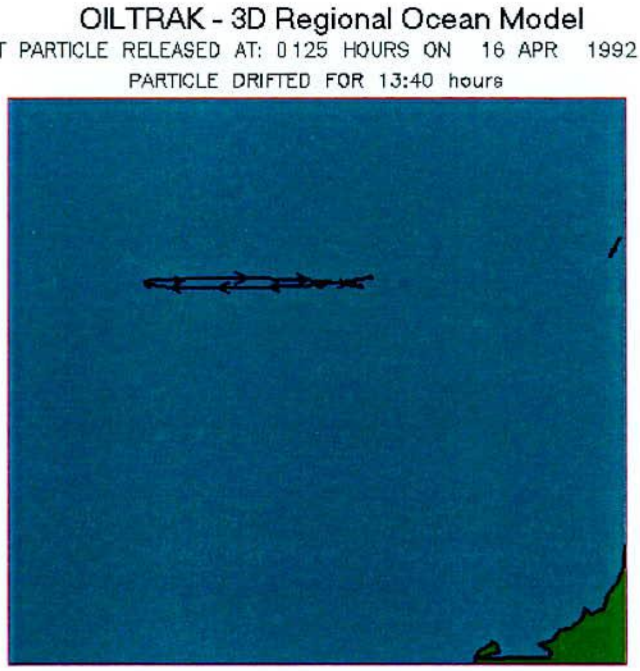


Figure 5.2: GCOM3D prediction of the path of the mat shown in Figure 5.1

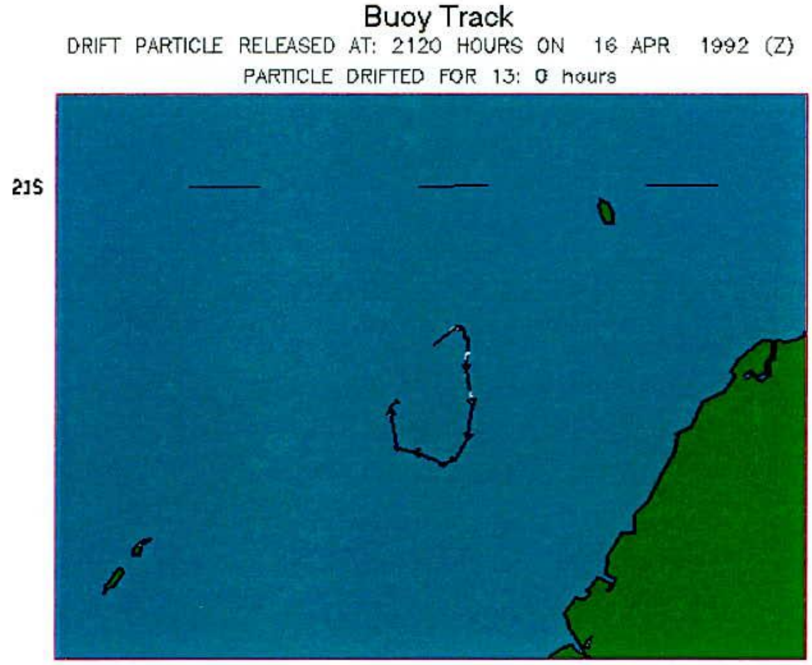


Figure 5.3: Track of a fibre mat released on 17th April 1992 between Onslow and Barrow Island (Note the location relative to the Muiron Islands, in the lower left corner of the image). The mat was released on a flooding tide during a neap-tide cycle.

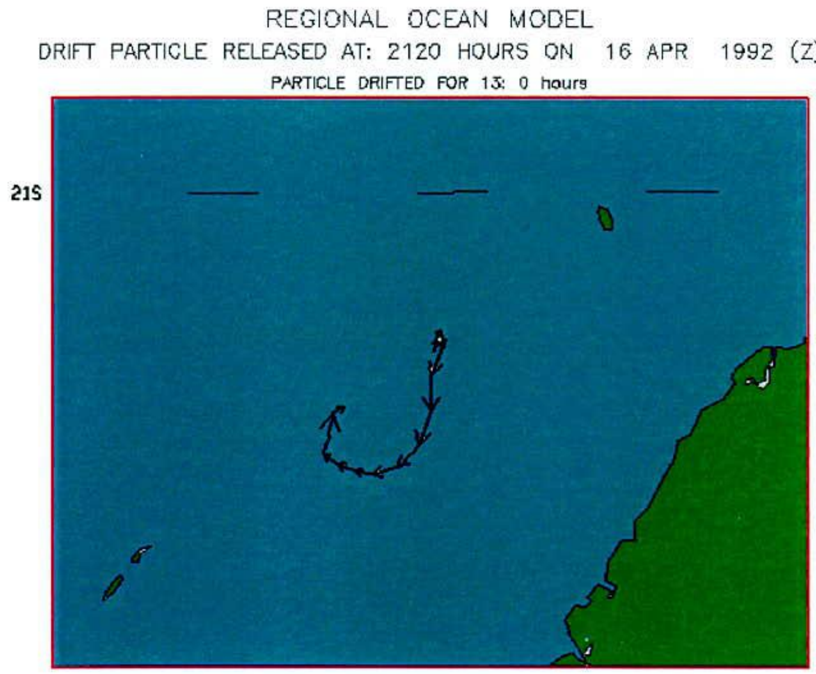


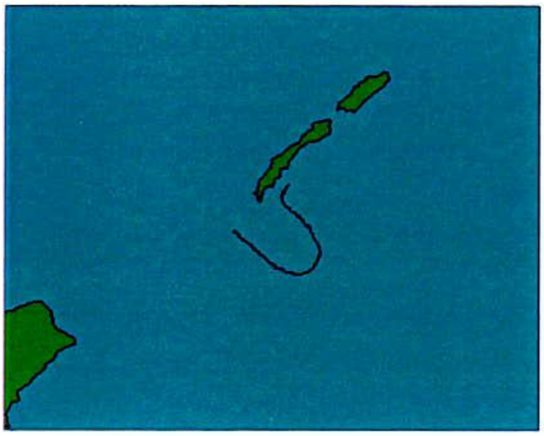
Figure 5.4: GCOM3D prediction of the path of the mat shown in Figure 5.3

Case 2

A fibre mat was released during a flood tide on September 28, 1992 from a position close to that of the proposed Chelonia well and tracked by differential GPS for 11 hours. The winds observed on the ship were approximately 15 knots from the south-south-west in the morning, dropping to 8 knots from the south-west in the afternoon. GCOM3D was set up with a horizontal resolution of 700 m and with 8 vertical layers (the surface layer was four metres thick). The 700 metre horizontal resolution was chosen to allow resolution of the gap between North and South Muiron Islands. The model was provided with observed winds and data for seven tidal constituents (M2, S2, N2, K2, O1, K1 and P1) derived from nearby tidal. The observed and predicted tracks are shown in Figures 5.5 and 5.6.

Buoy Drift Track

Buoy released at 23:40 on 27 Sept 1992 (UTC)

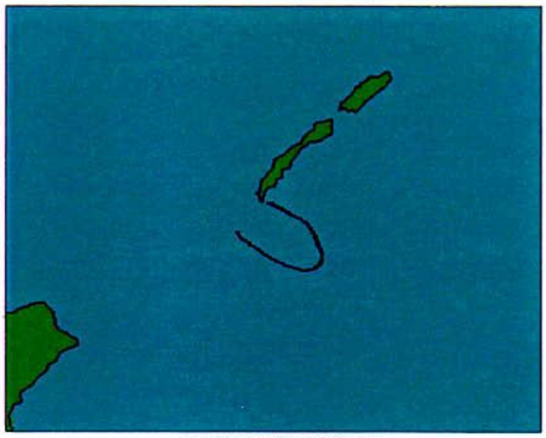


Global Environmental Modelling Services

Figure 5.5: Observed track of a fibre mat released near Muiron Islands on a flooding tide during a spring-tide cycle.

OILTRAK - 3D Regional Ocean Model

Particle Released at 23:40 on 27 Sept 1992 (UTC)



Particle drifted for 11:30 hours

Global Environmental Modelling Services

Figure 5.6: GCOM3D prediction of the path of the mat shown in Figure 5.5

Case 3

Two foam rubber mats were released from the Mydas well site in November and December 1993 and tracked by GPS. The first mat was released during an ebbing tide and the track continued through to a flooding tide. Winds were from west and south west throughout the deployment but increased over time from 12 to 22 konts. The second mat was started on a flooding tide and completed on an ebbing tide. Winds were initially light and variable in direction but then increased to 18 knots from the south west for the last 4 hours. The same GCOM3D model set up used for the quantitative risk assessment of the Chelonia well was used to model the path of the mats based on wind observations made on the tracking ship during the deployment. A comparison of the observed and predicted paths of the mats is shown in Figures 5.7 and 5.8.

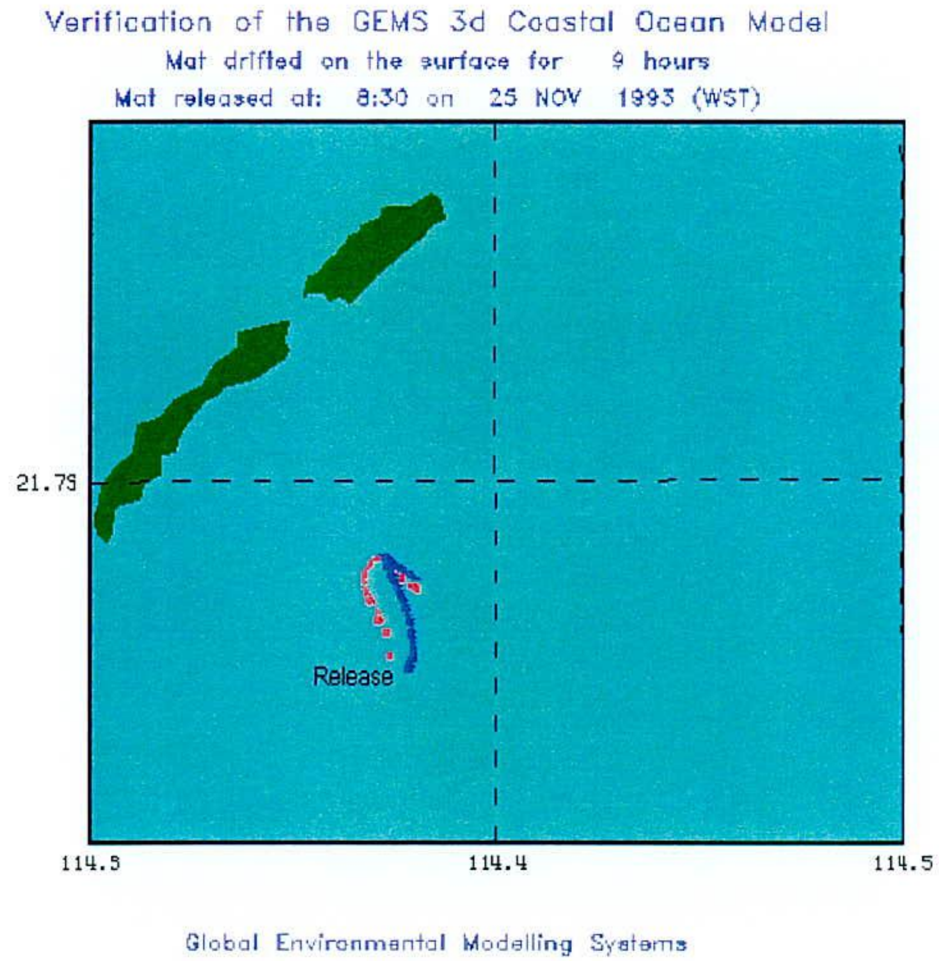


Figure 5.7 Observed (red) and predicted path of a mat released on 25th November 1993 on an ebbing tide during a neap-tide cycle.

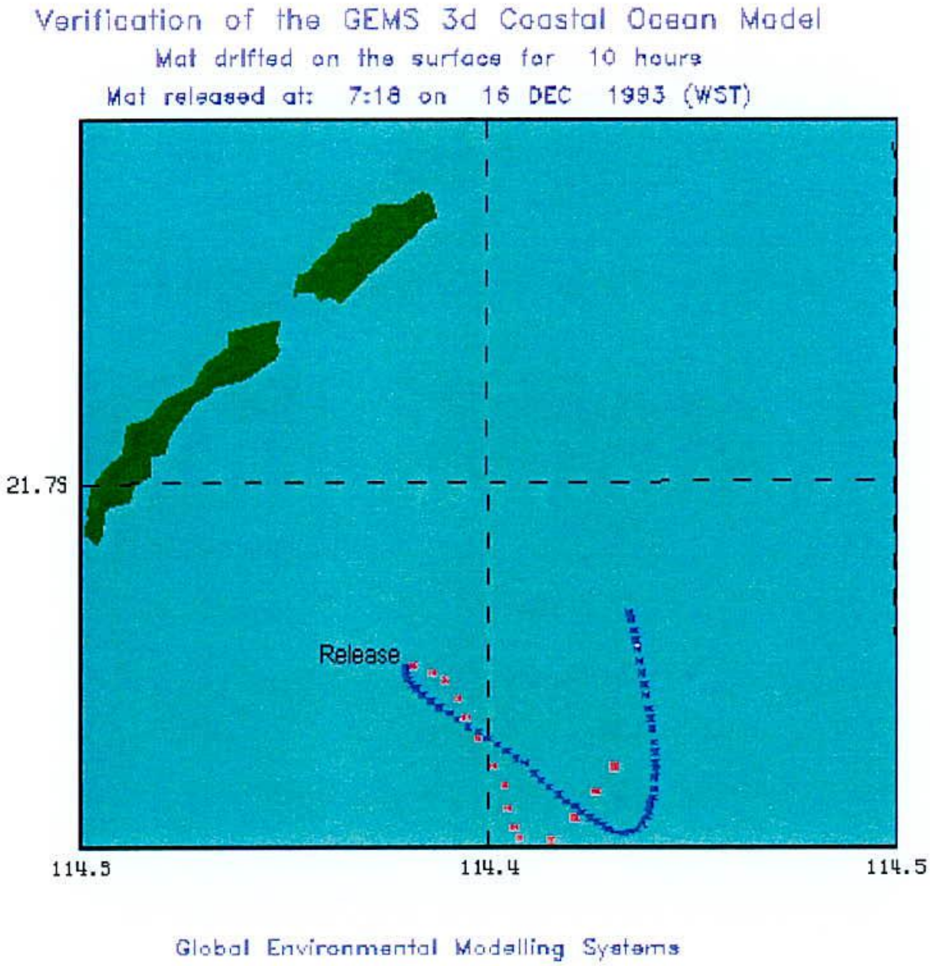


Figure 5.8 **Observed (red) and predicted path of a mat released on 16th December 1993 on an ebbing tide during a neap-cycle.**

Case 4

A mat was released from the location of the Hawksbill well site in December 1993 and tracked for 9 hours by GPS. The mat was released during slack water prior to a flooding tide and continued into an ebbing tide. Winds observed on the tracking ship were from the north and northeast at 5 to 12 knots throughout the deployment. GCOM3D used the same parameters as above for the Mydas tracks and was supplied with winds observed during the deployment. A comparison of the observed and predicted path of the mat are shown in Figure 5.9.

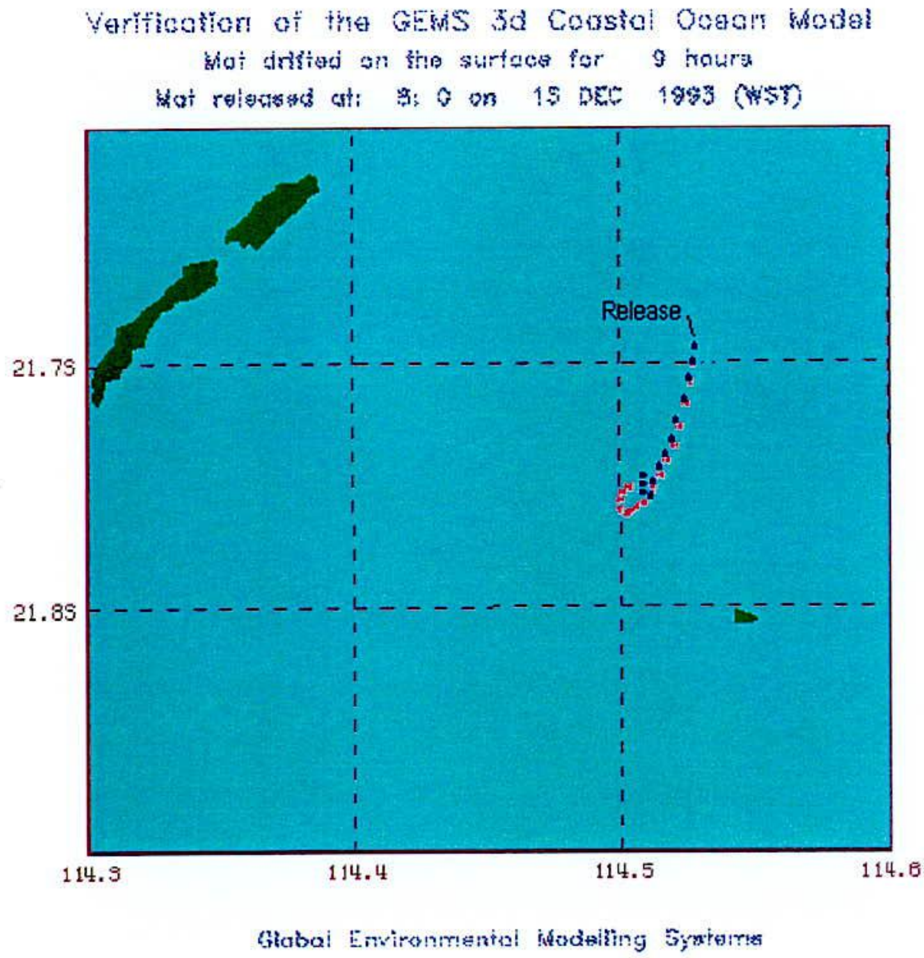


Figure 5.9 **Observed (red) and predicted (blue) path of a fibre mat released on 15th December 1993.**

Case 5

A mat of open cell foam with a slick upper surface was released from the Chelonia location on 1st April 1998. The mat was released mid-way through a flooding spring tide and tracked through an ebbing tide. Winds were initially light (0-2 knots) from the south east and increased to 7 knots as the direction changed though east to north. As for case 3 and 4, GCOM3D was set up with the same model parameters as used for the Chelonia assessment and supplied with the observed winds. A comparison of the observed and predicted path of the mat are shown in Figure 5.10.

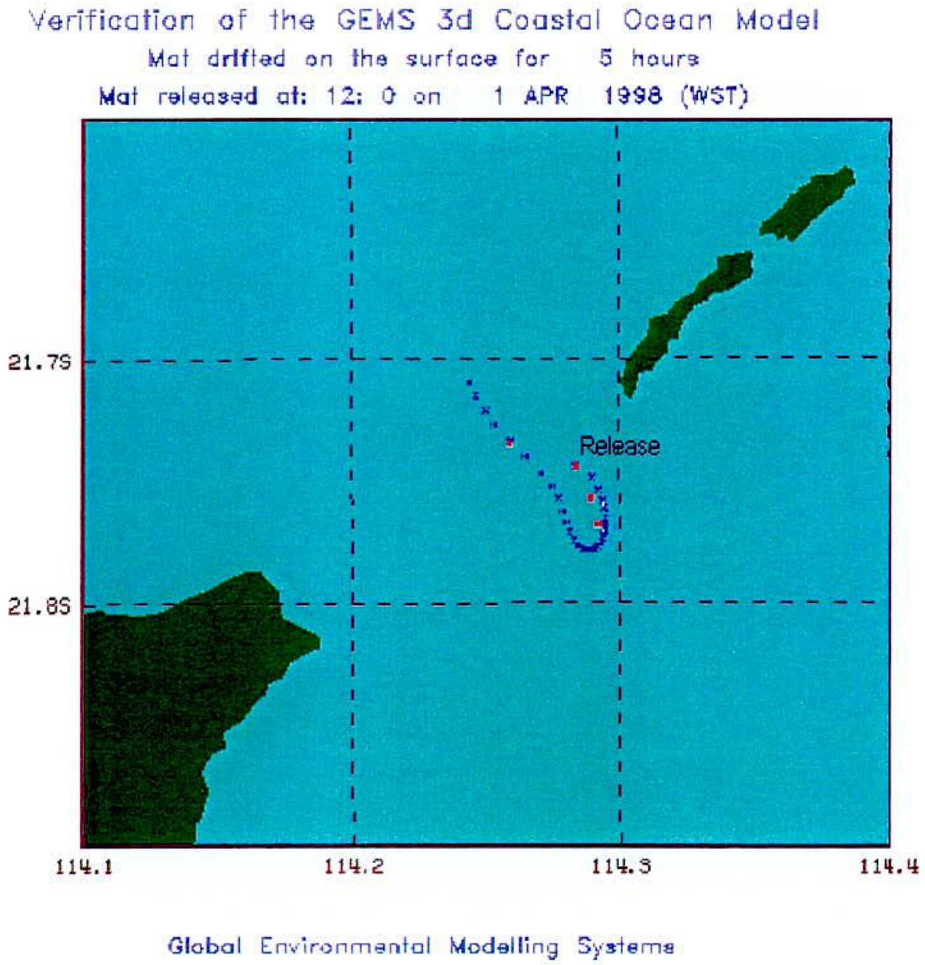


Figure 5.10 **Observed (red) and predicted (blue) path of a fibre mat released on 1st April 1998.**

Case 6

Apache Energy undertook a current measurement program at the Chelonia well site and at Nor-West Reef (Table 2). Measurements were made using an acoustic doppler current profiler (ADCP), which measured the speed and direction of water currents at 0.5 m depth intervals from just below the surface to just above the seafloor. The ADCP was positioned for a complete spring tidal cycle (7 to 10 hours) on the seaward side of Norwest Cape and and for 3 weeks at the Chelonia well site to record over a neap -spring- neap cycle. Model comparisons were predicted using the GCOM3D set up over the grid used for the Chelonia risk assessment. As a validation of the model using wind derived from Thevenard Island, the model was supplied with wind data recorded on this Island during the deployment period. At this time, wind data from this source is only available up until 5th April 1998, which covered the short term deployment at Nor-West Reef and a spring-neap period of the Chelonia deployment. Comaprison of modelled and observed current predictions for these sites are shown in Figures 5.11 to 5.13.

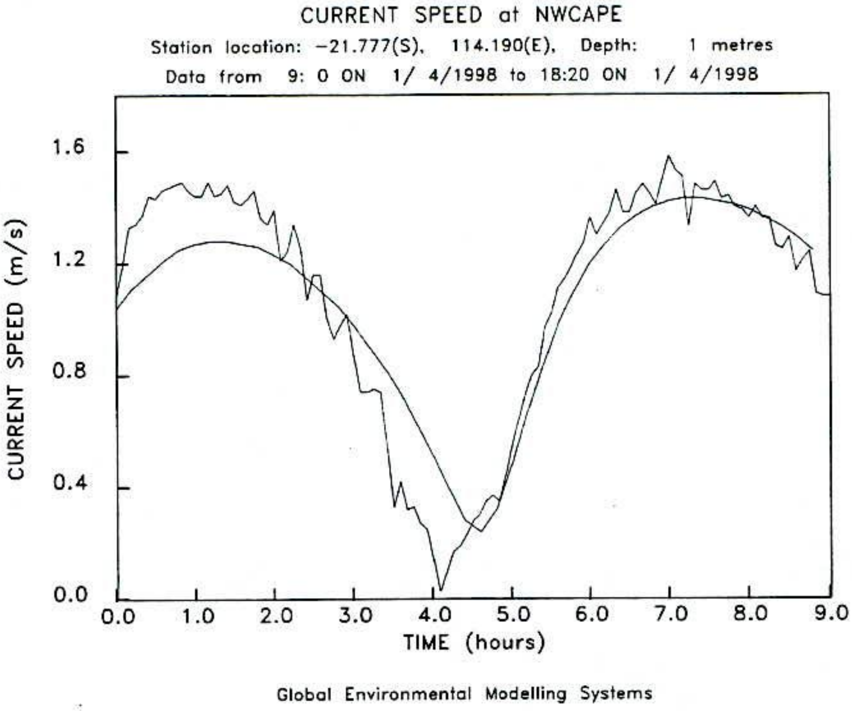


Figure 5.11 Comparison of predicted (smooth line) and observed (jagged) current speeds at North West Cape during a spring tidal cycle on 1st April 1998.

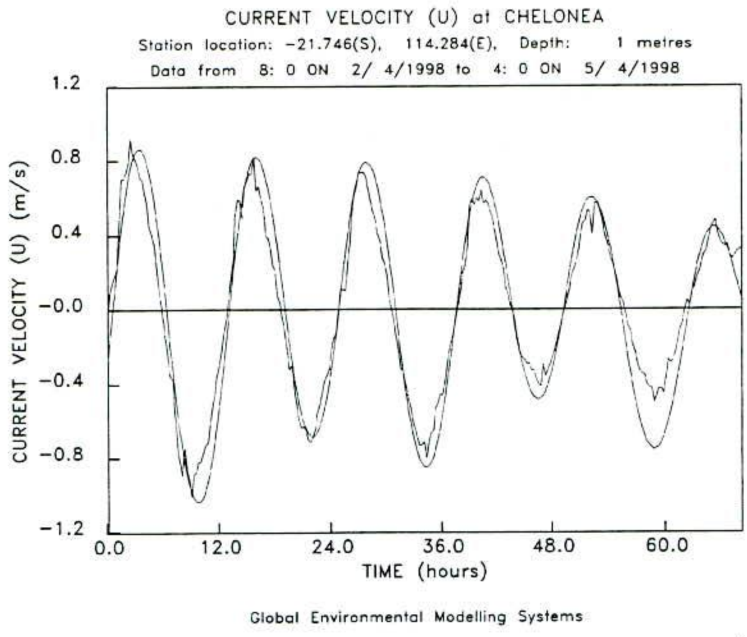


Figure 5.12 **Comparison of the predicted (smooth line) and observed (jagged) east to west component of the current speeds at Chelonia during a spring to neap tidal cycle (2nd to 5th April 1998).**

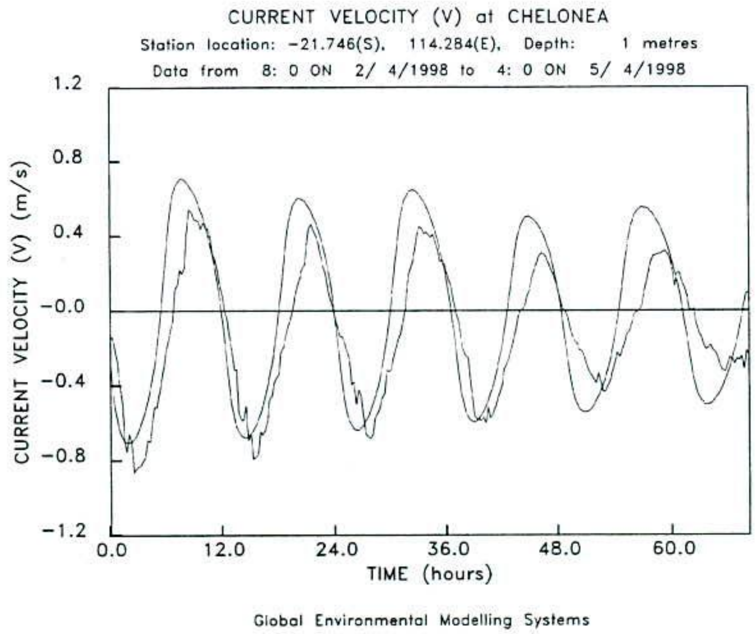


Figure 5.13 **Comparison of the predicted (smooth line) and observed (jagged) north to south component of the current speeds at Chelonia during a spring to neap tidal cycle (2nd to 5th April 1998).**

Table 1. Release conditions for mat track exercises in Exmouth Gulf, which have been used to validate GCOM3D predictions. Case number refers to the description in the text.

Case	location	Release position		Tidal state	Date	Time	Duration (hrs)
1	Near Serrurier Island	21.5500	114.6583	Neap – Ebb	16 Apr 92	0925	14
1	Near Serrurier Island	21.5500	114.6583	Neap – flood	17 Apr 92	0520	13
2	Chelonia– 1	21.7463	114.2757	Spring – flood	27 Sep 92	0700	12
3	Mydas-1	21.75211	114.3778	Neap – Ebb	25 Nov 93	0830	8.5
3	Mydas-1	21.75060	114.3795	Spring – Flood	16 Dec 93	0718	9 (2 mats)
4	Hawksbill	21.68860	114.5306	Spring – Flood	15 Dec 93	0800	9
5	Chelonia – 2/3	21.74547	114.2834	Spring – Flood	1 Apr 98	1200	5

Table 2. Summary of ADCP measurements of surface and subsurface current speeds and directions

Station name	Measured position		Profile depth	Tidal state	Start Date	Duration (hrs)
Nor-West Reef	21.7627	114.1805	1-30 m	Spring (flood to ebb)	1 Apr 98	10
Chelonia	21.7437	114.2841	1-22 m	Spring-Neap cycle	2 Apr 98	440.5

Satellite validation over Exmouth Gulf

Predictions of GCOM3D were further verified by comparison with sea surface temperature data captured by satellite (NOAA Satellite data processed by Department of Land Administration).

Satellite images show distinct delineation of sea surface temperatures between offshore waters and the waters of the Gulf and adjacent shelf. Images collected in both summer and winter show a temperature differential of 4- 6° C between the two bodies of water. Images collected in winter (July; Figures 5.14 and 5.15) show higher temperatures outside the Gulf due to the warm Leeuwin Current offshore. Images collected in summer (December; Figures 5.14 and 5.15) show the opposite case - higher sea surface temperatures within the Gulf than the offshore waters. A relatively narrow band of confluence separates the two water bodies in each case, roughly following the shelf break. This zone of confluence is dynamic and shows the path of surface flows as tongues of warm (red) and cold (blue) water displacing the receiving body of water. Zones of mixing show up as intermediate colours (yellow-green) whose extent and distribution also help to indicate the nature of the sea surface flows.

Figures 5.14 to 5.17 show tidal current predictions of GCOM3D over the region leading up to the corresponding time that the satellite image was captured (the lower plot in each case shows the closest time step to that of the image).

In example 1, taken at 1443 on 8th July 1997 (Figure 5.14), the warm waters of the Leeuwin current can be seen flowing down the coastline outside the shelf break, while colder waters occupy the Gulf and coastline to the north. Mixing patterns along the line of confluence indicate that this image was captured after the tide had begun to ebb. A wide area of mixing surrounds tongues of warm water emerging into the Gulf from the preceding flood, while a number of small jets of cold water can be seen displacing the warmer waters. Surface water flows predicted by the model are consistent with those observed in the image. The model closely predicts the timing of the tidal change as well as the pattern of water flow on the flooding and ebbing tides. In particular, the model represents the relative magnitude of floodwater currents between the major channels (as indicated by the tongues of warm water) as well as the positioning of jets of ebbing water.

In example 2, taken at 1456 on 16th July 1997 (Figure 5.15), the mixing patterns indicate that the image was captured late in the cycle of an ebbing tide, when strong tidal currents emerging between North West Cape and the Muiron Islands had displaced the warmer shelf waters. The sharp delineation between this jet and the receiving waters indicates that water is still ebbing strongly at this location, while the more diffuse boundaries observed elsewhere indicate that the flood has commenced at other locations. This pattern is consistent with those predicted by the model, which shows over 1 knot of flow from the Gulf in the area of North West Cape and waning currents elsewhere.

Example 3 shows a summer situation, and was taken at 1515 on 17th December 1997 (Figure 5.16). At this time the Gulf waters were warmer than the offshore waters and the Leeuwin current was absent. The image shows relatively cool water moving north along the Ningaloo coast before flowing into the Gulf, however the wide mixing zone indicates that the image was taken as this flow was waning. A zone of mixing on the seaward side of the Muiron Islands also indicates the presence of weaker flood currents that have begun to break down as the tide begins to ebb. Further indications that the tide has begun to ebb are the warm water jets that have begun to emerge from the gulf around the southern end of the Muiron Islands. The model predicts similar surface flows over the region as the fooding tide begins to ebb.

The final example, taken at 1504 on 18th December (Figure 5.17) was also captured late during the flooding tide, but at an earlier part of the tide to the preceding example. As for the 17th, cool water can be seen moving north along the Ningaloo coast penetrating into Exmouth Gulf. At this earlier state of the tide this water can also be seen surrounding the Muiron Islands and flowing north. As before, the model is reliably predicting the water flows and the timing of flow changes.

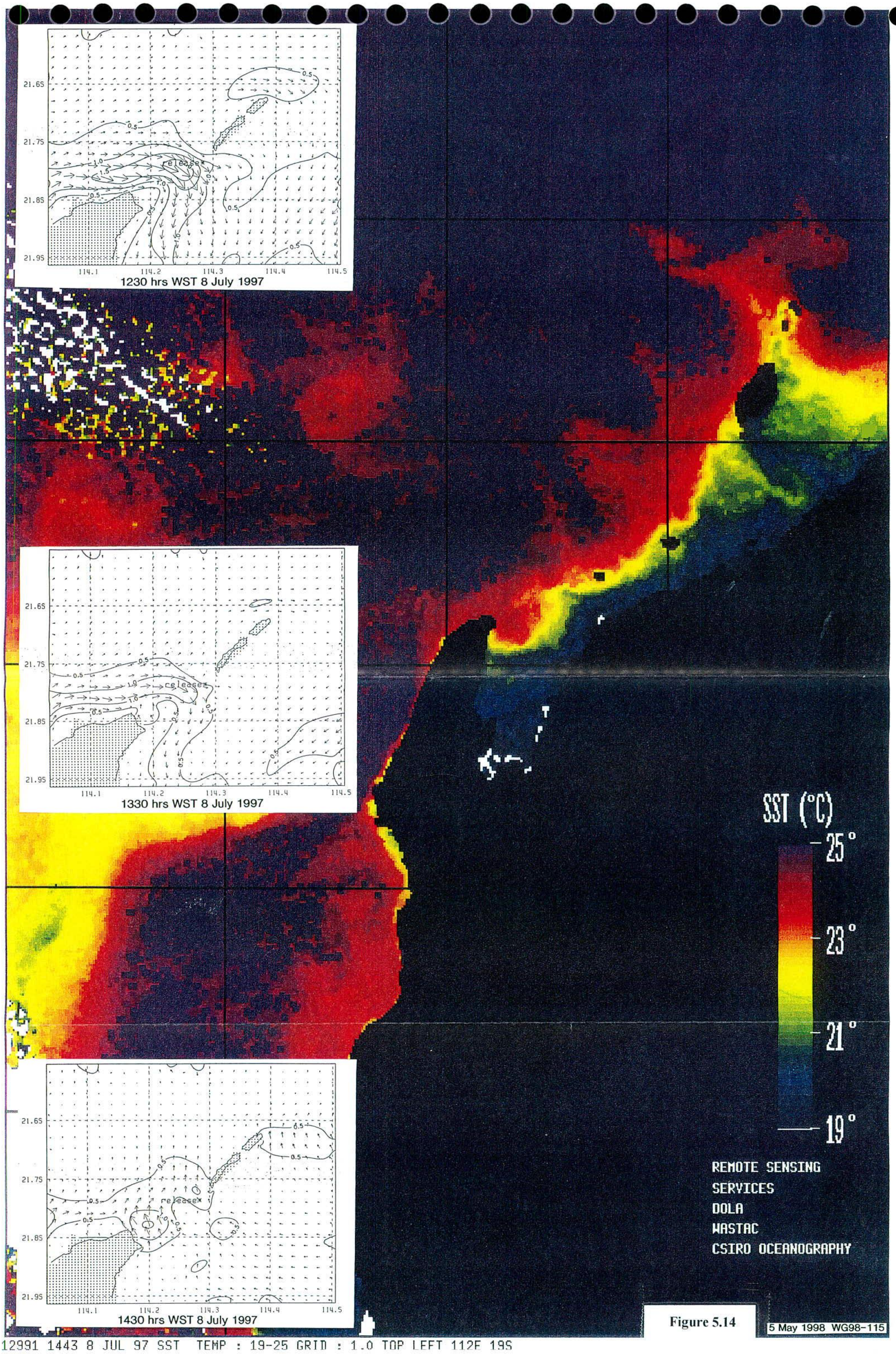

1230 hrs WST 8 July 1997
1330 hrs WST 8 July 1997
1430 hrs WST 8 July 1997
release
21.65
21.75
21.85
21.95
114.1
114.2
114.3
114.4
114.5
SST (°C)
25°
23°
21°
19°
REMOTE SENSING
SERVICES
DOLA
WASTAC
CSIRO OCEANOGRAPHY
5 May 1998 WG98-115
N14 12991 1443 8 JUL 97 SST TEMP : 19-25 GRID : 1.0 TOP LEFT 112E 19S

Figure 5.14

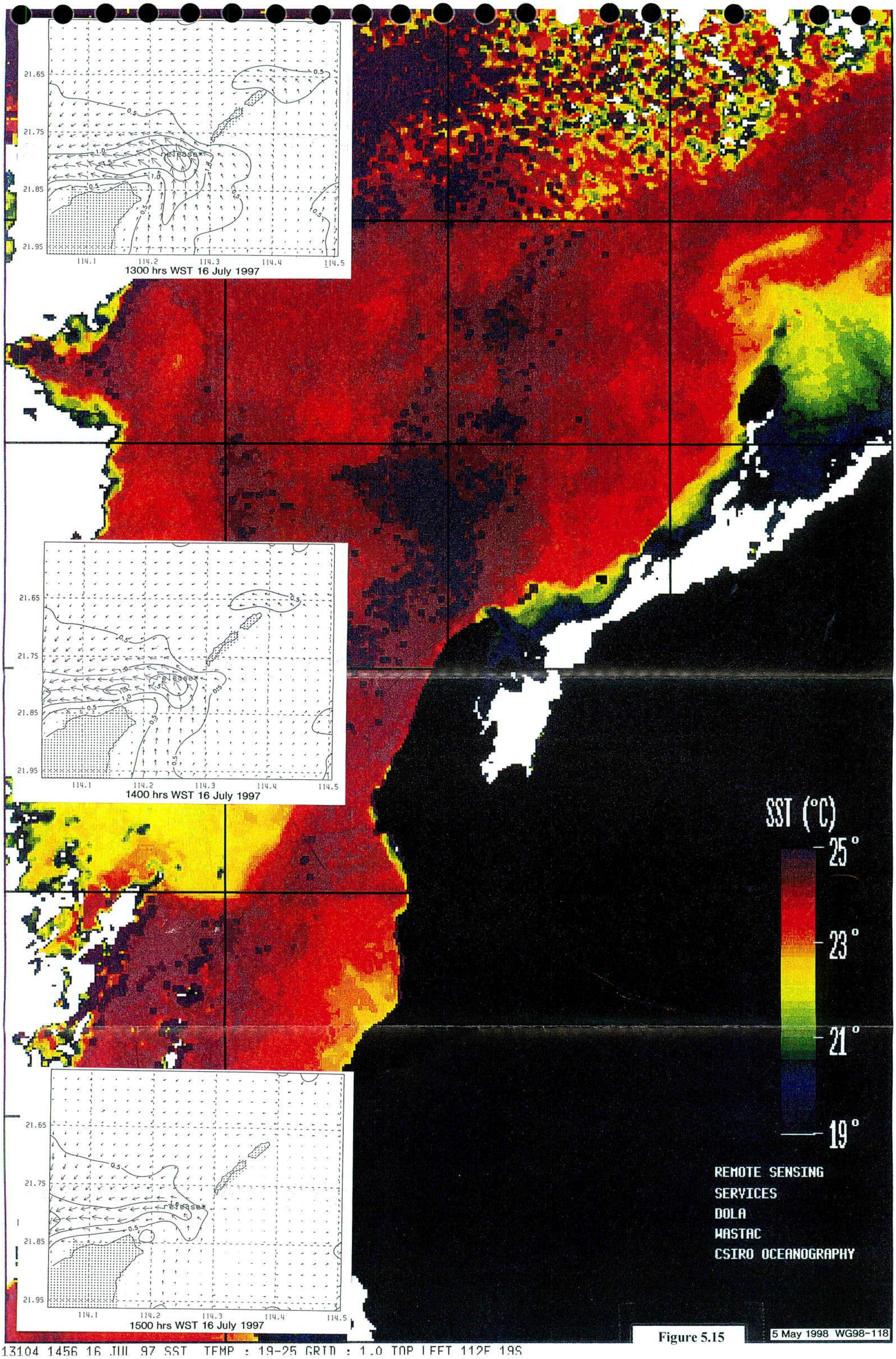


Figure 5.15

5 May 1998 WG98-118

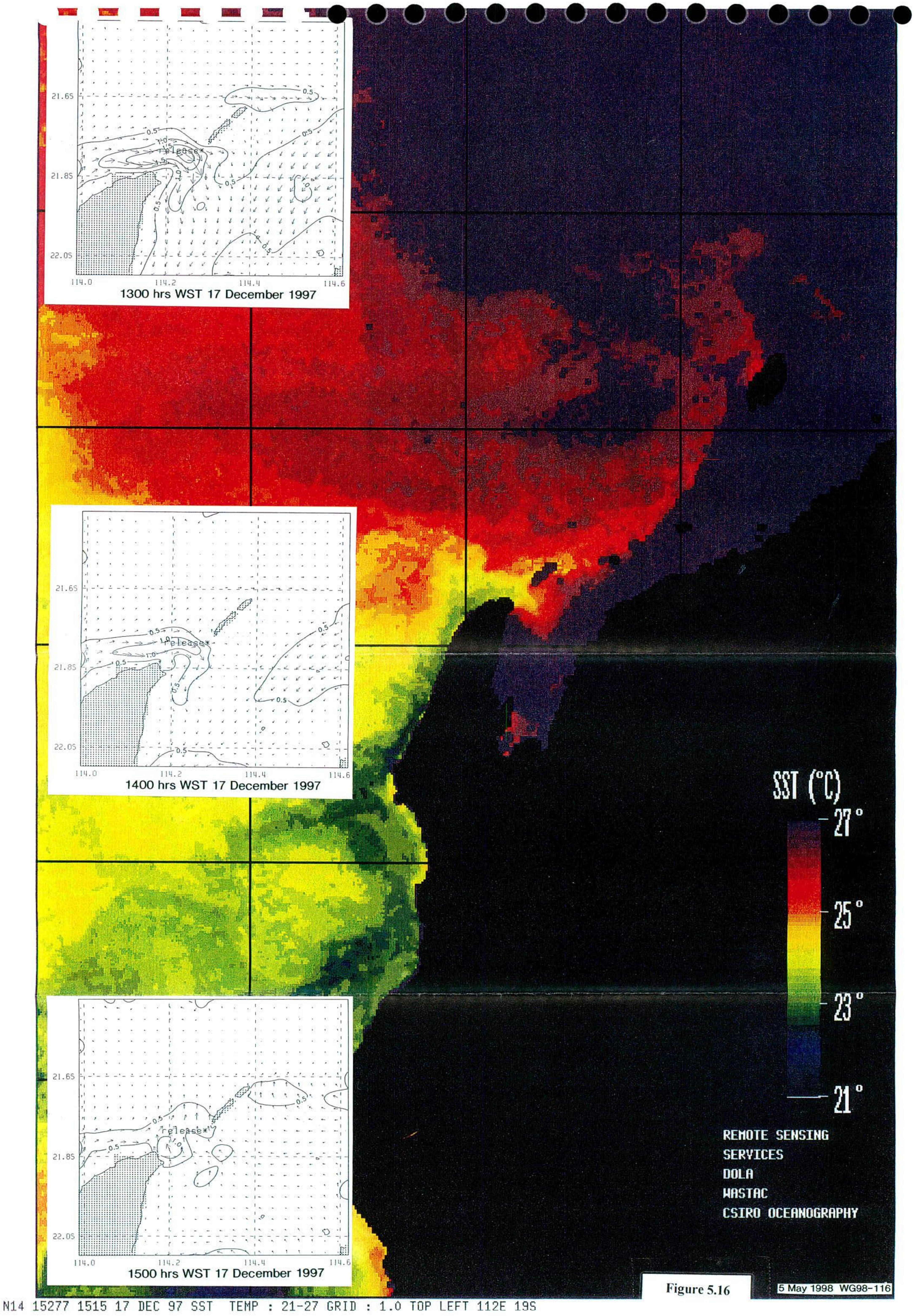

1300 hrs WST 17 December 1997
1400 hrs WST 17 December 1997
1500 hrs WST 17 December 1997
release
SST (°C)
27°
25°
23°
21°
REMOTE SENSING
SERVICES
DOLA
WASTAC
CSIRO OCEANOGRAPHY
5 May 1998 WG98-116
N14 15277 1515 17 DEC 97 SST TEMP : 21-27 GRID : 1.0 TOP LEFT 112E 19S

Figure 5.16

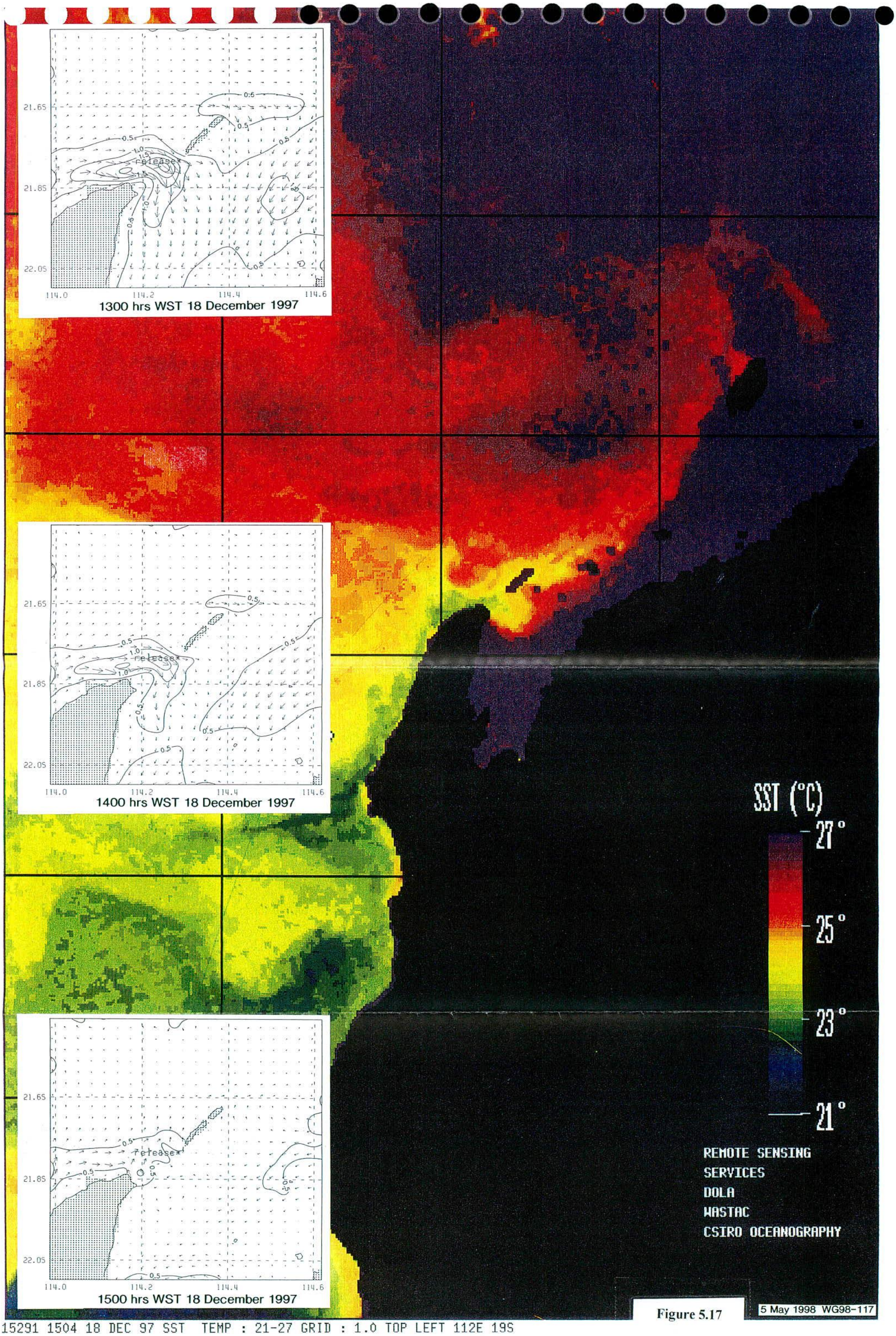

1300 hrs WST 18 December 1997
1400 hrs WST 18 December 1997
1500 hrs WST 18 December 1997
release
21.65
21.85
22.05
114.0
114.2
114.4
114.6
SST (°C)
27°
25°
23°
21°
REMOTE SENSING
SERVICES
DOLA
WASTAC
CSIRO OCEANOGRAPHY
5 May 1998 WG98-117
N14 15291 1504 18 DEC 97 SST TEMP : 21-27 GRID : 1.0 TOP LEFT 112E 19S

Figure 5.17

3.2 Verification near the Montebello Islands

Apache Energy undertook a verification study of GCOM3D current predictions around the Montebello Islands using an acoustic doppler current profiler (ADCP), which measures vertical profiles of the currents. The ADCP was deployed between March 15 and 22, 1996 for approximately 24 hour periods at locations around the Montebello Islands to sample the vertical structure of the current flow during a number of tidal cycles (Figure 5.18). The ADCP data from a depth of 4 metres were extracted for comparison with model predictions. GCOM3D was set up at a scale of approximately 500 m and was provided with hourly wind observations for the period (recorded at Varanus Island, 20 km to the south) and tidal data from a number of locations in the region. Figures 5.19 to 5.23 show the predicted and observed data for the experimental period. The root mean square (RMS) error in current speeds predicted averaged across the three sites was 0.04 m/sec and the RMS error in current directions averaged across the three sites was 14 degrees. Note that the "observed" currents were generally under-measured at times of peak flow as strong currents caused the current meter to lean over away from the major flow.

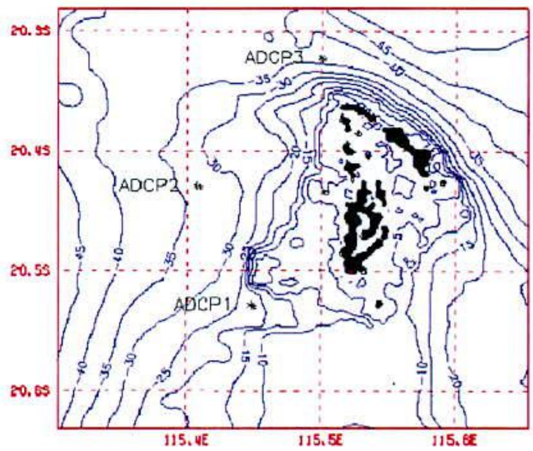


Figure 5.18 ADCP measurement locations around the Montebello Islands.

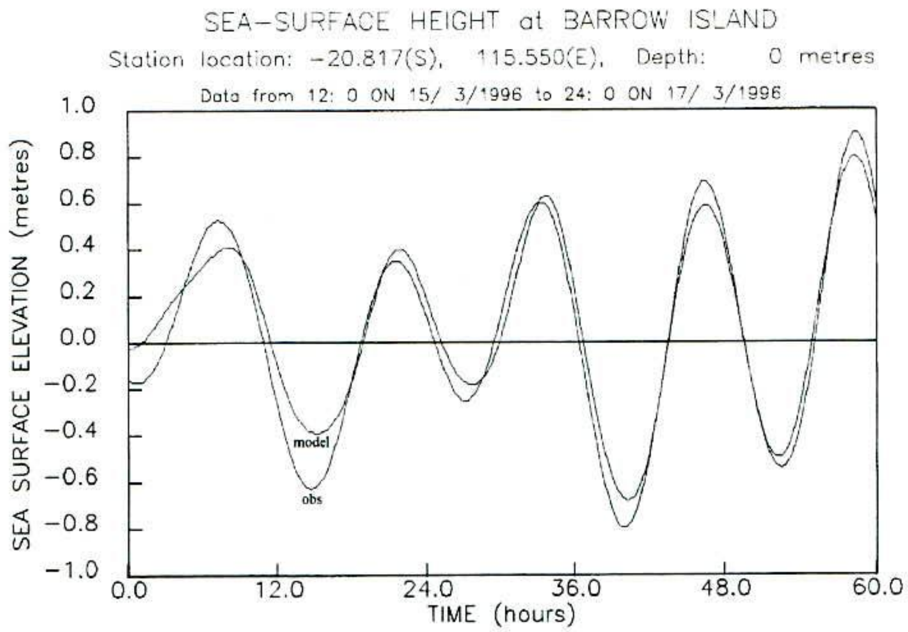


Figure 5.19: Model predictions of tidal heights compared with observations on April 16 and 17, 1996 at WAPET tanker mooring.

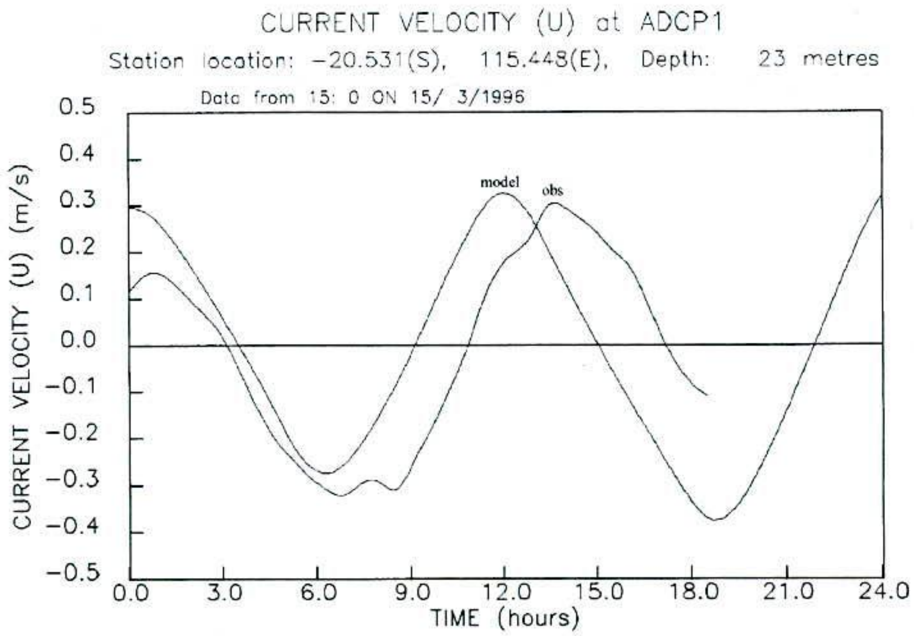


Figure 5.20: Model predictions of the west-east current component compared with observations on April 16 1996 at site ADCP1 near the Montebello Islands

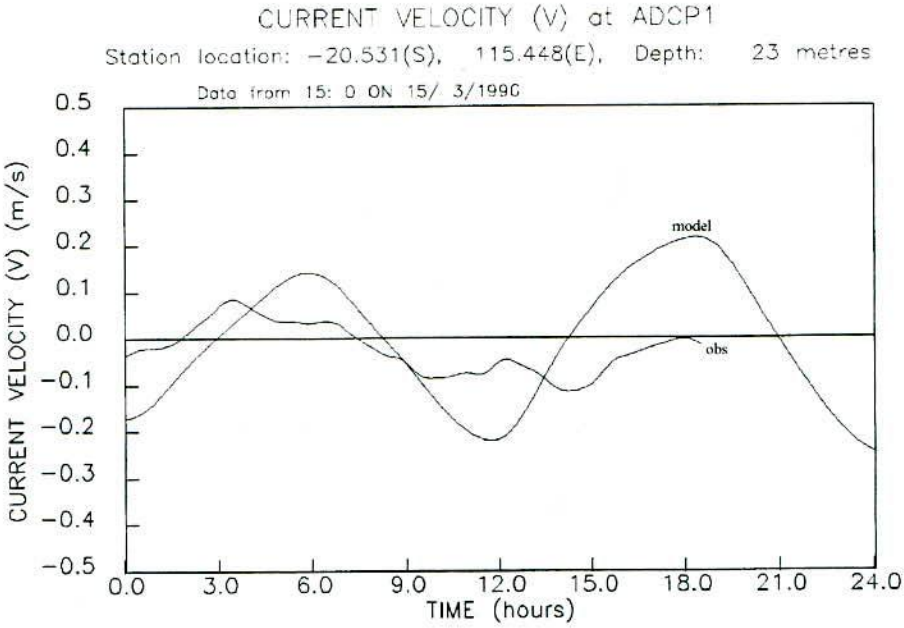


Figure 5.21: Model predictions of the south-north current component compared with observations on April 16 1996 at site ADCP1 near the Montebello Islands

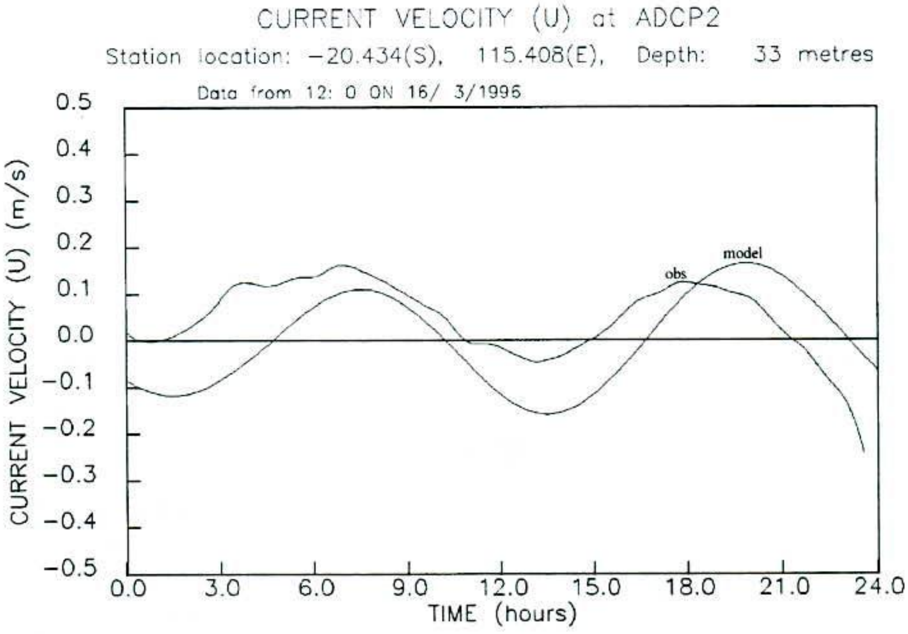


Figure 5.22: Model predictions of the west-east current component compared with observations on April 17 1996 at site ADCP2 near the Montebello Islands

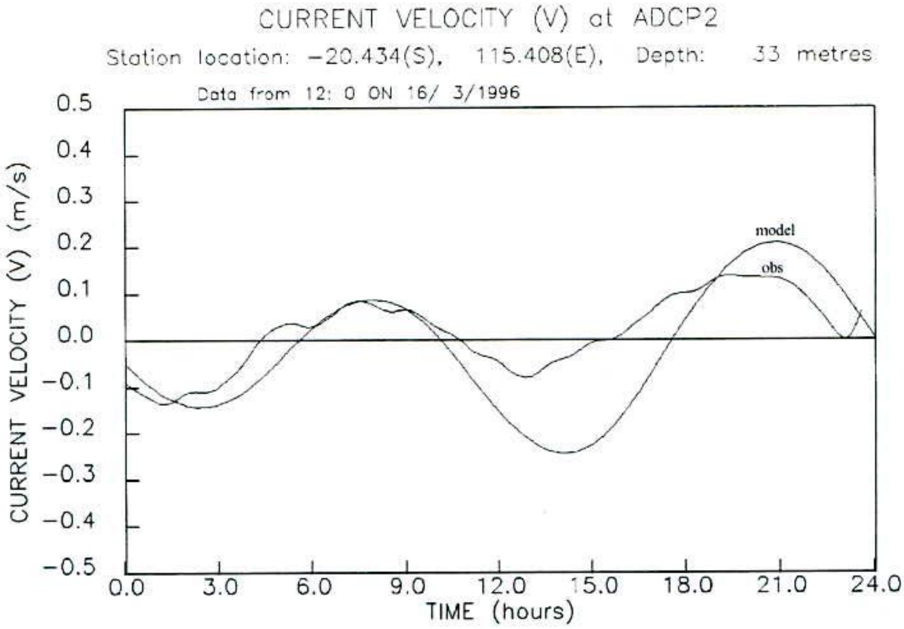


Figure 5.23: Model predictions for the south-north current component compared with observations on April 17 1996 at site ADCP2 near the Montebello Islands.

Further validation of GCOM3D was carried out near the Montebello Islands against the observed track of oil spill mats. Mats of thin, closed cell foam were released and tracked on two separate occasions: from 15^{00} to 1800 hours on 6^{th} August 1997, and from 1000 to 1500 hours on 7^{th} August 1997. GCOM3D was set up over the same model area described above and used the speed and direction of wind that was logged at Varanus Island (20 km to the south) during the tracking periods. In each case, the model predicted a similar trajectory to that observed for the floating mats (Figures 5.24 & 5.25).

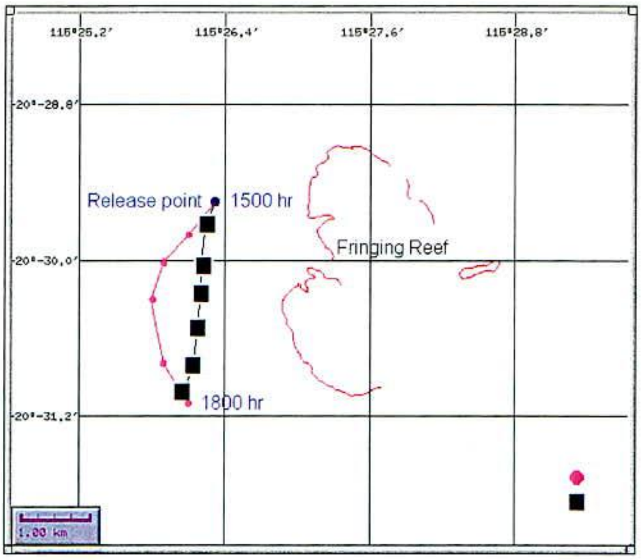


Figure 5.24 Comparison of the predicted (circles) and measured (squares) path of a floating mat released near "Wonnich" reef on 6th August 1997.

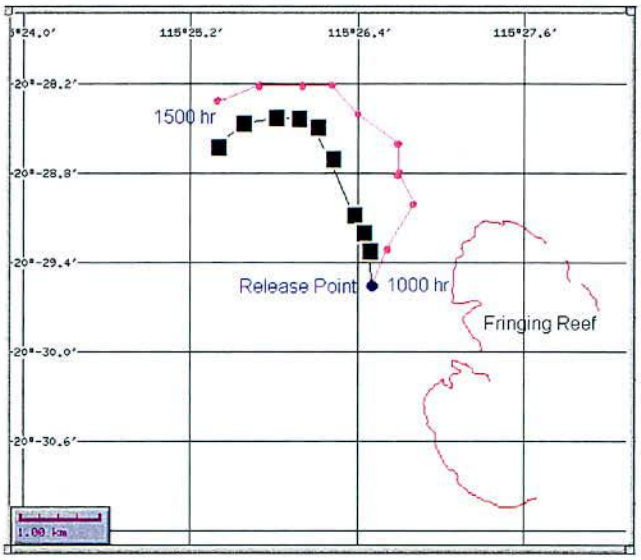


Figure 5.25 Comparison of the predicted (circles) and measured (squares) path of a floating mat released near "Wonnich" reef on 7th August 1997.

3.3 Mermaid Sound Verification

The oil spill trajectory model predictions in Mermaid Sound were verified against existing current meter data provided by Woodside Offshore Petroleum. At the site chosen for the verification (latitude 20° 31.4', longitude 116 ° 43.7', depth 14 m) the current meter was at a depth of 6 m. The Perth office of the Bureau of Meteorology provided historical hourly wind data for a three-day period (April 27 - 29, 1986) during the current meter observations. GCOM3D was run for this 72 hour period driven by winds and by five tidal constituents (M2, S2, K2, K1, O1) with vertical levels set at 2, 6, 10, 14, 18, 25 and 40 metres. The second level coincided with the depth of the current meter observations. A comparison of the observed current speed over time with the model predictions is shown in Figure 26.

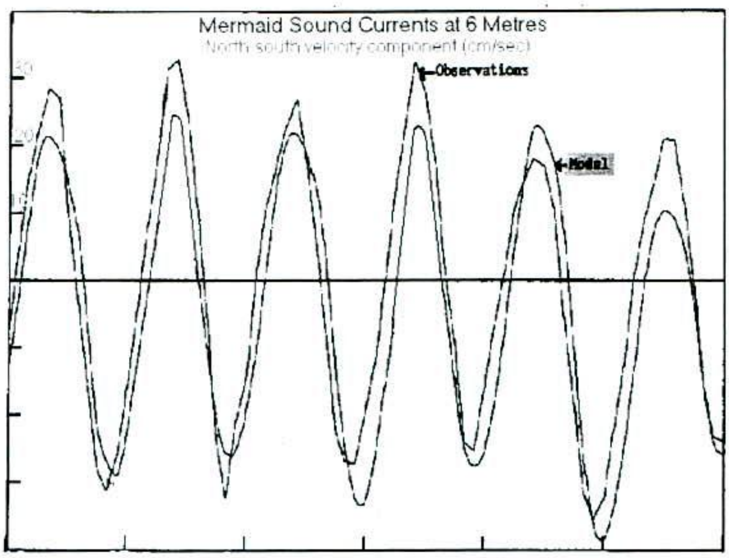


Figure 5.26: Comparison of observed currents and predictions from GCOM3D at a depth of 6 metres in Mermaid Sound for the period April 27 to 29, 1986.

3.4 Lowendal Islands verification

A detailed field study was carried by the Australian Institute of Marine Sciences to measure and model the dispersion of produced formation water from the Harriet production platform (King and McAllister 1997). The survey measured fine resolution measurements of both the horizontal and vertical concentrations of produced water elements (benzene, toluene) over a wide range of hydrographic conditions. These measurements were then used to verify the predictions of the MUDMAP plume discharge model with ocean current predictions provided by GCOM3D. It was concluded that the model could predict the position of the plume within 50 m over the near field (first few kms) and within 400m over the far field (10-20 km). Predicted concentrations of the plume were within a factor of 2 of the measured concentrations within the near field. Example comparisons between the observed and predicted plume concentrations are shown in Figures 5.27 and 5.28. Full details are described in King and McAllister (1997).

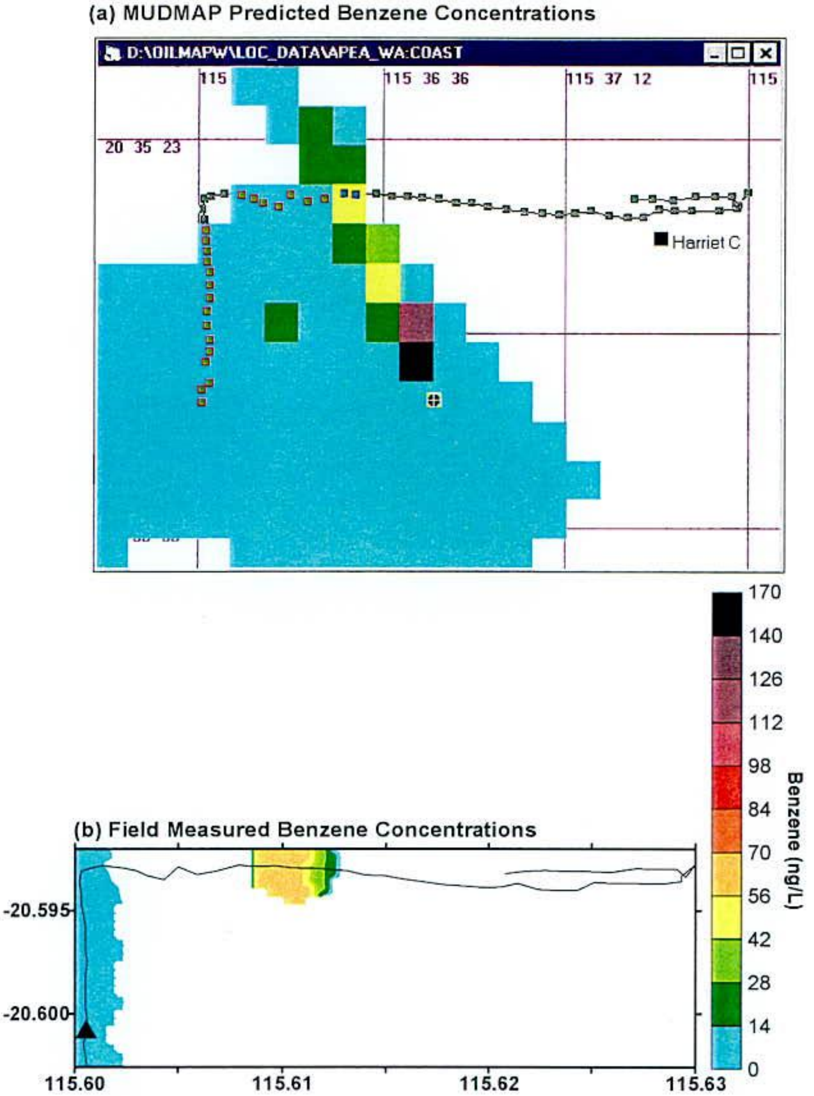


Figure 5.27: Comparison of field measured plume distribution of benzene with that predicted by MUDMAP for 1430 – 1500 September 25, 1995. The sampling ship's track is shown on each plot (from King and McAllister 1997).

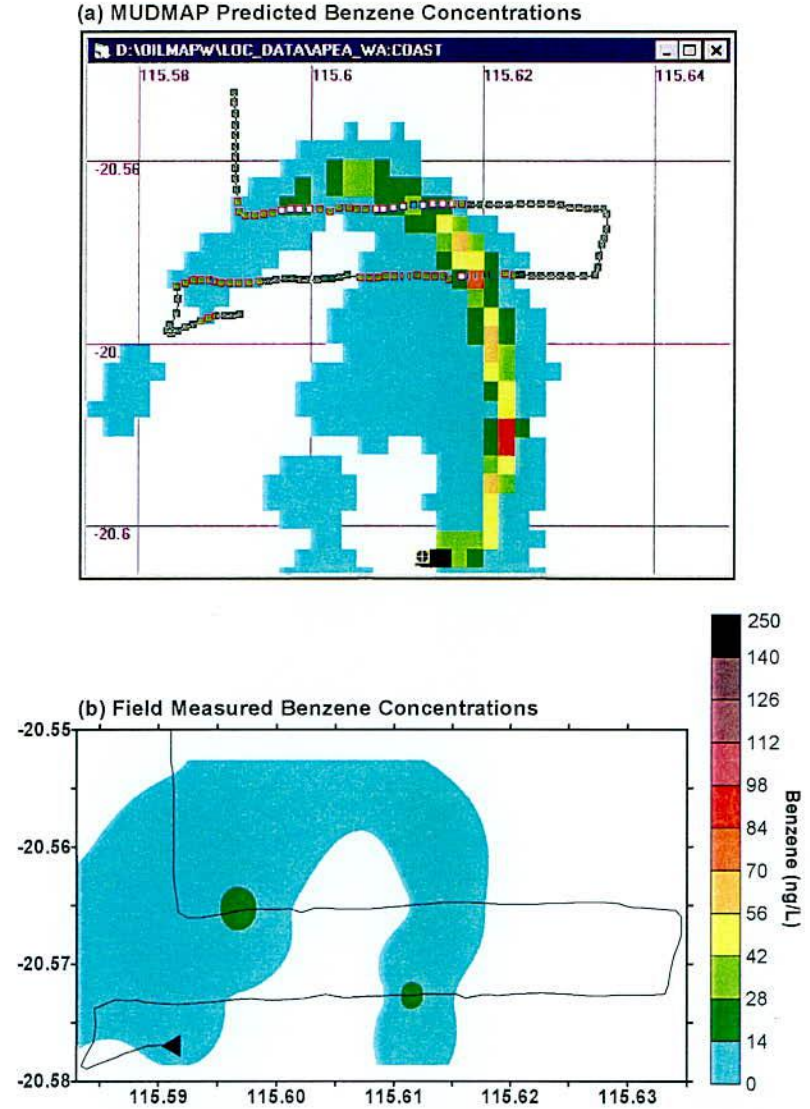


Figure 5.28: Comparison of field measured plume distribution of benzene with that predicted by MUDMAP for 1630 – 1700 September 25, 1995. The sampling ship's track is shown on each plot (from King and McAllister 1997).

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Spaulding M.L. (1988). " A State-of the Art Review of Oil Spill Trajectory and Fate Modeling". *Oil & Chemical Pollution* (4) 39-55.

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APPENDIX 6

Effects of oil on resources

EFFECTS OF OIL ON NATURAL AND SOCIAL RESOURCES

1. Introduction

There is no clear-cut correlation between the size of the spill and extent of damage. The environmental effects of oil pollution on marine organisms varies greatly depending on the volume of oil, the type and physical state of the oil, the capacity of sediment penetration, location of the spill, climate and seastate, the life history of the species involved and the level of exposure. Impacts can be caused by physical contamination, smothering, toxicity bioaccumulation, and tainting (Jones 1986). These effects can be short term or long-term, lethal or sublethal. Damage by oil can result in changes in behaviour, biochemical attributes, physiological attributes which may impact the flora and fauna at an individual level through to the ecosystem level (Sheehan 1984). Commercial, recreational and social interests can also be impacted.

An overview of the impacts of a light crude oil on various resources is presented in Table 14 of the main text.

Oil pollution will exert its most severe consequences in shallow, sheltered waters where dilution and dispersion is limited. The impact is of a lesser degree in open water or areas of high energy.

As there have been no significant spills of Western Australian oils which have reached nearshore or onshore resources, predictions for the potential impact of spills on the local marine communities has been based on spill incidents referred to in the literature.

2. Sources of Disturbance

In evaluating the potential impacts of an oil spill, it is necessary to place the impact of a spill within the context of existing disturbances as it is against these variables that the consequences of an oil spill must be compared.

Potential anthropogenic and natural sources of disturbance are listed in Table 6-1.

3. Biological Recovery Process

The biological recovery of an ecosystem which has been damaged by oil begins as soon as the toxicity of the oil has degraded to a level which is tolerable to the most robust colonising organism (Baker *et al.* 1990). This recovery time can vary from a few days to more than a decade, but recovery will occur. Considerable variation in tolerances and sensitivities to oil have been observed among different species and different life stages which. Generally, the effects increase in intensity and persistence from pelagic (open ocean) to subtidal to intertidal communities. The reproductive strategy of each type of animal is also an important factor in the recovery of a species.

The water mass is dynamic and rarely static. It moves with the wind, tides and currents. Large scale oceanic processes such as the Leeuwin current and local processes such as tides influence and affect the distribution, recruitment and survival of marine flora and fauna.

The majority of marine plants and invertebrate animals produce millions of gametes (eggs and sperm) which drift and develop in the water mass. Marine species with planktonic larvae are rarely site dependent - similar benthic communities are likely to occur wherever appropriate conditions are present. Such locations may be miles away, but the communities are likely to be closely related genetically and in community structure. Species with planktonic larvae are most likely to recover quickly after an oil spill.

A few marine invertebrate species reproduce by generating and caring for a relatively small number of eggs or young. These species may become endemic to a particular habitat. If the habitat has been destroyed, the local population may take a long time, if ever, to recover.

The initial phase of recovery after some disturbance or organic enrichment, is characterised by a small number of species, but in very high abundances (Pearson & Rosenberg 1978; Kingston 1987). As conditions improve, other less hardy species are able to establish themselves, and by competition, reduce the numbers of the initial colonizers. In time, the flora and fauna characteristic of the area is restored.

Marine communities, whether they are soft sandy bottom, rocky shore, coral reef or mangrove, are in a constant state of flux and change due to natural physical and biological factors such as predation, competition, recruitment success, cyclones and sandwave migration. Studies investigating the temporal trends in marine soft bottom and rocky shore habitats have reported wide variations in population abundances and diversity from season to season (Lewis 1972; Gray *et al.* 1984). This complicates predicting or assessing the impact of oil as is it difficult to distinguish oil induced effects from natural fluctuations.

Much of the work carried out to date on the effects of oil has concentrated on single species. However, no one species lives in isolation. Ecosystems are composed of a multitude of different plants and animals that have developed a relationship between themselves and the physical attributes which surround them (air, water, soil). An oil spill could cause a major disruption to this relationship resulting in changes in the composition and functioning of the ecosystem, or in key processes such as primary production or nutrient cycling.

The re-establishment of a biological community after some perturbation is unpredictable as it depends on various factors including the availability of recolonizing organisms, biological interactions and climatic variables, food availability and suitable substratum for settlement.

Recovery is marked by the re-establishment of a healthy biological community in which the plants and animals characteristic of the community is present and is functioning normally (Clark 1989). A re-established community may not have exactly the same composition, diversity, biomass or age structure as that which was present before the damage. This change does not necessarily diminish the biological importance of that community. It must also be considered that it is impossible to determine if a community which has recovered from an oil spill is the same or different from the community which would have persisted had the spill not occurred.

4. Impacts of Oil on Natural Resources

A brief overview of the impact oil would have on the different types of resources found in and around the Montebello Islands is given below.

In general, the effects of hydrocarbons on marine life may include:

- lethal toxic effects - where death of an organism results from direct interference of a component of the oil;
- sub-lethal effects - chronic, biological effects of oil through disruption of physiological and/or behavioural responses, but not resulting in immediate death;
- bioaccumulation - where oil may be transferred through the food web;
- tainting - uptake of oil or certain fractions of oil;
- direct smothering and suffocation;
- physical or chemical alteration to a habitat resulting in a change in population or community structure.

4.1 Plankton

Plankton are the minute animals and plants floating about in the oceans, forming a component of the food chains in the marine environment. Plankton provide an important source of food to animals living in all types of marine habitats: mud, sand, coral reefs, mangroves, rocky shores. Suspension feeders (e.g. barnacles, corals, some polychaete worms) feed on live and dead particles suspended in the water column. Other animals feed on the dead plankton that has settled on the seabed (e.g. crabs, sea urchins, prawns). The larvae of many marine organisms spend time in the plankton during the early stages of their life cycle (e.g. corals, fish, crayfish). Plankton exhibit high natural mortality and are very patchy both spatially and temporally.

In the event of an oil spill, the plankton within the immediate area of the spill would undoubtedly suffer high mortality but repopulation is likely to be rapid due to high reproductive rates and immigration from areas outside the impacted area (Davenport 1982). Plankton is free floating and abundant in surface waters and so can be swept into previously contaminated areas from neighbouring unpolluted waters by surface currents. In open waters, populations may return to normal within days of a spill, although recovery may take longer in enclosed bays where water movement is less and oil may persist.

From a literature review, Volkman *et al.* (1994) concluded that there was general agreement that oil toxicities to plankton showed little or transient effects in both experimental and field experiments.

4.2 Benthic and Intertidal Communities

Subtidal communities

The risk of an oil spill affecting the seabed of offshore waters is minimal, but in shallow water, oil droplets may reach the bottom, particularly in rough weather. Fresh crude with a high proportion of toxic light components can cause local damage to the flora and fauna of shallow benthic habitats. The incorporation of heavier oil into the sediment can lead to a residence time of several years. However, sediment resuspension from tide, current and storm activities will help in the degradation process and allow recovery of the community. If the oil is not persistent, the recovery time can be within a few years, depending on the reproductive strategy of the various marine organisms.

Rocky Shores

Many rocky shore animals lay eggs directly into the sea. These eggs develop into larvae and become a component of the plankton. The larvae may eventually settle onto a suitable substratum and develop into an adult. As a part of the plankton, larvae can move great distances as they are swept by currents, tides and winds and hence their numbers are highly variable from both temporally and spatially (Underwood & Chapman 1995).

The effect of oil on the rocky shore tend to be minimal and recovery rates are rapid (2 years) due to the high energy level which helps break down the oil and because oil does not stick easily to rock (IPIECA 1991). The recovery of rocky shore plants and animals depends on the settlement of the young stages out of the plankton. Settlement and subsequent growth depends on adequate reduction in the volume and toxicity of oil residues.

Mudflats and Sand Beaches

The faunal diversity of mud and sand beaches can be correlated to the size and composition of the sediment, and the tide and wave energy. In general, mudflats consist of small particles and low energy, but of a range of sizes while sandy beaches consist of larger particles and higher energy and a small range of sizes. In terms of diversity, mudflats will generally have a higher diversity of animals than sandy beaches.

There is a characteristic fauna of fish that are usually associated with sand beaches (ref) which includes bait fish and juvenile fish. Infauna will be low in diversity and abundance and consist mainly of amphipods and ghost crabs. Some of this fauna is a source of food for some species of seabirds, and turtles use the sand beaches for nesting.

The main impact from oil results if the hydrocarbon is stranded on the beach. Sheltered shores, or low energy coastal habitats may retain oil for long periods of time affecting the recovery rate. Tidal flushing, currents and fauna that turn the sediment over (bioturbation) will help to decrease the amount of time for the oil to degrade.

Seagrasses and Algae

Algae and seagrasses are photosynthetic organisms which use the energy of sunlight to reduce carbon dioxide to organic compounds which they use as food. Unlike seagrasses, algae do not have roots. They receive all their nutrients directly from the water. Algae do not produce flowers, but rather spores which are released directly into the water by the adult plant. Algae provide food for a host of different marine organisms and some species form large floating mats which act as habitats for a flotilla of marine animals. Both are important as sediment stabilizers and fauna habitats.

The effects of oil on algae will be dependent on its distribution. Intertidal species in low energy, sheltered sites are the most at risk due to direct contact and the potential residence time of the oil. The response to seagrass to oil spills appears to vary considerably (Thorhaug 1987).

Seagrass beds and algae will survive a spill provided that no actual coating. Coating causes considerable destruction (Thorhaug & Marcus 1987) but reasonably rapid recovery of these areas through recolonisation (algae) or regeneration (seagrass) has been observed following oil spills (AGC Woodward-Clyde 1992).

The fauna associated with seagrass beds appear to be quite susceptible to oil (Jackson *et al.* 1989). Intertidal and shallow subtidal assemblages are most at risk, due to the direct effects of coating. Shallow sediments may also be affected, damaging the rhizomes of seagrasses and so preventing long-term recovery. Deeper assemblages will escape the effects of surface oil in all but extreme weather conditions or where oil is heavy.

Corals

The response of corals to oil spills varies according to geographic locations and the species of coral (Harrison *et al.* 1990; Guzman *et al.* 1990; Keller & Jackson 1994). Laboratory experiments have documented a number of lethal and sub-lethal responses of coral to oil exposure. Sub-lethal responses include:

- uptake and depuration in mucous;
- zooxanthellae expulsion;
- decreased calcium uptake and zooxanthellae production;
- impaired feeding response;
- impaired larval settlement; and
- larval death.

Experimental studies have shown direct contact with oil is not immediately fatal to corals, but that its may lead to rapid necrosis of the contacted tissues. A review of field and laboratory experiments by Connell & Miller (1981) concluded that oil that is immersed, solubilised and dispersed in water has a much greater effect than oil floating on the surface.

Translation of these sub-lethal effects measured in the laboratory to field situations has generally proven difficult, but studies of oil spills in a number of regions have shown a range of species to be sensitive to oil, with emergent corals being more vulnerable due to the potential for direct contact with the floating oil. Sensitivity to oil has been found to vary from species to species with factors such as structural complexity and natural mucous production affecting oil response.

Th effects of spilled oil on corals are dependent on both physical and biotic factors such as depth of immersion, tidal movement, weathering of the oil, composition of the oil and coral species present.

Mangroves

Mangrove communities are potentially the most sensitive of the marine environments to coating by oil (Lai *et al.* 1984; Wardrop 1987). Oil spills may result in the immediate destruction of all flora and fauna within the community. The mangroves themselves are highly susceptible to even light coating by oil and suffer permanent damage and mortality due to loss of leaves through chemical burning, or smothering of the breathing pores (lenticels) or the aerial roots (pneumatophores). Mangroves are also known to take up the light end component from the oil through their roots and leaves, causing tissue damage and eventual death (Woodside 1989; Klekowski *et al.* 1994). Oil retained in the sediment may also inhibit the germination of mangrove propagules, resulting in the slow recovery of the affected area.

Mangrove communities typically occur in sheltered areas of low wave energy, making retention of oil within the sediments a potentially long term problem. The retention of oil in the substrate may result in chronic exposure to oil due to the flushing of retained oil out of the sediment over each tidal cycle. The burrows of organisms and the roots of trees also act as a conduit for light oils, allowing the penetration of oil deep into the sediment.

In open, aerobic sediments, the loss of light oil appears to take about 18 months (Woodside 1989). However, in areas where the sediments were anaerobic, with a high organic content and poorly flushed, degradation is slow and the oil persists over 20 years or more (Burns *et* *al.* 1994). Re-emergence of young trees will be unlikely until at least the toxic components of the oil are lost. Estimates of recovery rates range from tens to hundreds of years to regain a mature forest (Burns *et al.* 1993).

Fin Fish

The death of adult fish has been attributed to toxic effects after of water or tainted food, ingestion and to suffocation caused by clogging of the gills (Clark 1982; Jones 1989). Large kills of adult fin fish in open water would not be expected due to their mobility and ability to avoid oil contaminated water. Mortality of adults in sheltered, enclosed bays, especially demersal fish, would be higher if oil became mixed through the water column or settled in the bottom substratum.

The greatest damage to fin fish would be during and just after the spawning period when the more sensitive eggs and larvae may float on the surface of the ocean. This may result in a short term decrease in fish stocks. However, the literature indicates that mortalities among pelagic fish and larvae are limited in size and will have no measurable impact on fish stocks. For example, 10 months after the Exxon Valdz spill, there was a record catch of pink salmon. The reason for this increase was attributed to the oil acting as a fertilizer, helping to prolong an algal bloom which provided food for the fry (Anon 1990). On the negative side, the oil spill killed off diving seabirds which fed on the salmon fry.

4.3 Seabirds, Marine Reptiles and Mammals

Seabirds

The most serious effect of oil is on the birds plumage. Birds rely on the air trapped in their feathers to provide insulation and buoyancy and oiled feathers mat down and lose their water repellent properties. This leads to death by drowning or hypothermia.

Lightly oiled birds are able to clean themselves by preening within two weeks (Birkhead *et al.* 1973) but in doing so ingest oil. This ingested oil may cause liver, kidney and other tissue damage, may reduce the fertility of eggs that are laid (Grau *et al.* 1977), or result in death. Although highly mobile and potentially capable of avoiding polluted areas, seabirds may be attracted to dive into oil slicks, mistaking the sheen for fish.

Many pelagic tropical species feed by picking or snatching prey from at or near the sea surface without settling on the water (e.g. Bridled Terns, Sooty Terns, noddies, frigatebirds). Wedge-tailed Shearwaters, Bulwar's Petrels, gadfly petrels, storm petrels feed while paddling on the surface of the water. Boobies and Tropicbirds plunge dive to about a metre or so below the surface.

On the North West Shelf, seabirds are often associated with large floating rafts of the brown algae *Sargassum.* A range of juvenile and larval fish, crustaceans and terrestrial insects shelter in the rafts and act as a food source for the birds. Bridled Terns in particular appear strongly reliant on *Sargassum* (Wooller 1995). In the event of an oil spill, oil may become entrained into the rafts with the potential of toxic effects (Butler *et al.* 1983).

The movement of pelagic predatory fish, particularly tuna, are important to many seabirds. Species such as the Sooty Tern may be totally dependent on tuna to bring prey to the surface of otherwise deep ocean. Platforms and monopods function as fish aggregators, attracting fish such as tuna and mackerel. As a consequence, the seabirds also tend to concentrate to varying degrees around these structures where they may be vulnerable to localised spills (Dunlop *et al*. 1995).

Many seabirds have a yearly, single egg clutch and chicks with relatively long fledgling periods (e.g. Wedge-tailed Shearwater, Bridled Terns). In Bridled Terns, the minimum age of first breeding is four and a reproductive life extending 6-15 years. Wedge-tailed shearwaters have a reproductive life of 10-20 years.

In terms of impact from an oil spill, the concern in not the deaths brought on by oiling, but the number and fate of the survivors. Recovery of a population depends either on (i) the existence of a reservoir of young breeding adults from which breeding colonies can be replenished or (ii) a high reproductive rate. Animals with a large breeding potential may rapidly regain their losses. Mortality is only significant if it results in a substantial decrease in the breeding population.

Turtles

Little is known about the direct effects of oil on turtles. Eye infections may result from direct contact with oil, however most animals would be expected to avoid polluted areas. The lighter oils produced by the Harriet oilfield may be capable of penetrating the sandy sediments found on nesting beaches and subsequently interfering with egg-laying or egg development. However egg laying and development usually occur high on the beach beyond the reach of stranded oil. Nesting females and young hatchling turtles might be coated with beached oil as they emerge from and enter the water.

Marine Mammals

Information on the impact of oil on marine mammals is limited. However, Baker *et al.* (1990) believe that these species appear to ignore floating oil and are unharmed when they encounter it.

Like turtles, marine mammals may suffer eye infections after direct contact with oil (NRC, 1985). Other potential effects include surface fouling, direct and indirect ingestion and inhalation of toxic fumes (Volkman *et al*. 1994). Whales and dolphins have been observed to avoid surface oil slicks and dugongs are presumed to be able to do so, although no information on their response to oil is currently available (Baker *et al.* 1989). As marine mammals move freely in open water, they would not be exposed to prolonged or sustained exposure to oil.

Work carried out by Hellou *et al.* (1990) found low concentrations of polycyclic aromatic hydrocarbons (PAHs) in the skeletal tissue of ten species of marine mammals in eastern Canada, implying that PAHs can accumulate in mammalian tissue. However, the data mist be interpreted with caution as the concentration and retention of hydrocarbons will depend on the level of exposure, sex, body organ and ability of the animal to depurate.

Dugongs may be indirectly affected by ingestion of coated seagrass leaves.

5. Effects of Oil Spills on the Social Environment

5.1 Prawn Fisheries

The prawn fishery in Exmouth Gulf will be at minimum risk from an oil spill. The pelagic larval stages and the benthic juvenile and adult stages of prawns are more sensitive to oil than fin fish or molluscs and catches may be reduced due to mortality or to reduced fishing effort in polluted areas. Pelagic fish are able to avoid spills but benthic fish may suffer from pollution of substrates.

As filter feeders, pearl oysters will ingest oil particles if they sink through the water column and this may cause mortality.

5.2 Tourism

An oil spill may have a temporary effect on the operations of charter boats and recreational fishing. The actual recreational fish stocks are unlikely to be affected as game fish are highly mobile and so able to avoid the effects of a spill.

6. Bacteria

This group of organisms is given separate recognition due to their natural occurrences and their potential to help in the remediation process after an oil spill.

Biodegradation is a natural process whereby bacteria or other micro-organisms alter and breakdown the organic molecules of oil.

The natural population of bacteria found in the marine environment has the potential to degrade hydrocarbons very rapidly, especially if additional nutrients are added. These bacterial populations have been found to be very complex and a number of different species work together to degrade the hydrocarbons. Extensive bioremediation techniques were developed after the *Exxon Valdez* spill and results have been very promising. One finding was that background microbial degradation occurred at very fast rates (Hoff 1993) supporting the claim that under certain circumstances, natural cleansing may be the best clean-up option. However, the technique still needs refining before it can be used large scale clean-up technique.

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Table 6-1: Potential Man-Induced & Natural Stressors

Anthropogenic Sources	**Potential Impact - Comments**
Shipping	Accidental spillage of oil. Illegal operational discharges.
Tourism	Tourism to the islands is still fairly limited due to their distance from the shore. Visitors come to the islands mainly in the winter and seek sheltered anchorage in the sheltered bays.
Recreational Fishing	Overfishing and depletion of stocks. Damage to coral reefs from anchoring. Charter vessels visit the islands on a regular basis, but numbers are relatively low compared to other offshore islands.
Pearl Farming	Increased organic matter load in sheltered waters.
Global Warming	Increase in water temperature and water level. Increased temperatures may be cause of mass coral bleaching.
Natural Sources	**Potential Impact**
Crown-of-Thorns Starfish	Destruction of coral through feeding. A recent outbreak is thought to have occurred on the west fringing reef of the Montebello Islands. Some have been observed on the Lowendal Islands also. No reason for outbreaks determined as yet.
Drupella cornus	Mortality of coral through feeding. Another coral predator (gastropod) which aggregates in large numbers and causes death of coral. The cause of outbreaks is unknown. *Drupella* has been observed on the reefs around the Lowendal Island.
Phytoplankton Blooms	Invertebrate animals and fish mortality due to oxygen depletion or release of toxins. Occurs mainly in shallow, sheltered waters.
Insect Infestation Boring Organisms	Defoliation. Loss of branches. Death. Affects predominantly mangrove trees.
Parasitic protozoans	A naturally occurring protozoan causes 25-50% mortality to oysters by destroying connective tissue in gastric system.
Cyclones	Extensive physical damage to corals and mangroves. Beach erosion. Algal blooms due to release of nutrients in resuspended sediments.
Cyclonic Rainfall	Short-term reduction in salinity of shallow waters. Freshwater run-off from land.

APPENDIX 7

Refuelling procedure

Refuelling Management Plan

1. Refuelling will be carried out under the direct supervision of the Barge Master.

2. A work permit specific to fuel transfer will be drawn up based on the detailed refuelling procedures.

3. The refuelling will be carried out only during daylight hours on environmentally sensitive areas (i.e. adjacent to coral reefs and islands).

4. The refuelling hose will be fitted with camlock, dry coupling links.

5. The refuelling hose will be a wire reinforced, floating hose.

6. Refuelling will be carried out at a time when the prevailing currents will carry any accidentally spilt fuel away from environmentally sensitive locations.

7. Refuelling will be carried out in suitable sea conditions to the discretion of the Master of the Supply Vessel and the person in charge (PIC) of the rig.

8. Communications are to be maintained between the rig and the refuelling vessel at all times during refuelling using hand held radios.

9. The refuelling is to monitored by personnel on watch at appropriate locations on the supply vessel and on the rig.

10. Sufficient oil spill clean-up material will be stored on the drilling rig and support vessel to clean-up small spillages.

11. Refuelling will be recorded in the log book of both the supply vessel and the rig. Any difficulties experienced will be entered into the log and reported immediately to the drilling manager.

Refuelling Procedures

- Ensure all personnel are aware of intention to refuel and emergency response procedures.
- Discuss refuelling plan and tank sequence with officers involved.
- Close and blank off all unnecessary manifold valves and connections.
- Place oil absorbent materials in key locations.
- Establish common communication link between bunkering station, duty officer, engine room and refuelling barge.
- Check all bunker tank air pipes are open and unblocked.
- Ensure all sounding pipe caps are tight, except when sounding tank.
- Reconfirm space remaining in all bunker tanks to be filled.
- Check all bunker tank high level alarms are functioning.
- Ensure all fire precautions are observed.
- Check hose is of sufficient length.
- Inspect hose and couplings for damage.
- Check weight of hose does not exceed SWL of vessel's lifting gear.
- Place drip trays under hose couplings and flanges.
- Check delivery note quantity and specification are correct.
- Discuss bunkering plan with supplier.
- Discuss vessel's emergency response procedure with supplier.
- Discuss supplier's own emergency response procedures.
- Establish communication link between vessel and supplier.

- O Agree with supplier the quantity of diesel to be pumped aboard.
- O Agree unit of measurement (e.g. metric tonnes, cubic metres, barrels).
- O Agree maximum pumping rate and pressure.
- O Appoint seaman to tend mooring lines during bunkering.
- O Ensure designated overflow tank is prepared.
- O Prepare filling line and open all relevant valves.
- O Commence bunkering at minimum pumping rate.
- O Monitor supply line pressure.
- O Examine hose connections for leakage.
- O Reduce pumping rate and/or open next tank before topping up.
- O Close valves as each tank is completed.
- O Witness, date, jointly countersign and retain sealed bunker samples.
- O Ensure sufficient ullage in final tank for hose draining/line blowing.
- O Notify supplier when final tank is reached.
- O Give suppliers timely warning to reduce pumping rate.
- O Give suppliers timely warning to stop pumping.
- O Drain hoses into tanks on completion of bunkering and close all filling valves.
- O Ensure hose is fully drained.
- O Close and blank off manifold connection.
- O Blank off disconnected hose couplings.
- O Reconfirm all bunker line and tank filling values are secure.
- O Reconfirm all bunker soundings.
- O Sight, agree and record barge meter soundings.
- O Verify all bunker receipt details are correct.
- O Complete entry into barge vessel and rig logs.

APPENDIX 8

Environmental policy

Apache ENERGY LIMITED

ENVIRONMENTAL MANAGEMENT POLICY

Apache Energy shares the community's concern for the proper care and custody of our environment for present and future generations.

We recognise that human activity despite being a legitimate and integral part of our global environment, has the potential to disturb the balance of nature and must be planned and managed with the utmost diligence.

We believe that by demonstrating leadership in environmental management our efforts will clearly show a concern for, and commitment to, ensuring that our oil and gas operations are performed in a manner which will have the absolute minimum effect on all animal and plant species and their surroundings.

This will be achieved by:

- advancing and promoting an environmental awareness and ethic in the workforce through education and training;
- developing and implementing systems to thoroughly identify, review and manage all activities which have the potential to affect the surrounding biological, chemical and physical environment;
- promoting research into and facilitating the monitoring of biological and physical processes to develop baselines, measure environmental change and to expand and broaden our scientific knowledge base;
- rehabilitating and restoring disturbed areas to a condition compatible with their prior use or status;
- reducing the production of waste products and energy through conservation, recycling and the use of renewable resources;
- maintaining an emergency response capability to mitigate any potentially damaging effect of an accident; and
- maintaining open community and government consultation regarding our work and accomplishments, and the development of meaningful and science based laws, regulations and environmental standards.

This policy has been reviewed and endorsed by Apache Energy management who foresee benefits in, and take responsibility for, its successful implementation. By accepting employment with Apache Energy, each employee acknowledges that he/she is responsible for the application of this policy. Success will be achieved when each project is completed without pollution and disturbed areas have been rehabilitated.

John A. Crum

John A Crum, Managing Director

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