ENERGY

Appraisal Drilling Programme for Wonnich Field South-west Montebello Islands (988)

Consultative Environmental Review

'OST DAMES & MOORE

APPRAISAL DRILLING PROGRAMME FOR WONNICH FIELD SOUTH-WEST OF MONTEBELLO ISLANDS (988)

CONSULTATIVE ENVIRONMENTAL REVIEW

Report for : Apache Energy Limited
Level 3
256 St George's Terrace
PERTH
Western Australia 6000

by : LeProvost Dames & Moore
South Shore Centre
85 The Esplanade
SOUTH PERTH
Western Australia 6151
A.C.N. 003 293 696
Telephone: (09) 474 1933
Facsimile: (09) 367 6780

17 January 1996

LDM Ref: 31479-002-367
DK:244-A21 [LDMR040]

Report No. R583, Rev. 4

WONNICH APPRAISAL DRILLING PROGRAMME
CONSULTATIVE ENVIRONMENTAL REVIEW

Invitation to comment

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

The Consultative Environmental Review (CER) proposes to drill two appraisal wells from the same surface location in Exploration Permit TP/8.

In accordance with the *Environmental Protection Act,* a CER has been prepared which describes this proposal and its likely effects on the environment.

The CER is available for public review forup to four (4) weeks from 20 January 1996 closing on 16 February 1996.

After receipt of comments from Government Agencies and the public, the EPA will prepare an assessment report with recommendation to the Government, taking into account issues raised in public submissions.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action including alternative approaches.

It is useful if you can suggest ways to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents and may be quoted in full or in part in each report unless specifically marked confidential.

Submissions may be fully or partially utilised in compiling a summary of issues raised or where complex or technical issues are raised, a confidential copy of the submission (or part of it) may be sent to the proponent.

The summary of issues raised is normally included in the EPA's assessment report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues.

Joint submissions may help to reduce the workload for an individual or group while increasing the pool of ideas and information.

If you form a small group (up to 10 people) you may wish to indicate the names of all 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 with 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 review document:

- 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 the issues raised are clear. A summary of your submission is helpful;

- refer each point to the appropriate section, chapter or recommendation in the review document;

- if you discuss sections of the review document, 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: 16 FEBRUARY 1996

Submissions should be addressed to:

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

Attention: Mr Tim Gentle

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EXECUTIVE SUMMARY

- This document is a Consultative Environmental Review (CER) submitted by Apache Energy Limited and the Joint Venture Participants to seek environmental approval for an appraisal drilling programme located in Exploration Permit TP/8.
- The proposal is to drill two appraisal wells from a single location located offshore approximartely 7.5 km west-south-west of Hermite Island, Montebello Islands.
- Drilling is scheduled to commence in mid-April using a jack-up rig, and will take approximately 62 days.
- A low toxicity, water-based drilling fluid will be used for the horizontal well. 'Petrofree', a synthetic ester-based drilling fluid will be used for the high angle deviated well.
- The major marine ecological habitats of the region include macroalgal and seagrass beds, fringing and patch coral reefs, rocky shores, sandy beaches and mangals. These habitats support fauna of both commercial and conservation significance. Drilling will take place approximately 1 km to the west of the southern sector of the Montebello Islands fringing reef.
- Social, commercial and historical resources of the region include the towns of Onslow and Dampier, the Onslow Prawn Fisheries Grounds, pearl fishery, three historic shipwrecks, historic nuclear testing sites and limited tourist activity adjacent to the Montebello Islands.
- Drill cuttings and drilling fluid will be disposed of in the lost circulation zone of the formation and not into the marine environment.
- Liquid discharges to the marine environment will be sewage, grey water and mascerated putrescible kitchen wastes. Solid wastes will be sorted and disposed of by recycling or at an approved landfill. These wastes will not have any adverse environmental effect.
- The main potential impact will be from an accidental oil spill. The quantitative risk assessment indicated that the chances of any oil spill is small. Small spills (1 bbl) are more likely to occur than blowouts (>20,000 bbls). Emphasis will be placed on preventing any oil spills from occurring in the first instance.
- Wonnich crude is a light oil which evaporates rapidly. At water temperatures greater than 20^{o}, the light end, toxic component of the oil will dissipate in 20 minutes.
- As the predominant wind direction for the proposed drilling programme is from the north-east, east and south, the risk of an oil spill impacting the resources of the Montebello Islands is decreased.
- Apache Energy will undertake the environmental strategies, guidelines and management commitments given in this CER for the Wonnich appraisal drilling programme and, in all cases, will fulfill those commitments to the satisfaction of the appropriate statutory authorities.

1. INTRODUCTION

1.1 Background

In 1994, Ampolex Limited (Ampolex), representing the Joint Venture Participants for Exploration Permit TP/8, sought approval to drill an exploration well at the Wonnich petroleum prospect at a location 18 km to the north of Barrow Island and 7.5 km to the south-west of Hermite Island, one of the larger islands of the Montebello group of islands (Figure 1).

The level of environmental assessment for the exploration well, designated Wonnich-1, was set at a Consultative Environmental Review (CER), and the required report was submitted to the Environmental Protection Authority (EPA) by Ampolex in February 1995 (Ampolex Limited 1995).

The proposed drilling programme was subsequently granted environmental approval, subject to conditions, by the Minister for the Environment in June 1995. Drilling commenced in the following month, Wonnich-1 being drilled by the jack-up drilling unit 'Ron Tappmeyer' between 8 July and 13 August 1995.

Wonnich-1 was drilled without incident and resulted in a hydrocarbon discovery in Flag Sandstone formation. Production testing assessed a 77 m column of natural gas overlying an 8 m column of oil. The oil is a light crude oil with an API gravity of 34^0, making it similar to Harriet Field crude (API gravity 38^0). By way of comparison, diesel fuel is slightly lighter (i.e. has a lower specific gravity), with an API gravity of 36^0.

1.2 The Present Proposal

To further delineate the hydrocarbon reservoir identified by Wonnich-1, the TP/8 Joint Venture Partners propose to drill two appraisal wells from a single location located offshore approximately 7.5 km west south-west of Hermite Island (Figure 2).

The programme calls for the drilling of no more than two appraisal wells: one high angle deviated well and one horizontal well (which will include a deviated pilot hole).

The site for the appraisal drilling will be located approximately 1 km from the southern part of the Montebellos fringing reef system (Figure 3). A low toxicity, water-based drilling fluid will be used for the horizontal well and an ester-based drilling fluid will be used for the deviated well, with down hole disposal of drill cuttings for both wells. In all other respects, the proposal is similar to Wonnich-1.

The proposal has been referred to the EPA which has set the level of assessment at CER level, i.e. the same level as set for Wonnich-1.

This CER:

- describes the environmental setting in which the proposed drilling programme will take place;

- presents an environmental analysis of drilling activities and their potential effects; and
- details the management strategies to be adopted to minimise the actual and potential environmental effects arising from drilling.

The assessment of the effects of the project on the environment is based on reviews of previous studies of the natural history and geological characteristics of the region, and the direct experience of the environmental consultants and Joint Venture Partners. Additional sources of information used in the preparation of this report are noted in the text and listed at the end of the report.

1.3 The Proponent

In December 1995, Apache Energy Limited (Apache) replaced Ampolex as the proponent for the Wonnich program. Apache will be managing the appraisal drilling program and acting for the project on behalf of the Joint Venture Partners.

The Joint Venture Partners in TP/8 are:

Ampolex (Western Australia) Inc.	24.0000%
Ampolex (Varanus) Pty Ltd	1.0000%
Apache Northwest Pty Ltd	22.0000%
Kufpec Australia Pty Ltd	19.2771%
Novus Harriet UK Limited	12.5000%
Marubeni Oil Australia Pty Ltd	12.2229%
Hardy Petroleum Ltd	8.4000%
New World Oil & Developments Pty Ltd	0.1000%
	100.0000%

The address for Apache is:

Apache Energy Limited
3rd Floor
256 St Georges Terrace
PERTH WA 6000

Telephone number: (09) 422 7222

Contact person: Dr Iva Stejskal

1.4 History of Exploration and Development in the Region

The Montebello region is currently subject to various onshore and offshore petroleum production leases and exploration permits. The first exploration wells were drilled on Trimouille Island in 1967 by West Australian Petroleum Pty. Limited (WAPET). WAPET has since produced in excess of 250 million barrels of oil from Barrow Island, immediately south of the Montebello Islands.

The first offshore exploration well drilled in waters adjacent to the Montebello Islands was in 1969 (Flag-1) followed by Tryal Rocks-1 and Campbell in 1979 (Figure 2). The Campbell drilling program led to the discovery of the Campbell gas field which was brought into production in 1992. The Harriet oil field was discovered in 1983.

Apache, its Joint Venture Participants and their predecessors, have been engaged in the exploration and production of oil and gas in licence area TL/1, 5 & 6, which lie immediately to the south of TP/8, since 1986.

In licence area TL/1, 5 & 6, and adjacent areas TP/8 and WA-192-P, which are geologically similar, there have been 48 wells drilled since 1982 without an incident or significant oil spill.

1.5 Legislative Requirements and the CER Process

Exploration and development of offshore petroleum resources in Western Australia is undertaken subject to a number of State and Commonwealth Government Acts. The principal State Act, the *Petroleum (Submerged Lands) Act* 1982, as amended, applies to projects located in State waters. State waters extend for a nominal distance of three nautical miles (5.5 km) offshore from the mainland but are extended to include the waters surrounding the islands under State jurisdiction, which include the Montebello Islands and consequently the Wonnich appraisal drilling site. The *Petroleum (Submerged) Lands Act* is administered by the Department of Minerals and Energy Western Australia (DME).

The review of the environmental impacts of developments in Western Australia, including petroleum exploration and development, is controlled by the *Environmental Protection Act* 1986. The EPA, acting under the provisions of the Act, has determined that the Wonnich appraisal drilling proposal be formally assessed under Part IV of the Act and has set the level of assessment at a CER.

Guidelines for the preparation of this CER have been provided by the Department of Environmental Protection (DEP) and are set out in Appendix 1.

The EPA's stated objective of the environmental review process is to "... protect the environment, and environmental impact assessment is deliberately a public process in order to obtain broad ranging advice. The review requires the proponent to describe the proposal, the environment, potential environmental impacts and the management of these potential impacts, so that the environment can be protected to an acceptable level."

The purpose of the CER is therefore to:

- communicate clearly with the public and government agencies, so the EPA can obtain informed public comment to assist in providing advice to government;
- describe the proposal adequately, so that the Minister for the Environment can consider approval of a well-defined project; and
- provide the basis of the proponent's environmental management program, which shows that the environmental issues resulting from the proposal can be adequately managed.

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, DME, Department of Conservation and Land Management (CALM), Department of Fisheries, Western Australian Museum (WAM), other agencies, community groups and individuals.

1.6 Justification of the Project

Petroleum exploration and production is the single most significant economic activity in Australia's marine environment. The total production value from Australia's petroleum industry exceeded $7.8 billion during 1993/94. For this period, 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 hydrocarbons. The Western Australian Government regularly releases permit areas for tender to oil and gas companies and consortiums to encourage onshore and offshore hydrocarbon exploration.

The Carnarvon Basin, within which the Montebello Islands are located, accounts for 98% of the State's total oil production and more than 99% of the gas and condensate production.

The proposal by the TP/8 Joint Venture Participants to conduct the Wonnich appraisal drilling program is an integral component of Australia's search for new oil and gas reserves. The project will benefit the community through capital expenditure, payment of royalties and employment.

1.7 Public Consultation

A list of parties interested in, or potentially affected by, the initial Wonnich drilling program were identified and contacted by Ampolex prior to the drilling of Wonnich-1.

Following the public review period for Wonnich-1, only three submissions were received on the CER from individuals or groups other than Government agencies. Ampolex subsequently responded to the issues raised in those submissions, and those made by Government agencies. The summary of issues raised in the submissions, and Ampolex's responses are reproduced in the EPA report on the Wonnich-1 proposal (EPA 1995).

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 Wonnich 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 drilling.

2. PROJECT DESCRIPTION

The drilling program details may be summarised as follows:

Surface Hole Location: (to be verified)	20°29'55.89"S 115°26'31.31"E
Approximate water depth:	20 - 25 m
Number of wells:	Potentially two, to be drilled from the same location.
Temporary well names:	Wonnich-East Wonnich-Flank
Type of wells:	
Wonnich-East	Deviated extended reach
Wonnich-Flank	Horizontal (including deviated pilot hole)
Total vertical depth:	
Wonnich-East	2,400 m
Wonnich-Flank	2,330 m
Approximate length of drilling period:	
Wonnich-East	32 days
Wonnich-Flank	30 days
Type of Drilling unit:	Jack-up drilling rig
Drilling fluid:	Low toxicity water-based drilling fluid 'Petrofree', an ester-based drilling fluid.

Further details on the programme are provided below.

2.1 Location

Wonnich-East and Wonnich-Flank will be drilled from the above surface location which lies approximately 1.5 km east of Wonnich-1 and 1 km from the southern sector of the Montebello fringing reef (Figure 3).

The seafloor at the proposed exploration well site lies at a depth of approximately 20-25 m and in this area consists of limestone pavement that is either covered with sheets of mobile, coarse white calcareous sands, or is exposed and/or thinly veneered and sparsely colonised with algae.

The nearest landfall to Wonnich is the rocky, western shore of Hermite Island which lies approximately 6 km to the east of the fringing reef. There are two bays on the western side of the island, Wild Wave Lagoon and Turtle Lagoon, the latter supporting a small mangrove community which fringes the sheltered shoreline. The bays are located near to the northern end of the island, the closest, Wild Wave Lagoon, being about 9 km from the well site. The remainder of the shoreline is exposed limestone.

2.2 Timetable and Drilling Schedule

Drilling of the Wonnich appraisal wells is scheduled to commence in mid April 1996 and there is a planned completion time for both wells of 62 days. The proposed directional profiles for the two wells are shown in Figures 4 and 5.

2.3 Site Survey

To determine the physical properties of the seabed, prior to installation of the rig, a sonar survey will be undertaken to confirm the bearing capabilities of the substrate. Grab samples will also be taken to confirm the nature of the surface sediments.

2.4 Logistics

The drilling rig to be used for the appraisal programme will be a self elevating, cantilever jack-up barge. The barge is towed into position by one or two support vessels. When in position, the legs are jacked down to the seafloor and the barge raises itself approximately 15 m above the sea surface, supported by the legs which bear on the sea floor.

The one or two support vessels which will tow and position the rig will also supply the rig with fresh water, food, fuel, bulk drilling fluid materials and drilling hardware. These vessels will operate between the rig and the Port of Dampier. Another vessel will stand by the rig to act as the oil spill response vessel providing a rapid response in the unlikely event of an oil spill.

The drilling rig and support vessel crews will be accommodated aboard their respective vessels. Crew changes will involve transfers by helicopters to and from Karratha Airport.

2.5 Drilling Procedures

In a typical appraisal well, a 36 inch hole is first drilled with seawater (90%) and clay (10%) to a depth of about 25 m below the seabed and a 30 inch conductor casing is installed into the hole. The casing is cemented into position and a riser and diverter are attached to allow drilling fluid recirculation and well control. Drilling then continues in a $17^1/_2$ inch hole with the next string of casing set at approximately 1,100 m. Deeper hole drilling will utilise a drilling fluid specifically formulated for each well. Upon cementing of this casing, a Blow-Out Preventer (BOP) will be installed and the casing tested. Drilling of the well then continues to total depth with casing strings of decreasing diameter being set and cemented to allow the control of formation pressure and well bore instability. After the cementing of each casing string, the casing and the BOP is pressure tested before drilling continues. Formation pressures within the well bore and the volume of returned drilling fluid are continuously monitored. If flowing formation is intercepted, the drilling fluid density is increased proportionately to provide primary well control. The BOP is used to seal the well in the rare event of a surface blowout.

At the completion of drilling of each well, electric logging tools are run or the well is production tested to evaluate the reservoir. Should the well be found to be uncommercial, it will be abandoned in accordance with DME approved programs. Cement plugs will be set at various depths in the well bore to seal the well, the casing will be cut off 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, as is considered likely, the field is considered to be commercially viable, the wells will be sealed using mechanical and cement plugs under government approved programs, and suspended until a decision regarding development can be made. All work on the wells will be undertaken in accordance with the regulations and guidelines set out in the *Petroleum (Submerged Lands) Acts*, Schedule: Specific Requirements as to Offshore Petroleum Exploration and Production - 1990.

On completion of the appraisal drilling program the rig will be jacked down and towed away.

The results of the drilling program will then be evaluated before either ceasing exploration of the Wonnich discovery, conducting further appraisal work or seeking approval to develop the field.

Any proposal for further appraisal drilling or to develop the commercial production of gas or oil following the successful evaluation of the resource would involve a new and independent approval process under the Environmental Protection Act.

2.6 Safety Precautions

Before drilling operations commence on each well, 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 storm conditions. Previous drilling at Wonnich-1 and construction programs in the adjacent production licence areas have provided information on the nature and stability of the seabed and the underlying strata, particularly with respect to the expected depth of penetration by the rig legs. The positioning and jack-up operation will be closely supervised by the drilling supervisor, rig supervisor and vessel skippers.

During drilling, a 500 m radius temporary exclusion zone around the rig will be declared under legislation and gazetted accordingly. The few vessels that do operate in these waters will be informed by radio about the exclusion zones applying around the rig on approach.

The well will be designed and engineered to standards approved by DME to ensure that well pressures remain under control. Annular, ram and drill string BOPs will be used. A typical BOP stack design system would comprise of the following:

- double 'U' ram, 10,000 psi working pressure;
- single 'U' ram, 10,000 psi working pressure; and
- an annular preventer, 5,000 psi working pressure.

The BOP system will be able to contain pressure far in excess of pressures previously encountered at Wonnich-1 (3,308 psia) 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 gained from Wonnich-1 and the numerous wells previously drilled in the vicinity will facilitate well design. 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 accident or emergency situation, will be submitted for approval to DME as required by legislation as part of the approval to drill the wells. Copies of the Emergency Response Manual and Oil Spill Contingency Plan are introduced in the Environmental and Safety induction process and are made available to crew members prior to the commencement of any work.

2.7 Production Testing

Production testing may be conducted at the end of drilling operations if hydrocarbons are encountered. The hydrocarbons will flow under reservoir pressure and be burnt using an efficient 'green' burner system (see Section 3.2.2.2).

3. ENVIRONMENTAL ANALYSIS OF DRILLING OPERATIONS

A description of the natural, commercial, industrial and social resources of the area surrounding the appraisal drilling site are given in Appendix 3.

This section of the report describes the types of activities associated with the drilling operation, the potential effects and the mitigating actions which will be put into place. In any exploratory drilling programme there is also a risk that the operation will give rise to an unplanned event such as an oil spill. An overview of the actual and potential effects and their proposed management is given in Table 1.

3.1 Routine Activities

3.1.1 Physical Activities

3.1.1.1 Rig Positioning and Anchoring

The two causes of physical effects associated with drilling operations are from the imprints on the seafloor caused by the three legs of the drilling unit, and the anchors of the support vessels.

The weight of a jack-up drilling unit results in the formation of a depression in the seafloor at each of the sites where the legs are positioned. The area of each of the depressions will be approximately 175 m^2. The depth of the depression is dependent on the nature of the substrate and will vary from site to site. Once the drilling unit moves off site the depressions tend to act as traps for sand and marine detritus. The depressions rapidly fill and therefore the effect is of a temporary nature. In environments where sediment supply is small, such as limestone pavements, the depressions will tend to remain open over a longer period. These then form a sheltered habitat suitable for colonisation by benthic organisms such as corals, sponges and algae, and provide cryptic spaces for fish and crustaceans.

The support vessels will use normal anchors while on standby by the drilling rig. Anchoring will be confined to sandy bottoms and not allowed on coral reefs or in the vicinity of known shipwreck sites.

3.1.1.2 Artificial Lights

Due to safety regulations, lights on the drilling rig must be kept alight 24 hours per day. These lights are an attractant to marine life and seabirds, and may result in a concentration of these animals around the rig. However, experience has shown that this effect is limited, mainly due to the noise of the drilling operations.

TABLE 1: Environmental Analysis of Impact
Wonnich - East and Wonnich - Flank Appraisal Wells

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Predicted Environmental Effects	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 eventually fill with sand and become recolonized.	Limited damage expected due to hard (limestone) seabed.
Anchoring	Rig and supply vessels.		Two anchors.		Negligible. Anchoring will be confined to sandy bottom in deep water.	Anchoring guidelines will be developed to ensure that no anchoring will occur on coral reefs or bommies.
Artificial lights	Lights on rig.	Fluorescent lights meeting safety standards.			Lights are an attractant to marine life and some birds. May result in a 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.		If flying too low, noise may frighten nesting birds and fledglings.	Helicopters will not fly within one km of the islands. No personnel to land on the islands without permission of CALM.

Table 1: continued

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Predicted Environmental Effects	Mitigating Actions
Solid and Liquid Wastes						
Drilling fluids	By-product of drilling operations.	Water based fluid. Ester based 'Petrofree'.	Zero to ocean.	Water based fluid will be discharged down annulus. No discharge. Petrofree will be retained and returned to Dampier for recycling.	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 and minimum loss of fluid.
Drill cuttings	Rock chips cut out of formation by drill bit.	Coarse to fine rock and sand chips.	362 m^3	First 16.3 m^3 will be deposited onto the seabed adjacent to the well. The cuttings from the remainder of the well will be discharged down the annulus into the lost circulation zone.	Local concentration of cuttings will result in the smothering of seabed flora and fauna. Extent of impact, given quantity of cuttings, should be no greater than 10m diameter around well. Recolonization will be rapid.	Cuttings from the 36" hole are discharged onto the seabed minimizing spreading and turbidity plume.
Cooling water	Diesel fueled power generators.	Temperature slightly above ambient seawater (~3 °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 (~15m above sea level) to facilitate cooling and oxygenation.

Table 1: continued

Description	Source	Quality/ Composition	Quantity	Treatment and/or Discharge Point	Predicted Environmental Effects	Mitigating Actions
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 which will evaporate and dissipate very rapidly.	Separation equipment will have automatic shut down capability if oil content exceeds statutory limit.
Galley wastes	Kitchen wastes.	Putrescible and burnable wastes.	Variable.	Putrescibles are macerated to statutory size prior to discharge to sea.	Negligible. Rapid dilution will ensure that nutrification will not occur.	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.	6,000 L per day.	Treated via the sewage treatment plant and discharged above sea level.	Negligible. Detergents will break down rapidly and dilution will ensure nutrification will not occur.	Biodegradable soaps to be used on the rig. Sewage treatment plant to be maintained to ensure effective treatment.
Waste oil	Machinery.	Hydraulic and lubricating oils.	Variable.	Used oil contained in drums and returned to mainland for recycling.	None.	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 activities.	Paper, wood, steel.	Variable.	Burning, landfill or recycling.	Negligible. Burning some materials on the rig (e.g. wood, paper) may create some black smoke.	Waste will be segregated on the rig into clearly marked skips for appropriate waste disposal method.

Table 1: continued

Description	**Source**	**Quality/ Composition**	**Quantity**	**Treatment and/or Discharge Point**	**Predicted Environmental Effects**	**Mitigating Actions**
Pipe dope	Sealant, lubricant, cleaning of pipestring.	Heavy metals, grease.	75 L per well.	Retained on drill cuttings.	Negligible. Pipe dope is amalgamated with the drill fluid which will be discharged down the annulus.	Use pipe dope which has lowest concentration of heavy metals and hydrocarbons, is biodegradable, but still meets safety and performance criteria.
Others						
Production testing	Hydrocarbon reservoir	Hydrocarbons	4,000 bbls per day.	State of the art 'green' burners.	Black smoke.	'Green' burners to be used to ensure most efficient combustion to minimize black smoke and potential hydrocarbon fallout. Technical experts to be on the rig at all times during testing.
Fishing	Workforce.			None.	Negligible.	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 minimize volume of emissions.

3.1.1.3 Noise

Drilling activities, machinery, helicopters and boat engines will cause noise during the whole of the drilling operation. Helicopters flying directly over the Montebello Islands at low altitudes could potentially disturb roosting or nesting seabirds.

Helicopters servicing the rig will be instructed to remain at least 1 km offshore from islands as they fly to and from the rig to avoid disturbing adult or fledgling birds which may be present. No personnel will be allowed to land on any of the islands unless permission is given by CALM. Noise is seen to be a short-term factor confined to the drilling period.

3.1.2 Liquid and Solid Wastes

Drilling operations give rise to a number of types of waste material. The major ones are drilling fluids, drill cuttings and cooling water, while minor waste streams include domestic wastewater, solid wastes and oils and grease from the machinery used on the rig. The nature and management of the various waste materials are described in the following sections.

3.1.2.1 Drilling Fluids

Drilling fluids perform a number of functions, including carrying cuttings to the surface; providing hydraulic power to the drill bit; exerting a hydrostatic head to prevent caving or sloughing of the formation; preventing flow of formation fluids into the borehole; and preventing kicks and blowouts (Hinwood et al. 1994).

In most production and almost all exploration wells drilled on the North West Shelf, water-based low toxicity drilling fluids are used. The water-based drilling fluid consists of a Potassium Chloride (KCL) partially hydrolysed polyacrylamide (PHPA) system. No hydrocarbons are used in this system: freshwater is used as the base. Various agents such as barite, bentonite, vegetable fibres, calcium chloride, lime and starch can be added to the base system to aid lubricity, cooling and density. A list of the most commonly used drilling fluid additives is presented in Appendix 4.

Drilling fluids based on esters are alternatives to water-based and oil-based drilling fluids. In situations where the geological formation can result in hole instability due to the angle of drilling, mineral oil-based or synthetic ester-based drilling fluids are commonly used.

To provide protection for the environment and at the same time meet the technical requirements of the drilling programme, Apache proposes to use 'Petrofree', a palm oil based formulation based on non-aromatic esters, rather than the more toxic mineral oil-based drilling fluid. It contains no toxic aromatic hydrocarbons, is biodegradable under both aerobic and anaerobic conditions, and does not bioaccumulate (Appendix 4).

While in most drilling programmes spent drilling fluid is discharged into the ocean, in this program neither the water-based fluid nor the 'Petrofree' will be discharged into the marine environment. Any residual water-based drill fluid left over from the drilling program will be discharged back down the annulus (the space between the drill string and the well bore) into a suitable porous stratum (lost circulation zone). In the case of 'Petrofree', the fluid will be separated from the cuttings via the solids control equipment and returned to the manufacturer in Dampier for re-use. Only a minor amount of fluid will be retained on the cuttings and this will be discharged down the annulus of the well, rather than on to the seabed, and hence will have no impact on the marine environment.

3.1.2.2 Drill Cuttings

Drill cuttings are crushed rock particles generated by the drill bit and brought to the surface in the drilling fluid. These inert rock particles vary in size from silt to gravel.

During the drilling of the 36" hole, the drill cuttings will be deposited on the seabed adjacent to the well. The volume of cuttings will be about 16 m^3. No drilling fluid is used for this section; only seawater and clay are used.

In the section of the well between the base of the 36" hole and the bottom of the second hole section (up to 1,100 m deep), no drill cuttings are returned to the surface as the cuttings and fluid are lost in the porous formation (lost circulation zone).

The drill cuttings and fluid from the deeper sections of the well, which are eventually brought to the surface, are separated through the solids removal equipment on the rig. The treated cuttings will be reinjected down the annulus of the well and not discharged onto the seabed.

3.1.2.3 Cooling Water

Seawater is used as a means of cooling machinery on the drilling rig. No chemical inhibitors or additives are added to the cooling water. The temperature of the cooling water will be 1-3°C higher than ambient seawater, but is cooled and re-oxygenated as it is falls from its discharge point at rig deck level (~ 15 m above sea level) to the ocean.

3.1.2.4 Deck Drainage, Waste Oily Water and Waste Oil

Deck drainage consists mainly of washwaster from cleaning of the decks and occasionally, rainwater. It may contain small amounts of spilt oil, cleaning chemicals and paint chips.

Deck drains in areas where machinery is present and cleaning solvent chemicals used will be a closed system. All runoff will be collected in a sump which is connected to an oily water separator. After separation of water from the oil to levels no higher than the statutory limits, the oil is transferred to drums for recycling onshore and the treated water is discharged to the ocean.

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

3.1.2.5 Domestic Wastes

Sewage, grey water from showers and laundry, and food scraps constitute the domestic wastes generated on the drilling rig.

Sewage is treated through a sewage treatment plant and then discharged to the ocean. Kitchen wastes are macerated prior to being discharged overboard. Kitchen, shower and laundry water are discharged directly overboard.

3.1.2.6 Solid Wastes

Solid waste is generated during routine human and drilling activities. This waste includes paper, wood, metal packaging, etc.

All solid wastes are segregated into marked skips prior to disposal. Burnable materials are burned on the rig in a special basket. Any residual ash is collected and disposed of onshore at a designated landfill site.

Drums and scrap metal are re-used or recycled, and non-reusable solids are disposed of onshore at an appropriate landfill site.

3.1.2.7 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. Approximately 75 L of pipe dope may be used during the drilling of one two-week well.

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 dope will be discharged into the marine environment as it will be amalgamated with the drill fluids and cuttings which will be reinjected into the annulus of the well.

3.1.3 Production Testing

In some cases, the hydrocarbons in the reservoir may need to be tested to appraise their type, quantity and flow rate. To do this, the oil from the reservoir well is flowed at varying rates for periods ranging from a few hours to a few days. As there are no production handling facilities, it is customary to dispose of the produced gas and/or liquids by burning.

The main impact from production testing could be oil fallout during burning due to incomplete combustion. This is detailed in Section 3.2.2.2.

3.1.4 Summary of the Effects of Routine Operations

No drill cuttings or drilling fluid will be discharged to the marine environment. Cuttings and surplus water-based drilling fluid will be reinjected down the annulus into the porous, lost circulation zone of the geological formation. 'Petrofree' will be returned to Dampier for recycling.

Drilling effects on the physical environment will be confined to the footprints left by the rig. This will be a temporary effect as the footprint will be recolonised rapidly with a similar range of organisms to those present before drilling.

The nearest corals, located at a distance of 1 km from the drill site, will not be affected by the routine discharges (grey water, cooling water, sewage, etc.) due to the dilution which will occur between the discharge site and the reef. Other resources, in particular seagrass beds and mangroves, are located more distant from the drill site and will be unaffected.

Marine fauna, such as dolphins, dugongs and turtles, may avoid the rig during the drilling operations, but otherwise will not be affected.

The proposed operation is some 7.5 km from the closest island. Noise and light from the rig are likely to deter some birds from closely approaching the rig. The main effect will be to remove a small area of the ocean from the region supporting the bird population for the duration of the drilling program. Given the water depth and the distance from more productive biological systems, it is not considered that this effect would be measurable.

The area in which the Wonnich appraisal well site is located is not used for commercial finfish purposes and is not significantly used for recreational fishing or tourism. The effect of the exclusion zone around the rig will consequently have little effect on the occasional visitors to the area.

Routine drilling operations should not interfere with the pearling operations which are carried out within the Montebello Islands.

The historic sites occurring within the island group will similarly not be impacted. The wreck of the *Tryal* (or Trial), located some 14 km from the drilling site, and the *Wild Wave*, believed to be located 'near rocks' some 3-4 km south from the drilling site, are sufficiently remote not to be affected by drilling operations. The Masters of the support vessels will be instructed not to anchor in the near vicinity of the wreck sites, nor on coral reefs.

The overall effects of routine drilling and operational discharges on the conservation and ecological values of the area are therefore expected to be minimal and confined to the immediate vicinity of the drilling rig.

3.2 Accidental Discharges

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

Apache is aware that a spill of oil at the Wonnich location has the potential to cause significant short- to medium-term damage to some of the marine resources of the Montebello Islands. The planning for and control of the drilling operation is focussed on the prevention of such an occurrence. While an Oil Spill Contingency Plan will be developed and exercised, there should be no doubt that the primary focus is on spill prevention. This will be achieved through strict management and operating procedures, and incorporation of safety equipment.

3.2.1 Quantitative and Environmental Risk Assessment of Spills

A quantitative and environmental risk assessment of the drilling operations has been carried out for a jack-up drilling rig. An overview of the assessment process is given in Appendix 5. The purpose of the assessment was to:

- identify the potential sources of spills;
- estimate the quantity of liquid which could be spilt from each of the sources;
- assess the frequency of a spill occurring from each of the sources;
- run trajectories under various scenarios and spill sizes to assess the resources at risk;
- assess the effects of spills on these resources; and
- develop preventative and response strategies to mitigate damage.

3.2.2 Potential Sources and Sizes of Discharge

The potential sources and sizes of liquid discharge from drilling operations are summarised in Table 2. Generally, the sources are:

- leakage or spillage of diesel or lubricating oil from engines;
- leakage or spillage from diesel transfer hoses;
- an accidental discharge of oil during production testing;
- 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 the fuel tank either on the rig or on a support vessel due to impact; and
- an uncontrolled discharge at surface due to loss of control of a well;

The largest spills would occur from a refuelling accident, transfer of drilling fluid, rupture of a fuel tank, or a blowout. However, the quantities, release rates and durations are limited by emergency shut-down provisions.

3.2.3 Spill Size Frequency Data

An international database (Appendix 5) was used to carry out the quantitative risk determination. This database contains information on oil, diesel and drilling fluid spills from the North Sea and United States offshore areas. Spills are identified from failures for the equipment associated with loading/transfer spillage, blowouts, etc. These data were then used to estimate the size-frequency distribution to determine the probability of occurrence. The results have been factored to take into account the elements specific to the Wonnich drilling program. These elements include the number of wells to be drilled and the total number of days of drilling.

Table 2: Sources, Consequences and Prevention of Accidental Fluid Discharge into the Sea

Source of spill	Potential maximum size	Potential effects	Preventative actions
Leakage from engines or machinery	20L	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	Minor as the main chemical would be light oils.	Drums are stored on pallets and in bunded areas away from open grates wherever possible.
Spillage or leakage of cuttings from cuttings discharge system linking rig to annulus	500 L	Negligible. Cutting and fluid would disperse quickly, with the heavier materials sinking to the bottom. Will contribute to short term turbidity.	Continuous monitoring of fluid volumes and regular visual inspections carried out. Low Flow rate and facility for immediate shutdown will minimise volume released.
Oil fallout from production testing	1,000 L	Wonnich oil is light and the light ends would evaporate quickly. Could impact the back of the fringing reef if reef exposed during a low tide.	Effective 'green' burners to be used. Technical experts on the drilling rig to monitor the testing procedures at all times.
Leakage or spillage from diesel transfer hose	2,000 L	Diesel would evaporate very quickly. However, could impact the back of the fringing reef if reef exposed during a low tide.	Detailed refueling procedures developed and followed. Refueling only during suitable weather and seastate conditions.

Source of spill	Potential maximum size	Potential effects	Preventative actions
Spillage or leakage of drilling fluid from transfer hose	2,000 L	Minor. Fluid would cause short term turbidity but would disperse rapidly. Smothering unlikely due to dispersion.	Only dry materials for water based fluid passed from support vessel to the rig. Fluid is mixed in bulk tanks located within the hull of the drilling rig. 'Petrofree' shipped in 205 L drums and transferred to bulk tanks once on the rig.
Rupture of rig fuel tank due to impact	80,000 L	Some risk of fire. Could have major 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 abd tanks are protected by ballast tanks.
Rupture of support vessel fuel tank	80,000 L	Safety issue with potential fire or sinking of vessel. Could have a minor impact on the marine resources, but oil would be light and evaporate quickly.	Work adjacent to rig only in suitable weather conditions.
Blow-out	650,000 L per day over 45 days	Could have major impact on marine resources if an oil blowout. If a gas blowout, little effect to the marine environment, but would contribute methane to the atmosphere.	Blow-out preventors, pressure testing all casing, maintaining proper drilling fluid weights, kick drills, known reservoir pressures, double checking with mud logging unit.

Table 2: continued

From size frequency distribution curves, the total spill frequency per annum for various spill sizes were determined and are given in Table 3.

Table 3

Cumulative Spill Size Frequency for Two Wells over a 60 Day Drilling Program

SPILL SIZE (bbls)	SPILL SIZE (L)	FREQUENCY FOR ALL SPILLS		FREQUENCY OIL SPILLS ONLY
1	159.2	0.39	3.9 times every 10 years	0.22
10	1,592	0.078	7.8 times every 100 years	0.044
100	15,920	0.016	1.6 times every 100 years	0.0089
1,000	159,200	0.0031	3.1 times every 1,000 years	0.0019
10,000	1,590,000	0.00064	6.4 times every 10,000 years	0.0004
20,000	3,180,000	0.0004	4.0 times every 10,000 years	0.00025

3.2.4 Reducing the Frequency and the Risk

All reasonable engineering and procedural measures are used to prevent spills from occurring in the first instance (Table 2). These measures define the process of constructing a well in a safe, environmentally responsible and efficient manner. The process includes well design, policies, operating guidelines and procedures, and engineering measures. During the design stage of a well, an assessment is made of all the known or potential risks. Should an unplanned event occur, procedures are detailed in the Emergency Response Manual and Oil Spill Contingency Plan. Many of the operating procedures are stipulated in the Schedule to the PSLA which must be strictly adhered to before, during and after drilling.

3.2.4.1 Refuelling accidents

Spills of diesel fuel during refuelling caused by hose breaks, coupling failures or tank overfilling and generally involve volumes of less than 1,000 L, with quantities minimised by prompt shutdown of pumps or by automatic safety valves. For example, rupture of typical fuel hoses would result in the spillage of approximately 200 L of diesel. If all of the above systems failed, about 2,000 L of diesel could be spilt.

A jack-up drilling unit typically carries sufficient fuel to maintain operations for approximately three weeks. It will probably be necessary to refuel the rig twice while it is located at the drill site. Each transfer operation takes about two hours to complete.

In order to minimise the risks of spillage, the following measures will be taken:

- 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 rig transfer hoses will be fitted with 'dry' couplings;
- 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 be permitted only at times when the prevailing currents are moving away from the adjacent reef system, in order to provide the maximum time for response in the event of an accidental spill;
- refuelling will occur only at times when the sea conditions are sufficiently calm for there to be minimal risks to the transfer lines;
- refuelling will be supervised by the supply vessel and drilling unit Masters;
- 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; and
- suitable absorbent material will be held on the supply vessel and the rig to mop up any small spills.

3.2.4.2 Oil fallout during production testing

Well testing is conducted to evaluate any hydrocarbon-bearing formations for possible flow characteristics. Oil fallout during production testing could result in the loss of small volumes of oil from the burner to the ocean surface.

Oil burners which atomise the hydrocarbons are used to ignite and burn the mixture. Fallout of free oil can occur if improper combustion occurs or if the burners become plugged by well debris (i.e. sediment).

Volumes of oil involved in such a spill would not be large, 500 L or less. Measures taken to minimise this risk include continuous monitoring of the test equipment and using specialised 'green' burners which will allow the optimisation of the burning process by:

- incorporating sensors to monitor fluid pressure, temperature and flow rate;
- combining sufficient quantities of compressed air and water with the oil to allow an optimal burn; and
- incorporating remote control operation of the burner panels that allows the optimisation of the atomisation process and the orientation of the burners in all weather conditions.

3.2.4.3 Well control loss (blowout)

Extensive training, procedures and equipment are in place to maintain well control and prevent blowouts. Blowouts would not only impact the environment, but could also result in loss of life and property.

During drilling, 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.

A blowout is an uncontrolled kick and can take place at the surface or underground between two separate permeable formations.

Kicks are prevented by maintaining the correct density of the drilling fluid down the well bore. This is achieved by adjusting the concentration of various components of the fluid (see Appendix 4) so that the fluid hydrostatic pressure is greater than the formation pressure.

There are a number of warning signs which 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 the presence of gas bubbles in the returned 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. The problem is rectified by modifying the density of the drilling fluid.

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 if in the unlikely event that all warning signs are ignored and if the casing, wellhead or BOP failed. The drilling fluid system, casing design and BOP will be designed to control all expected formation pressures and meet DME standards.

The wells will be designed and operated to specifications approved by DME, and in accordance with DME 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 programme.

Given the experience and understanding of the stratigraphy and likely down hole pressures, the subsequent casing and cementing design, the use of BOPs and fail safe control valves effectively reduce the risk of this unlikely event at Wonnich. Well design is conservative to allow for any unexpected pressure in the formation.

The well characteristics and formation pressures are known from extensive experience of Wonnich-1 and the North West Shelf geology and formation structures. With the fail safe engineering approach employed, any spillage resulting from well control loss is extremely unlikely.

3.2.5 Fate of Spilled Oil

Fundamental to the determination of the consequences of spilt oil is an understanding of the behaviour, fate and effects of oil.

The fate of petroleum in the marine environment is dependent on a complex interaction of both abiotic (e.g. evaporation, temperature, sea state, wind) and biotic (e.g. biodegradation, time of year) which will result in changes in the composition and toxicity of oil over time (Jordan & Payne 1980). Computer modelling is one of the tools which can be applied in consequences analysis for the estimation of potential impacts.

3.2.5.1 Weathering and dispersal characteristics of Wonnich crude

The oil recovered from the Wonnich reservoir is a light crude with an API gravity of 34°. Other characteristics of the Wonnich crude and a comparison with other crude oils is given in Table 4.

Table 4

Oil Specifications

TYPE	°API GRAVITY	SPECIFIC GRAVITY AT 15° C	VISCOSITY cst 38° C	POUR POINT °C	FLASH POINT °C
Harriet condensate	39.2	0.82	3.6	+12	71
Harriet crude	38	0.84	2.5	+12	38
Diesel	36	0.84	4.9	+12	48
Wonnich	34	0.82	7.4	+18	$\leq$38
Bunker	10	0.98	300-3,000	+2	80

Weathering characteristics carried out on Wonnich crude showed that the oil has a tendency to form an emulsion at extremely high water temperatures (i.e. 40°C) which does not disperse when agitated (Geotech 1995). At 32° C, agitated oil in seawater reforms into a layer of oil on the surface of the water.

Evaporation tests indicate that under tropical conditions, evaporation of spilt oil will be rapid. At water temperatures above 20° C, evaporation of hydrocarbons with a molecular size less than C_{10} will be very rapid (approximately 20 minutes). This would comprise the most toxic component of the oil (Kagi et al. 1988).

The heavier ends would take longer to evaporate and the rate of evaporation would be dependent on water temperature. Evaporation would be slower in cooler water (Figure 6). At a water temperature of 32° C, about 50% of the remaining material would be lost in five hours. At 26°C, 50% of the remaining material would take 7.5 hours to evaporate.

Light crude oils and diesel fuels spread rapidly after spillage to form a thin film which will evaporate quickly in tropical conditions (Tables 5-7). For example, a two tonne (2,400 L) spill will spread to a thickness of less than 0.1 mm within three hours. Thinly spread oil photo-oxidises and is naturally dispersed by wind and wave action. This further breaks up and disperses the oil, so enhancing the biodegradation and weathering.

Table 5

Estimates of spreading behaviour of spills of four sizes of WONNICH 1, DST 1, Crude Oil on water at 20°C

Spreading up to 20 minutes was estimated using viscosity of the oil; subsequently values of viscosity of No 2. fuel oil were used in the calculation. In these calculations the size of the spill was adjusted progressively for evaporative loss.

spill size tonnes	4	20	100	200
spill size m^3	5.2	26	130	260
time (min)	Diameter of slick (m)			
20	166	284	485	611
40	180	308	527	663
80	201	343	587	739
120	217	370	633	798
220	247	422	722	909
320	270	461	788	993
420	289	493	844	1063
520	305	521	891	1123
1020	365	624	1068	1345
2020	443	758	1296	1633
3020	500	855	1461	1841

Table 6

Estimates of spreading behaviour of spills of four sizes of WONNICH 1, DST 1, Crude Oil on water at 26°C

Spreading up to 20 minutes was estimated using viscosity of the oil; subsequently values of viscosity of No. 2. fuel oil were used in the calculation. In these calculations, the size of the spill was adjusted progressively for evaporative loss.

spill size tonnes	4	20	100	200
spill size m^3	5.2	26	130	260
time (min)	Diameter of slick (m)			
20	166	284	485	611
40	180	307	526	662
80	199	341	583	735
120	214	367	627	790
220	243	416	711	895
320	265	453	775	977
420	284	485	829	1045
520	300	512	876	1104
1020	360	616	1053	1327
2020	439	751	1285	1618
3020	497	849	1452	1830

Table 7

Estimates of spreading behaviour of spills of four sizes of WONNICH 1, DST 1, Crude Oil on water at 32°C

Spreading up to 20 minutes was estimated using viscosity of the oil; subsequently values of viscosity of No 2. fuel oil were used in the calculation. In these calculations the size of the spill was adjusted progressively for evaporative loss.

spill size tonnes	4	20	100	200
spill size m^3	5.2	26	130	260
time (min)	Diameter of slick (m)			
20	166	284	485	611
40	179	306	524	660
80	198	338	579	729
120	212	363	621	782
220	240	410	702	884
320	262	448	766	965
420	280	479	820	1033
520	296	507	867	1092
1020	357	610	1043	1314
2020	436	746	1276	1608
3020	495	846	1447	1823

3.2.5.2 Toxicity of crude oil

Toxicity tests will be carried out on Wonnich crude, but were not available at the time of preparation of this CER. However, toxicity testing of crude oil from the nearby Harriet field has been undertaken and, as the two oils are of a similar specific gravity (Wonnich crude 34° API, Harriet crude 38° API), test results for Harriet crude are presented as an illustration of the likely toxicity of Wonnich crude.

To test the toxicity of Harriet crude, the water soluble fraction was tested on the tiger prawn *Penaeus monodon* and the copepod *Gladiaferens imparipes.*

The 96 hr LC_{50} was 7.3 mg/L for the tiger prawn. Juvenile copepods were found to be more sensitive (48 hr LC_{50} = 8.6 mg/L) than adults (48 hr LC_{50} = 15.5 mg/L).

The relatively high toxicity of Harriet crude oil is due to the high concentrations of low molecular weight polycyclic aromatic hydrocarbons (e.g. benzene, naphthalene, phenanthrene), the component of the oil which evaporates rapidly in the case of a spill. The toxicity of the oil is reduced as the oil weathers. Thus, a spill which reaches a shoreline quickly will be more toxic to the flora and fauna than if the slick has been weathering at sea for several hours to several days before stranding.

Wonnich crude, which has a slightly higher specific gravity and consequently can be expected to have a smaller fraction of low molecular weight, high toxicity aromatic hydrocarbons, could be expected to be marginally less toxic than Harriet crude.

3.2.5.3 Projected trajectories

The trajectory of any spilt oil will be determined by the interaction of the prevailing tide and wind at the time of the spill.

The oceanography of the Montebello region is very complex due to the localised flows between the islands and reefs, and the proximity of the continental shelf to the west side of the islands (Figure 3). However, based on current predictions, maritime maps and local knowledge (i.e. fishermen), the following points can be made:

- water currents about the Montebello Islands arise mainly from tidal action, surface wind stress and oceanic drift;
- tides are semi-diurnal (twice daily) with a spring tidal range of about 3.3 m;
- on a spring tide, surface currents up to 4 knots (2 m/s) occur in the shallow waters while deeper, open waters experience currents of about 1 knot (0.5 m/s);
- tidal currents generally flow parallel to the Lowendal and Montebello Islands with north-westerly ebbs and south-easterly floods;
- oceanic currents approaching the southern portion of the Montebello Islands divert towards the south while currents approaching the northern portion deflect to the north;

- adjacent to the continental shelf, currents move east across the slope towards the islands.

April, May and June, the proposed drilling time, are transition season months when the summer wind patterns gradually break down and a high pressure ridge becomes the predominant weather feature (Steedman 1989). Winds are not generally sustained throughout the day, but are stronger in the morning, tapering off in the afternoon.

Historical data indicates that, in April, winds are from the south-south-east (49% of the time) but a large component can come from the east-north-east (32%) and are generally 6-10 knots (Appendix 3). In the afternoon, the winds can shift, coming predominantly from the north-east (25%) or the south-west (22%), mainly 6-10 knots.

In May and June, the winds are predominantly from the east and the north-east (Appendix 3).

The oil spill trajectory model was run for an oil spill originating at the proposed drilling rig location (Appendix 6). Fifteen scenarios were conducted. The projected time of impact at various locations and resources impacted were identified from these trajectories and are given in Tables 5 - 7 and Appendix 6, Tables A6.2 and A6.3.

The worst case scenario will be if a spill occurs during a south-westerly wind and a flood tide. Under these conditions, a spill may hit the southern section of the west fringing reef in about two hours. However, being a flood tide implies that the reef will be partially or wholly submerged, thereby allowing the oil to float over the reef area.

The projected time of impact to Wild Wave Lagoon and Turtle Lagoon is 8-9 hours and 18 hours, respectively.

Factors which would mitigate an impact are the rapid evaporation rate of the light oil, ebb tides, high air temperatures, waves and wind action.

3.2.5.4 Effects of oil on key marine resources and sensitivities

As discussed Section 3.2.5.1, Wonnich oil is light and, if spilt, would quickly spread into a thin film under tropical conditions. Much of the oil, in particular the toxic low molecular weight petroleum compounds with high solubility, would rapidly vaporise as a result of high air and sea temperatures, wind and sunlight.

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 organisms. Volkman et al. (1994) provide a detailed overview of the possible effects of oil in shallow tropical waters. A general overview is provided in Appendix 7.

Intertidal mangrove stands occur in sheltered bays and lagoons scattered throughout the Montebello Islands (Figures 7 and 8) and are given the highest protection priority due to their local ecological significance, high sensitivity to oil spills and slow recovery time.

Sand beaches on the Montebello Islands, and Barrow Island and the Lowendal Islands to the south are being most heavily used by turtles, will receive a high priority status between November and February, a period when they are being most heavily used by turtles (for nesting and hatching) and when seabird numbers are generally higher.

The major shallow marine habitats of ecological significance are: (1) the coral fringing reef on the west side of the Montebello Islands; (2) the 'patch' reef areas located between the Lowendal and Montebello groups; and (3) the shallow algae and seagrass meadows fringing the islands. The coral reefs warrant a higher protection status because of their ecological, recreational and commercial significance. The fringing reefs are also considered likely to be exposed at low tide and therefore have a longer recovery period following oil spill damage.

Sensitivity classifications for marine resources, and measures recommended for their protection and clean-up are given in Table 8.

3.2.6 Response Actions and Strategies

Should an oil spill incident occur, Apache would immediately take the following actions:

- Follow procedures to protect human life and equipment. Implement procedures to reduce the risk of fire or explosion.

- Cut off the supply of oil to the spillage.

- Identify the extent of spillage and the weather/current conditions in the area.

- Implement offshore and onshore actions for oil spill tracking, dispersion, containment, collection, treatment and clean-up as appropriate.

- Response actions will be coordinated in accordance with the three tiers of Oil Spill Control depending on the size of the spill, the proximity to environmentally sensitive areas and the resources available to control the spill. Response team members and responsibilities are set out in the Oil Spill Contingency Plan.

- If an oil slick is likely to reach a shoreline, advise fisheries and pearling companies, and wildlife agencies. Advise appropriate agencies to assume responsibility for wildlife rehabilitation activities.

- Monitor affected shoreline and intertidal zones to determine environmental effects of spill impact and clean up operations.

Response strategies to spillage include the following principal options (Apache 1995):

- Take no action other than surveillance.
- Combat the slick at sea.
- Shoreline deflection and/or clean-up.

The implementation of a strategy or combination of strategies is dependent upon physical conditions prevalent at the time (Figure 9). The speed and direction of winds and currents, general sea conditions and the type of oil spilt will determine which option or combination of options is suitable.

TABLE 8 : RESOURCE CLASSIFICATION AND SENSITIVITY CODES

Coastal Feature	Sensitivity	Comments	Clean-Up Methods				Protection and Clean-Up Option	Sensitivity Code
			Protective Measures	Preferred	Possible	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 highest priority for protection and clean-up	2, 3	1, 7	3, 14	5, 8, 10, 11, 12, 13	1. Containment and recovery using booms. 2. Divert to less sensitive area or shore.	**S1** **Extreme Sensitivity** High protection and clean-up priority.
Coral Reefs	S2	Unless uncovered at low tide, most corals will not be exposed to floating oil. No dispersants to be used. Slow recovery if impacted.	2, 3	1, 3, 7	8	5, 9, 10, 11, 12	3. Sorbant materials as barriers. 4. Earth/sand barriers 5. Chemical dispersant.	**S2** **High Sensitivity**
Pearl Leases	S2	Oil pollution can cause severe economic damage, but resource can be replaced.	2, 3	7	3, 13	5	6. Natural cleansing (leave alone). 7. Manual clean-up of oil.	Protection and clean-up priority as resource use and circumstances dictate.
Jetties, Piers	S2	To be cleaned as priority dictates.	2, 3	1, 3, 6, 7, 8	9, 12	5	8. Skimmers, vacuums.	
Intertidal Lime - Stone Platform	S3	Some short term reduction in numbers of animals will occur - should recover quickly.	2, 3	7	3, 8	9, 10, 11, 12, 13	9. Low pressure seawater flushing.	**S3** **Moderate Sensitivity**
Sandy Beaches	S3	Sand beaches are low in ecological diversity. 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	10. High pressure seawater flushing. 11. Hot water steam cleaning.	Protection and clean-up priority as resource use and circumstances dictate.
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	12. Low pressure warm seawater wash. 13. Mechanical cleaning of oil or substrate removal.	**S4** **Low Sensitivity** Low protection and clean-up
Open water	S4	Monitor direction and spread of spill		7			14. Bioremediation.	

TABLE9.DOC
[illegible]/01/96 11:[illegible]

Take no action other than surveillance

If the spill is moving offshore into deeper water the slick will be monitored but left to biodegrade through natural processes. The response will be directed at monitoring the slick for as long as necessary via surface and aerial surveillance and by a computer tracking model to ensure that no danger to sensitive environmental resources arises. At night, mats with reflective lights will be used and tracked by vessels. In this way, localised responses to oil movements can be strategically organised at first light.

As dispersants will not be used at the drilling location (see below), leaving the slick alone with continuous surveillance will be the main response strategy as floating oil will cause the least amount of impact. Other strategies will be used if the spill moves towards the sheltered areas of the islands (see below).

If oil reaches the west fringing reef, little can be done other than allowing natural clean-up to occur. With a strong south-westerly wind and flood tide, oil would be carried over the reef. Impact from the oil could occur if portions of the reef were exposed at low tide. If the sea state was calm, there is a possibility that deflection booms could be set up on the leeward, shallow side of the reef to stop oil from coming back onto the reef on an ebb tide.

Combat slick at sea

Within this option three strategies are available: use of dispersants, mechanical dispersion and containment and recovery (Apache 1995).

Use of Dispersants

The application of a dispersant represents a deliberate introduction of an additional pollutant into the marine environment. As a general rule, dispersed oil may be as toxic, and potentially more toxic, to marine life than untreated oil. The use of dispersant can, therefore, lead to greater environmental impact within the immediate area, or immediately down current of the zone of dispersant use.

Despite the risk, the application of dispersant may be an important first line of defence if resources of high priority (e.g. higher sensitivity or slower recovery rates) are likely to be impacted by the oil if left untreated. Sensitive inshore habitats such as mangroves are best protected by preventing oil from reaching them.

The decision to use dispersants must satisfy two criteria:

(a) the spilled oil is amenable to dispersion; and

(b) the water depth, distance from sensitive resources and water exchange rate will be sufficient to either safely dilute the dispersed oil prior to reaching the resources to be protected, or result in relatively short-term exposure at harmful concentrations.

At present, the use of dispersants can only be considered in areas 8 km or more from land and in water depths greater than 10 m to ensure rapid dilution and dispersion to non-toxic levels in order to protect sensitive resources in the immediate path of the spill (Western

Australian State Combat Committee 1992). These criteria therefore preclude the use of dispersants in the immediate vicinity of the Montebello Islands (EPA 1993) and therefore will not be used for this drilling program.

Mechanical Dispersion

Evaporation and dispersion of oil can be assisted by propeller wash from small vessels and small craft. In the event of a small incident, this technique will be utilised as the main response to combating the incident.

Containment and Recovery

Containment and recovery would be the least viable option in the case of an oil spill in the open ocean and in the channels between islands as effectiveness of the equipment may be seriously hampered during periods of rough weather and strong tidal currents. However, where practical, the most attractive option will be to recover the bulk of the oil from the surface of the sea before it reaches any shallow intertidal areas or shorelines.

Containment and recovery may be possible in designated coastal sites, such as in pre-identified oil collection beaches.

Various types of booms can be deployed to prevent the spread of oil and to concentrate it in readiness for removal by skimmers and sorbents. The type of boom (i.e. shore boom, Jackson net, absorbent booms) used will be dependent on the tide and weather conditions at the time of the spill. In calmer weather or sheltered areas such as bays, a zoom boom or Jackson net can be deployed. Absorbent booms may be used as secondary defence behind the main boom.

Shoreline deflection and/or clean up

In situations where oil cannot be prevented from reaching the shore, attempts will be made to deflect the oil away from sensitive areas to designated collection points. This would be achieved through the deployment of shore booms or absorbent booms. This technique would be used at Turtle Lagoon and Wild Wave Lagoon.

Once onshore, floating oil will be contained and collected as quickly as possible to prevent it from reaching uncontaminated areas. If appropriate, booms can be used to hold the oil against the shore during clean up. The principal means of clearing any oil may be by leaving it alone, or physical clean-up by manual and/or mechanical methods.

Bioremediation techniques are a possibility for shoreline clean-up but these must be treated with caution as their use in tropical habitats is very limited.

3.2.7 Oil Spill Contingency Plan

A detailed Oil Spill Contingency Plan outlining priorities and actions in the event of an oil spill has been developed for approval by the regulatory bodies prior to the commencement of drilling.

Apache is a member of the Australian Marine Oil Spill centre (AMOSC) and so has priority access to the oil spill response equipment stockpiled in Victoria. AMOSC has standing arrangements to transport its equipment to any part of the coast (Onslow/Dampier) within 24 hours.

Apache is also a member of Marine Oil Spills Action Plan (MOSAP) which guarantees access to equipment and assistance from the other oil company operators in the region. In this regard, prior to the drilling operation, there will be discussions between Apache (Varanus Island) and WAPET (Barrow Island) as to the condition, availability, and response time for the equipment that is held.

As a part of the preparation for the drilling operation, an exercise will be held to test the Oil Spill Contingency Plan. This exercise will involve persons on the rig, the workboats, the Perth office support staff and relevant government departments. Its aim will be to identify any shortcomings in the plan and to educate all operators on their role in the plan.

3.2.8 Cyclone Response

The official cyclone season commences November 1 and ends April 30. Over a 10 year period, the Dampier Coast may experience approximately 18 cyclones (Severe Weather Section, Bureau of Meteorology), the majority of which are Category 2 or 3 cyclones. The Bureau categorises cyclones on the basis of intensity, with Category 1 being the least destructive and Category 5 the most destructive. In addition, the State Emergency Services (SES) issues a three stage warning system with each stage denoting a minimum time period before gale force winds are expected. However, this latter system does not give any indication of the intensity of the cyclone.

In response to the cyclone threat, a Cyclone Procedure has been prepared for Apache's operations as part of its Emergency Response Manual (Apache 1994) to provide a plan for securing the well and ensure the safety of personnel through evacuation if necessary.

The response priorities in the case of a cyclone, in the order of importance are:

(1) Protect life.
(2) Protect the drilling rig and its equipment.
(3) Protect the well and the environment.

Critical distance calculations and checklist (Figure 10) are used to determine the time required to secure operations in a logical 'step by step' manner and are used to calculate the minimum distance a cyclone can be allowed to approach the drilling rig before actions are set into motion to secure the well and rig and evacuate personnel.

Personnel will be evacuated from the rig to the mainland.

4. ENVIRONMENTAL MANAGEMENT

4.1 Introduction

The objective of the environmental management plan is to ensure that the environmental impacts of the drilling program are prevented or minimised. At a broad scale, the operation will be managed to comply with the Apache Energy Limited Environmental Policy which is given in Appendix 8.

4.2 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.

4.3 Environmental Audit

An environmental audit of the management commitments will be undertaken by Apache during the drilling of the Wonnich appraisal wells. Monitoring of environmental management performance will involve the inspection of equipment and operations by the Apache Environmental Co-ordinator to ascertain if appropriate standards are being met before and during the drilling program.

4.4 Monitoring Programs

4.4.1 Routine Monitoring Program

Apache and its predecessors have undertaken an ongoing environmental monitoring program since 1985 which centres on ecological units considered to be of high conservation value in the vicinity of Varanus Island [LeProvost Semeniuk & Chalmer (LSC) 1986]. These units are representative of the region. The baseline data collected from these studies constitutes a significant contribution to the knowledge of the biological resources of the region. In the event of an oil spill, this information can be used to quantify the extent of impact to these areas and to measure the speed of recovery.

The specific objectives of the monitoring program are:

(i) to confirm the prediction that marine resources that are considered to be of significant conservation value have not been adversely affected during the life of the development and operation of the oilfield; and

(ii) to be able to determine the nature and extent of the effects of an oil spill on the ecologically important elements of the biota if an accidental oil spill should occur.

The primary areas identified as being most at risk from oil spills are those shallow areas less than 5 m in depth and the intertidal zone [LeProvost Environmental Consultants (LEC) 1990]. Based on predicted trajectories of oil spills and information gained during baseline biological surveys, three ecological units were identified as being most at risk:

(i) mangroves;
(ii) limestone and fringing coral reefs; and
(iii) beaches used for turtle breeding .

These monitoring programs will continue for the life of the Harriet Oilfield project.

4.4.2 Monitoring Specific and Related to Drilling

- A pre-operational seabed survey will be conducted. Sediment samples will be collected, provided that the sediment is amenable to the drop coring technique. The samples will be used to confirm the physical characteristics of the sediments present at the drill site.

- A survey of the seafloor at the well site and adjacent area will be carried out immediately before and following drilling utilising divers or a Remotely Operated Vehicle (ROV). Any debris will be picked up and a visual assessment of the spatial extent of the cuttings will be made.

- An aerial photographic record of the coral reefs which are located closest to the Wonnich well location will be obtained before and after drilling. These will be compared with the pre-Wonnich drilling photographic record, to assist in confirming that no large scale changes in the condition of the reefs have taken place over the drilling period.

- Pre- and post-drilling marine monitoring surveys will be conducted on the adjacent coral fringing reefs. This program will be amalgamated with the long-term coral monitoring survey program routinely carried out for the nearby Harriet project (Section 4.4.1). The 1996 survey is scheduled for end February/early March.

Apache is presently investigating the suitability of using a technique based on side scan echo sounding as a means of identifying the types of bottom communities drilling may have impacted and determining the spatial extent of impact on the seafloor.

4.4.3 Remote Sensing

Apache commenced a long-term remote sensing program in November 1994 as a means of mapping and monitoring changes in the shallow water marine habitats of the Montebello and Lowendal Islands. Digital Multispectral Video technique is being used to acquire the data. The shallow marine habitats will be mapped, validated by ground truthing and entered onto a Geographical Information System (GIS) which is linked to an oil spill trajectory model.

In 1993/4, the Lowendal Islands were photographed and groundtruthed. This data is presently being entered into the GIS. The Montebello Islands were photographed in November 1995 and will be groundtruthed and mapped in the first quarter of 1996.

The water penetration capability of this technique allows the discrimination and characterisation of seabed types and may enable Apache to monitor any larger scale changes in the marine environment.

4.4.4 3-D Oil Spill Trajectory

Apache has invested in an in-house computerised oil spill system (OILTRAK and OILMAP) which is comprised of a 3-D ocean current trajectory and an interactive GIS which will cover the area of the Montebello Islands, Lowendal Islands and Barrow Island. The trajectory program (OILTRAK) models the path of an oil spill using predicted currents and real time tide and wind data. The GIS (OILMAP) is an interactive system which displays biological and commercial resources. This system will allow Apache to generate predictive oil spill trajectories under nominated wind and tide conditions, and to run real time trajectories during an actual oil spill using real time winds and tides in order to validate containment and clean-up strategies.

5. COMMITMENTS

5.1 Environmental Management Commitments

Apache, on behalf of the Joint Venture Participants will undertake the following environmental management commitments for the Wonnich appraisal drilling program.

(1) In carrying out this program of appraisal drilling Apache will comply with all applicable laws, regulations, and conditions, and all necessary approvals and authorisations will be obtained.

(2) Apache will adopt the environmental guidelines and procedures outlined in this CER and those specified in consultation with the appropriate regulatory bodies. These will be incorporated into the drilling contract of all contractors.

(3) Apache recognises its responsibility for the prevention of any adverse environmental impact and any containment or clean-up should it occur. In the event of an oil spill during the drilling of the Wonnich appraisal wells, Apache will take every possible action possible to protect the marine environmental resources of the Montebello Islands and adjacent areas. Each of the Participants will hold extensive insurance for liability, control of well and clean up (Appendix 9).

(4) Prior to locating equipment at the drilling location, approval for the Oil Spill Contingency Plan and the Emergency Response Plan will have been obtained from DME (in consultation with the DEP and CALM).

(5) Prior to drilling, mat tracking exercises will be carried out to validate the oil spill trajectory model.

(6) A debris survey of the seafloor at the well site will be carried out before and after drilling.

(7) Apache will liaise with the Western Australian Maritime Museum to ensure that drilling activities will not impinge on any shipwrecks.

(8) A community consultation program will be conducted prior to and during the drilling program.

(9) A pre- and post-drill monitoring program will be carried out and this will be amalgamated with the surveys routinely carried out for the Harriet project.

(10) Apache will undertake aerial photography of those coral reef areas of the Montebellos which are closest to the Wonnich well location.

(11) An environmental audit of the management commitments, guidelines and procedures will be undertaken by Apache during the drilling of the Wonnich appraisal wells.

5.2 Guidelines and Procedures

In undertaking the Wonnich appraisal drilling program, Apache Energy Limited, on behalf of the Joint Venture participants in TP/8, will ensure that the following guidelines and procedures are followed:

- All personnel involved at the location will be given an induction course which will include an outline of the material presented in the Consultative Environmental Review, commitments, and guidelines and procedures.

- The drilling unit will be fully fuelled before being towed on-site, in order to minimise the need for on-site refuelling.

- Apache will contract a dedicated oil spill response vessel to remain on location at the Wonnich site for the duration of the drilling program.

- Transfers of fuel and water-based drilling fluid from workboats to the rig at the location will be undertaken only:

  - under the direct supervision of the support vessel Master and the drilling unit Master;
  - in daylight hours;
  - at times when the prevailing currents would carry any accidentally spilt fuel away from the adjacent reef;
  - in suitable sea conditions, and
  - with crew of the workboat and the drilling rig constantly monitoring the operation via hand held radios.

- The testing of any hydrocarbons discovered by the well will be undertaken:

  - with the initiation of first hydrocarbons to surface in daylight hours but at a time that would result in any incompletely burnt oil being carried away from the adjacent reefs by prevailing tides or wind driven currents;
  - using 'Green Burner' technology;
  - with diesel available to the burner to ensure complete combustion; and
  - with the capacity to immediately switch flow from the burner to tanks if the burner fails to achieve complete combustion.

- 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.

- 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.

- A simulated oil spill contingency exercise up to the point of deployment of equipment will be conducted at the time of spudding the first well.

- Drill cuttings and residual water-based drilling fluids will be returned down the annulus, not onto the seabed. 'Petrofree' drilling fluid will be mixed on board the rig and will be returned to Dampier for recycling upon completion of the drilling program.

- 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 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.

- Prior to drilling, and at the completion of the program before the rig moves off location, 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.

- Helicopter pilots will fly at least 1 km offshore from any islands in the Montebello or Lowendal groups to avoid alarming birds.

- Workboats will stand off from islands and reefs and not permit crew access to these areas. Captains will be advised of the presence of known historical wrecks and instructed to avoid them. Captains will be instructed to avoid anchoring in areas where coral reefs occur. The vessels will be supplied with a chart showing the locations of the reefs and wrecks.

6. SUMMARY

The assessment of environmental effects of drilling in the permit area shows that the overall impact of operations will be minimal. The major risk of environmental damage arises from a well blowout scenario, however the likelihood of such an event occurring is extremely low. Engineering and procedural measures are in place to prevent this occurrence and comprehensive contingency plans are in place to respond to any spill if necessary. The impacts associated with the normal operation of the project are predicted to be inconsequential to the physical and biological features of the location.

Apache recognises the environmental sensitivity of the regions in which it proposes to drill and is committed to undertaking its drilling operations in a manner which is environmentally and socially acceptable. To achieve this, Apache will comply with existing legislative and operational regulations and the commitments to environmental management as outlined in this document.

7. ACKNOWLEDGMENTS

Acknowledgment is extended to *ecologia* Environmental Consultants who coordinated and researched some of the information contained in this document and to Ampolex Limited for arranging access to data for the Wonnich-1 well. The following individuals provided information in their areas of expertise: Mr Nick Dunlop (seabirds); Dr Bob Prince (turtles); Mike McCarthy (shipwrecks); Dr Chris Simpson (coral spawning).

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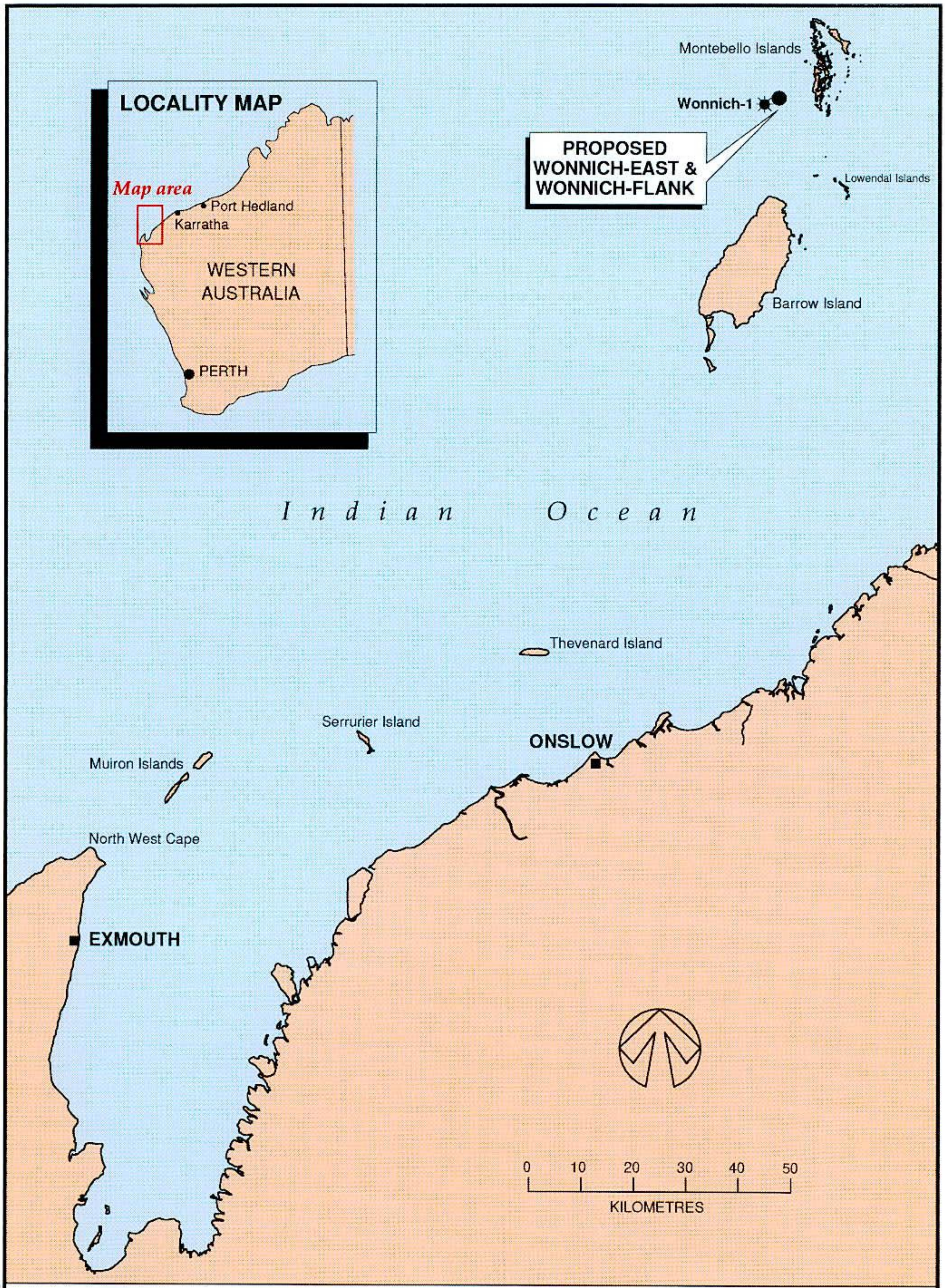
9. GLOSSARY

API gravity:	the universally accepted scale for expressing the specific gravity of oil
appraisal drilling:	drilling carried out to determine the likely physical extent, reserves and likely production rate of a field
aromatic:	the term used to describe organic compounds which contain one or more unsaturated ring structures, e.g. 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 = 159 L)
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
blowout:	an uncontrolled kick. A blowout 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
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
demersal:	refers to fish that live on or adjacent to the seafloor
DEP:	Department of Environmental Protection
DME:	Department of Minerals and Energy of Western Australia

drill string:	lengths of steel tubing roughly 10 m 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
m^3	cubic metres - 1 m^3 = 1,000 L
mangrove coast:	tropical or sub-tropical low-energy coast vegetated with mangroves
molluscs:	a group of soft bodied, unsegmented animals, usually with a hard shell such as shellfish
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
toxic:	capable, through chemical action, of killing, injuring, or impairing an organism
weathering:	physical disintegration and chemical decomposition of oil

Figures



LEPROVOST DAMES & MOORE

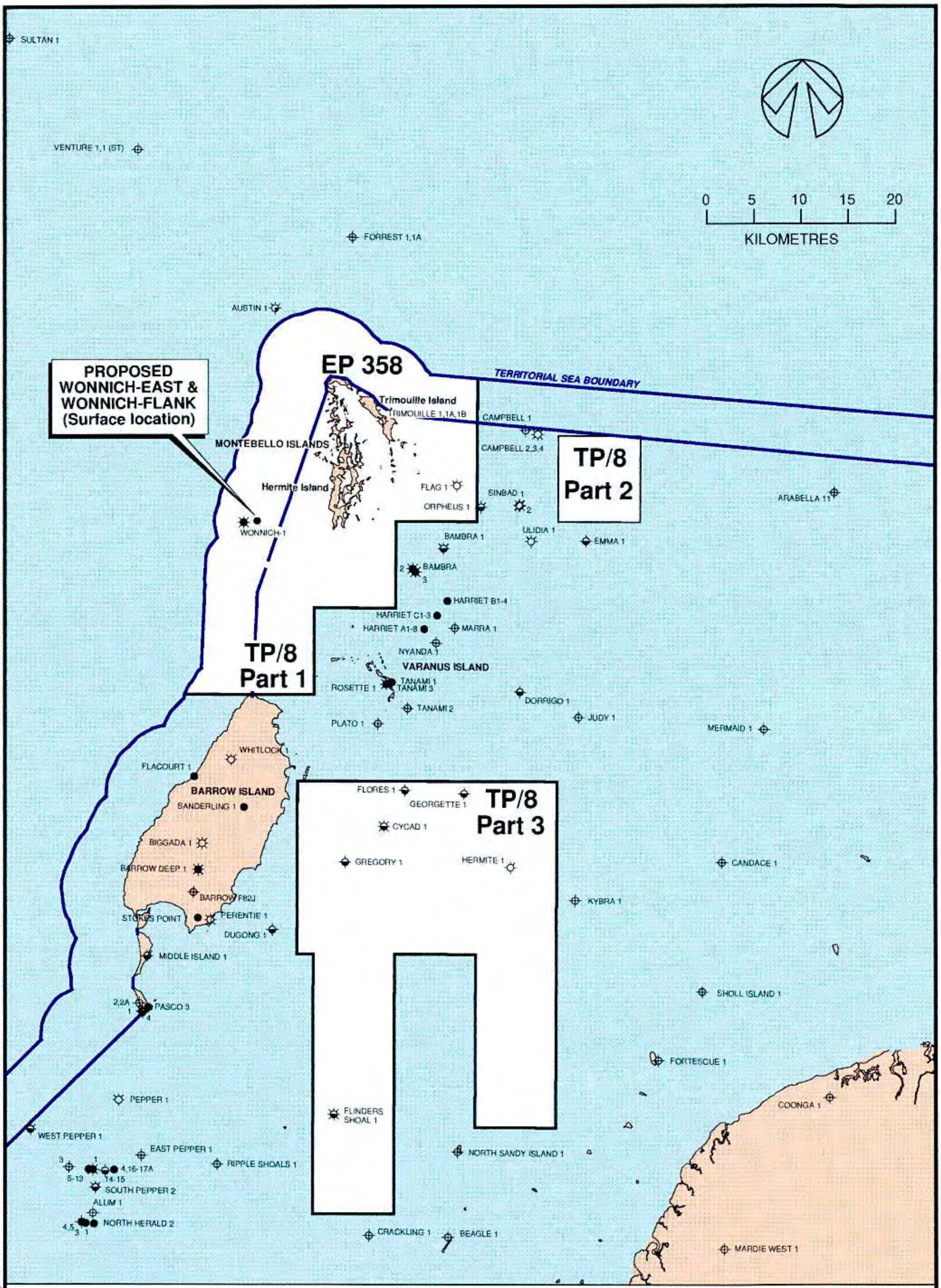
Apache Energy Limited
WONNICH APPRAISAL DRILLING CER

LOCALITY MAP

Figure 1

Environmental Drafting (09) 40 8105

31479-002-367 R583 FIG1.DGN 12/95



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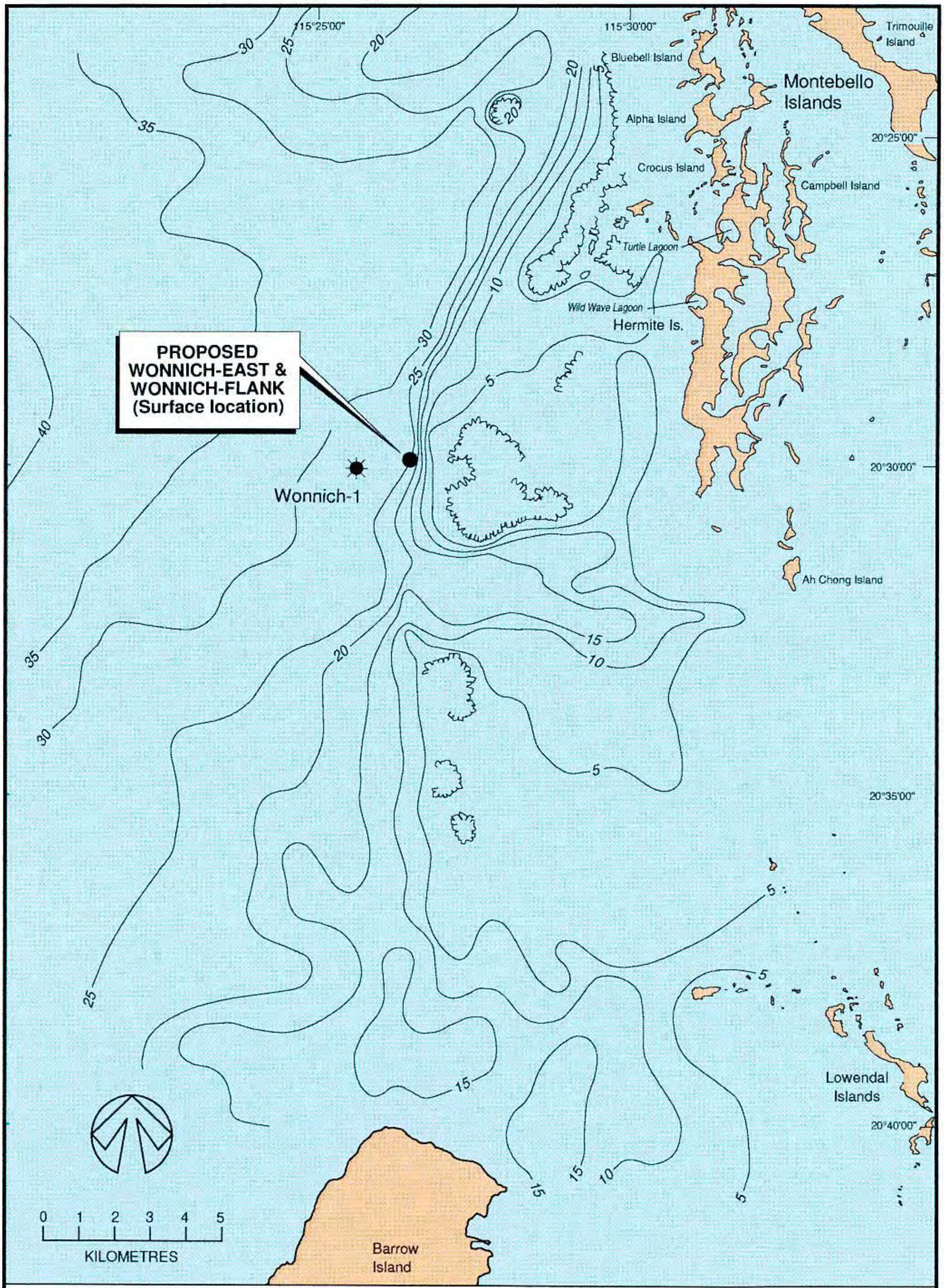
WONNICH APPRAISAL DRILLING CER

PERMIT AREAS AND WELL SITES

Figure 2

31479-002-367 R583 FIG2.DGN 12/95



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WELL SITE AND BATHYMETRY

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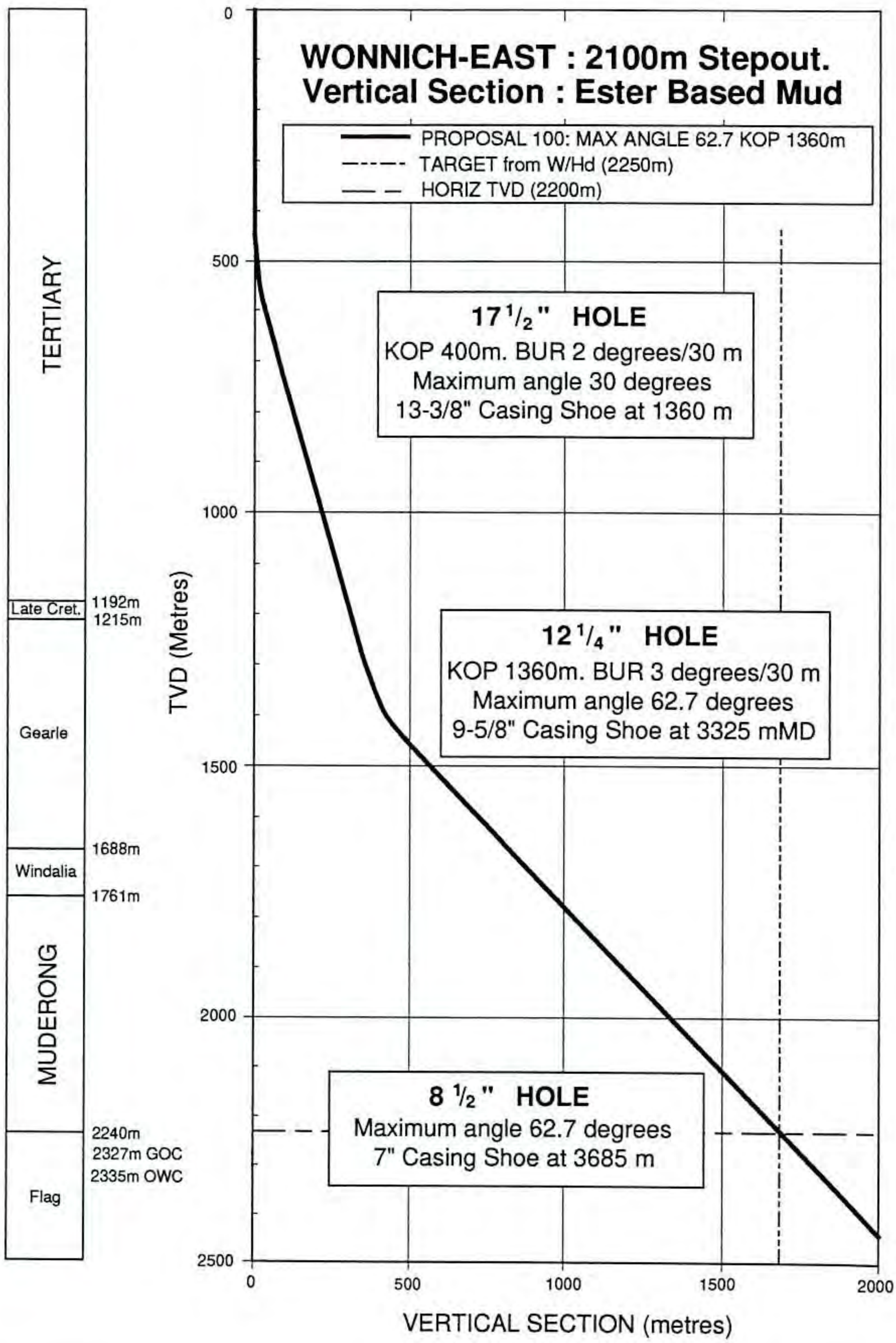
Figure 3

Environmental Drafting (08) 40 8105
31479-002-367 R583 FIG3.DGN



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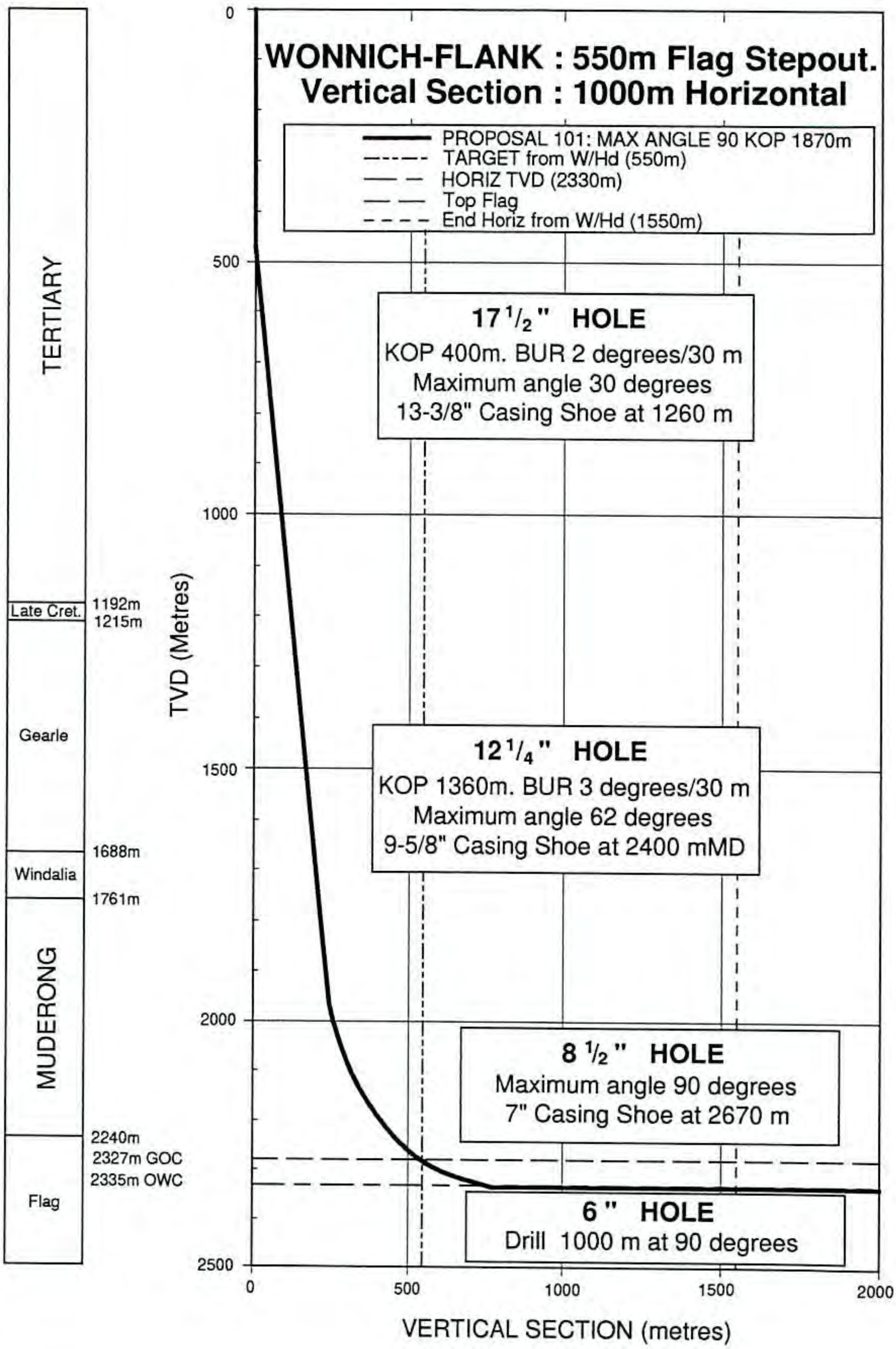
WONNICH APPRAISAL DRILLING CER

DIRECTIONAL PROFILE - WONNICH-EAST

Figure 4

Environmental Drafting (09) 40 8105

31479-002-367 R583 FIG4.DGN 12/95



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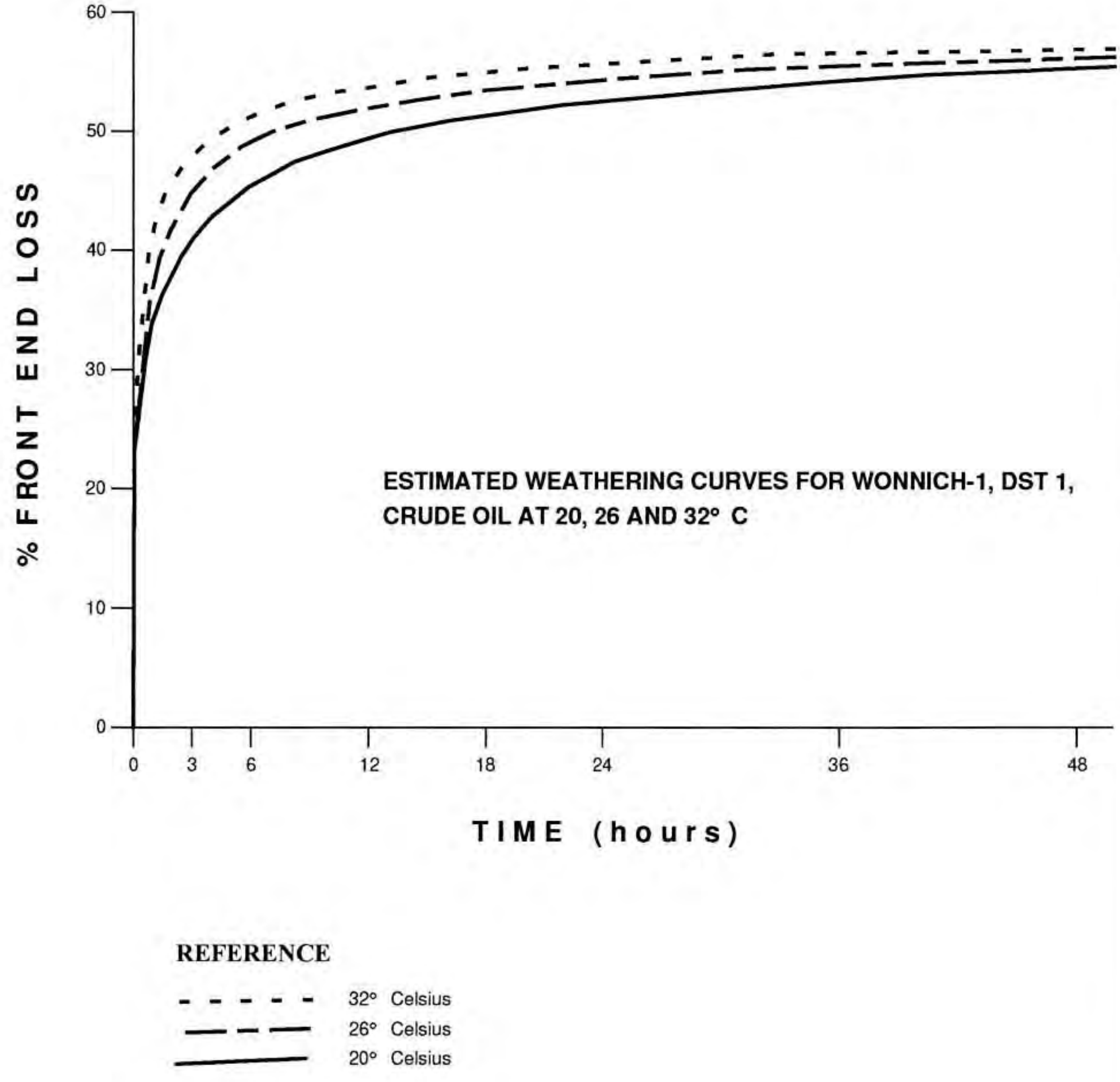
WONNICH APPRAISAL DRILLING CER

DIRECTIONAL PROFILE - WONNICH-FLANK

Figure 5

31479-002-367 R583 FIG5.DGN 12/95



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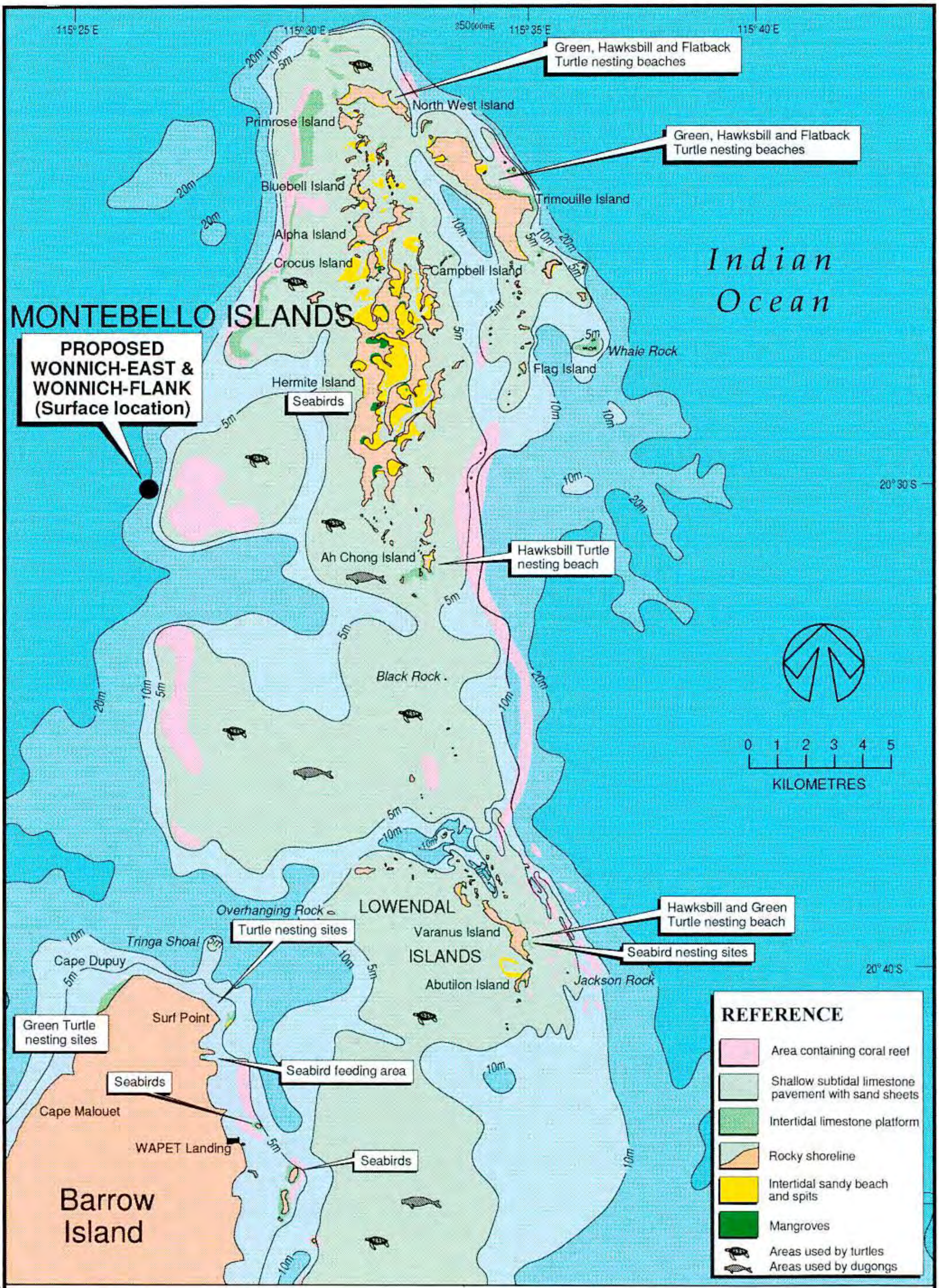
WONNICH APPRAISAL DRILLING CER

WEATHERING CURVES

Figure 6

31479-002-367 R583 FIG6.DGN 12/95



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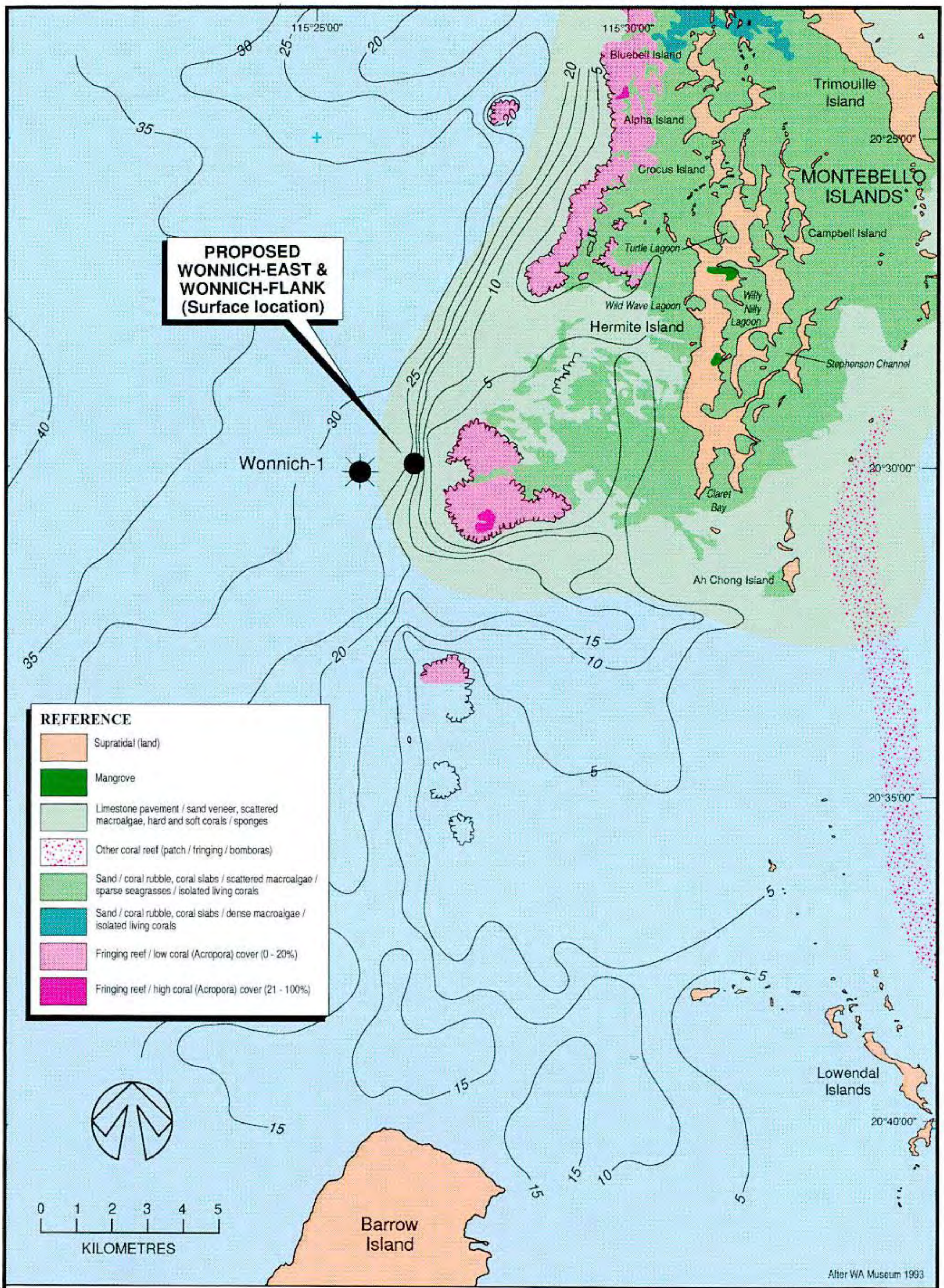
MARINE RESOURCES

Figure 7

Environmental Drafting (09) 40 8105

31479-002-367 R583 FIG7.DGN 12/95



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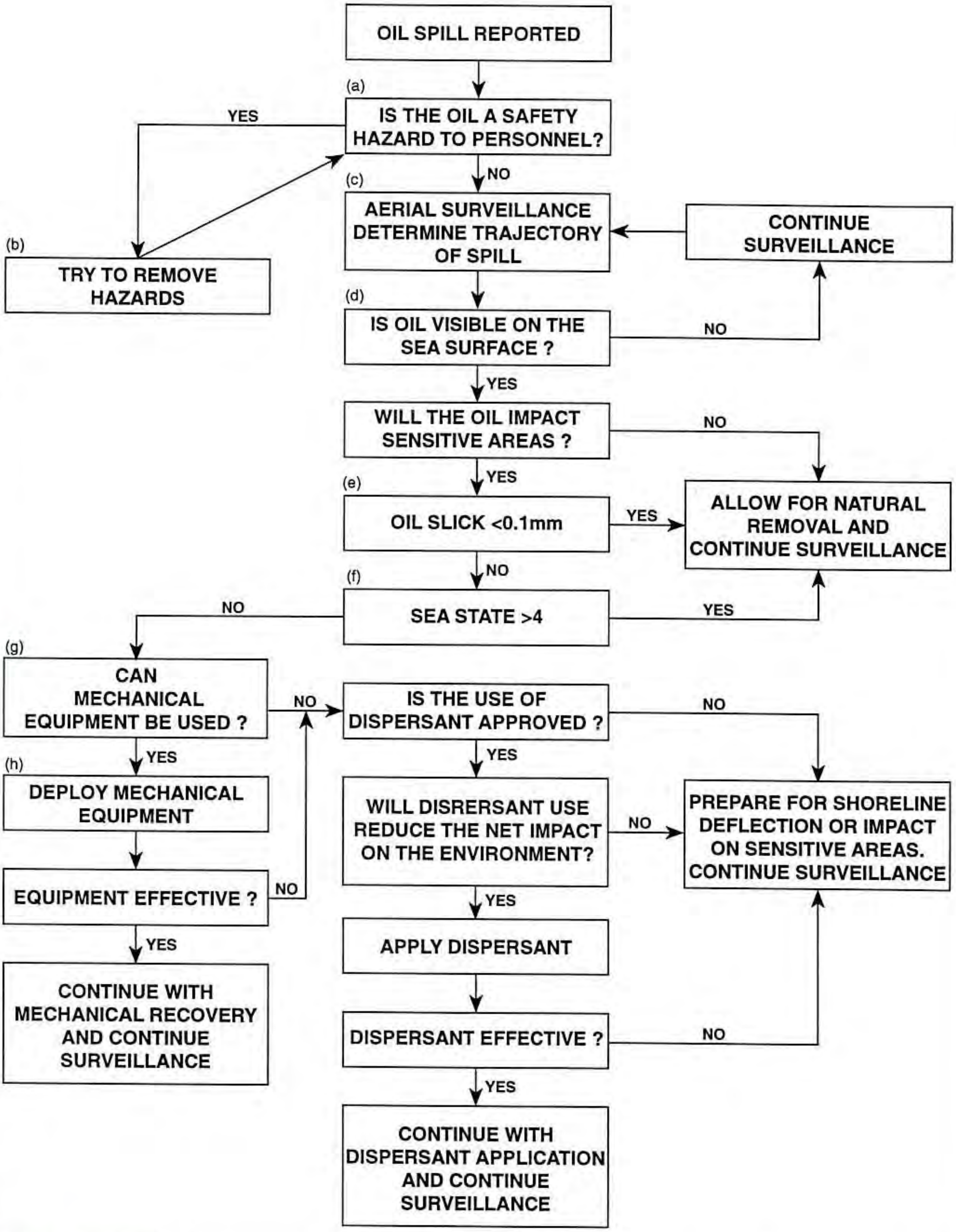
MARINE HABITATS

LEPROVOST DAMES & MOORE

Figure 8

Environmental Drafting (09) 40 8105
31479-002-367 R583 FIG8.DGN 12/95

OIL SPILL RESPONSE STRATEGIES
Marine Environment



( ) See footnotes page 3 - 4

Updated 19 December 1995 IS.m1217

Figure 9

APACHE ENERGY

CYCLONE CRITICAL PATH CHECK LIST

Date: ____________________ Time: __________________
Drilling Unit: (DU) _________________ Well: __________________
No. of Personnel on Board: Essential ___________ Non Essential ___________
Current Operation: ____

____

WEATHER FORECAST (12 hrs) Wind ___________ Sea Swell _______/___________
WEATHER FORECAST (24 hrs) Wind ___________ Sea Swell _______/___________
TROPICAL STORM WARNING Position: Lat _______________ Long _______________
Name ____________ Radius of perimeter (winds >33 kts) _______ Direction of Movement ____
Distance DU to Storm Perimeter: _____n.m. Velocity: _________ Time to DU: _____________hrs

CRITICAL PATH CALCULATION

Time to secure operations	S	____________________	hrs
Time to Evacuate Personnel	E	____________________	hrs
Time Contingency Allowance	C	____________________	hrs
Total Response Time	S + E + C	____________________	hrs
Velocity of Storm Movement	V	____________________	kts

CRITICAL DISTANCE CD = V(S+E+C) ______________nautical miles

Distance Remaining Before Critical Distance Reached = DR __nautical miles (measure on APC 070-002-2)

TIME REMAINING BEFORE CRITICAL
DISTANCE REACHED TR = DR ÷ V ______________hours

WELL DATA
Last Casing Size: ________ Depth: _______m Total Depth: ______m Open Hole: ______m
Mud Weight: ____SG Max Pore Pressure: _____SG Overbalance @ TD: ________kPa

HYDROCARBON INTERVALS

Zone	From	To	BHT
_____	_____	_____	_____°C
_____	_____	_____	_____°C

CEMENT PLUG TO BE SET

Plug	From	To	Tonnes	Time
_____	_____	_____	_____	_____

PLUGGING EQUIPMENT ON RIG
Cement on Board
Tonnes: __________ Class: __________
Bridge Plug Type: __________ Size: _____
RTTS Tool Type: __________ Size: _____

EVACUATION TRANSPORTATION AVAILABLE
Vessel: ________________ Speed: ___________kts Passenger Capacity: _____
Vessel: ________________ Speed: ___________kts Passenger Capacity: _____
No. of Helicopters Available: ____________ Round Trip flying time to base: __________
No. of Passengers Per Trip: ____________

Figure 10

Appendix 1

CER Guidelines

APPRAISAL DRILLING PROGRAMME FOR WONNICH FIELD SOUTH WEST OF MONTE BELLO ISLANDS (988) - APACHE ENERGY LTD

CONSULTATIVE ENVIRONMENTAL REVIEW

GUIDELINES

Overview

In Western Australia all environmental reviews have the objective of protecting the environment, and environmental impact assessment is deliberately a public process in order to obtain broad-ranging advice. The proponent is required to describe the proposal, receiving environment, potential environmental impacts, and the management of the issues arising from the environmental impacts, so that the environment is protected to an acceptable level. Protecting the environment means that the natural and social values associated with the project area are protected.

Contents of the CER

The contents reflect the purpose of the CER, which is to:

- communicate clearly with the public and government agencies so the EPA can obtain informed comment to assist in providing advice to the Minister for the Environment;
- describe the proposal adequately, so that the Minister for the Environment can consider approval of a well-defined project; and,
- provide the basis of the proponent's environmental management programme (EMP) showing that the environmental issues resulting from the proposal can be acceptably managed.

The language used in the body of the CER should be kept simple and concise, considering the audience includes non-technical people. Any extensive, technical detail should either be referenced or appended to the CER.

The CER would form the legal basis of the Minister's approval of the proposal and, hence, should include a description of all the main and ancillary components of the proposal.

The environmental management programme for the proposal should be developed in conjunction with the engineering and economic programmes of the proposal. Hence, the CER should be designed to be immediately useful at the start of the proposal. The basis of an environmental audit programme should be included as a concluding part of the CER.

The fundamental contents of the CER should include:

- a plain English executive summary;
- a summary table based on the key topics;
- introduction to the proponent, the project and location;
- a summary of the regional setting of the project;
- the legal framework, decision making authorities and involved agencies;
- description of the components of the proposal and identification of the potential impacts, including short-term, long-term and cumulative impacts;

- a pollution source flow sheet;
- description of the receiving environment which may be impacted, including provision of relevant quantitative data, species lists and marine habitat maps.
- discussion of the key topics, including an assessment of the significance as related to objectives or standards which may apply, and consideration of relevant Government reports or studies should be included;
- discussion of the management of the topics, including commitments to appropriate action;
- a summary of the environmental management programme (including oil spill prevention and contingency measures), including key commitments, monitoring work and the auditing of the programme; and,
- an appendix containing a consolidated list of all proponent commitments.

The CER for this project should include the following specific information relating to oil spill risk assessment and contingency planning:

- a quantitative oil spill risk assessment for a rig of the type proposed for the project. This should be carried out by an independent accredited risk analyst and should be sufficiently detailed to allow establishment of specific failure cases, and assessment of risk prevention / mitigation effects to ALARP ("as low as reasonably practicable") standards.
- linked to the oil spill risk assessment, a summary of proposed oil spill prevention measures, including both technical / engineering factors and human and organisational factors (HOF). The discussion of HOF should include information on management of contractor work practices.
- oil spill trajectory predictions specific to the drilling location. These should include worst case scenarios and predicted times to impact sensitive environments and resources (eg the Monte Bello pearl oyster leases). Predictions for different seasons (ie prevailing on-shore and off-shore winds) should also be included. The least risk window (LRW) should be identified.
- marine environment maps indicating locations of sensitive habitats (eg coral reefs, mangroves, sea bird feeding areas, enclosed bays) and sensitive resources (eg pearl farms);
- discussion of the environmental consequences (short-term, long-term) of credible oil spill events, including worst case scenarios. The discussion should include information on toxicity of oil or diesel spills and, in the event of a spill impacting sensitive environments and/or resources, the likely scale of impact and estimated recovery times.
- an abridged version of the oil spill contingency plan in the form of a stand-alone appendix provided with the CER. The key points from this plan should be included in the body of the CER and should include a discussion of the oil spill containment and recovery equipment, including suitability for the project, location of equipment, and response times. An outline of proposed response strategies for credible spill scenarios should be included. Discussion should include assessment of percentage of time when containment and recovery equipment is inoperable and information as to what contingencies will be in place during such times.

- If pre-approval for use of chemical dispersants is sought, the CER should describe the specific spill scenario(s) and met-ocean conditions where dispersants would be required. It should also detail the type of dispersant(s) considered suitable, information on eco-toxicity and proposed application method(s).
- details of oil spill insurance. Policy details and/or certificates of currency should be included as an appendix. As is normal practice, the information provided should demonstrate that the proponent's insurance will cover loss or reduction in value, quality or quantity of fisheries catch or aquaculture production.

Key topics

The CER should focus on the key topics arising from the proposal. A description of the project component and the receiving environment should be directly included with, or referenced to, the discussion of the issue. The technical basis for measuring the impact and any objectives or standards for assessing and managing the impact should be provided. Details of proposed monitoring and audit mechanisms should also be included.

Key topics and environmental objectives are listed in the table below.

Biophysical	
Topic	**Environmental Objectives**
Conservation values of the Monte Bello Islands and adjacent areas.	Protect the conservation values of the Monte Bello Islands and adjacent areas.
Pollution	
Topic	**Environmental Objectives**
Oil spill prevention.	Protect the environment from oil spills. Standard: international best practice based on quantitative risk management.
Oil spill contingency planning.	Ensure that, in the event of an oil spill, contingency planning properly protects the environment. Standard: international best practice.
Oil spill dispersants.	Ensure that, in the event of an oil spill, dispersants are only applied under conditions where the environment will be protected to maximum extent possible. Standard: international best practice.
Oil spill insurance.	Ensure insurance is sufficient to cover oil spill clean-up and third party damages to fishing and aquaculture industries. Standard: insurance industry international best practice.

Pollution (cont'd)

Topic	Environmental Objectives
Routine drilling discharges (drill cuttings, drilling mud, cooling water, pipe dope).	Ensure operations are managed so as to minimise any impacts from routine discharges. Standard: international best practice.

Social surroundings

Topic	Environmental Objectives
Historic shipwreck ("Wild Wave").	Protect historic shipwreck from disturbance. (Note the historic shipwreck is believed to be in the area of the proposal but exact location is unknown).

The proponent should consider these topics in relation to anchoring and jacking up the rig, drilling, and jacking down and removal. Further topics and key issues may be raised during the preparation of the CER, and on-going consultation with the Department of Environmental Protection and other relevant agencies is recommended.

The information presented should be based on best available data and, where uncertainty exists, provide best and worst case scenarios.

Assessments of the significance of an impact should be soundly based rather than unsubstantiated opinions, and the assessment should lead to a discussion of the management of the issue.

Information used to reach conclusions should be properly referenced, including personal communications.

Public consultation

The CER should include a summary of public participation and consultation activities undertaken by the proponent in preparing the CER. This should include 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 issues 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.

Environmental management commitments

The method of implementing the proposal and all the proponent's commitments listed in the CER would become legally enforceable under the environmental conditions imposed by the Minister for the Environment. The proponent's commitments should be separately listed, numbered and take the form of: who would do the work; what the work is; when the work would be carried out; and what agencies would be involved. The commitments show that the proponent is committed to actionable and auditable management of the environmental issues. If environmental issues are addressed adequately through proponent commitments, there may be no need for the EPA to make recommendations to the Minister on the same issues.

Appendix 2

Parties Consulted

Shire Clerk
Ashburton Shire Council
Onslow WA 6710

Mike McCarthy
Curator of Martime Archaeology
Western Australian Maritime Museum
Cliff Street
Fremantle WA 6160

Linley Thomas
Montebello Island Safari's
PO Box 152
Onslow WA 6710

Jimmy Seow
Department of Minerals & Energy
Level 3, 100 Plain Street
East Perth WA 6003

Frank Batini
CALM
50 Hayman Road
Como WA 6152

Dr Howard Jones
Fisheries Department
PO Box 20
North Beach WA 6020

Director
Morgan & Co Pty Ltd
7/55 Hampden Road
Nedlands WA 6009

Dr P Berry
WA Museum
Francis Street
Perth WA 6000

Capt. David Oliver
Department of Tranport
1 Essex Street
Fremantle WA 6159

Craig Howson
North Star Charters
PO Box 664
Broome WA 6725

Director
WA Tourism Commission
GPO Box XW261
Perth WA 6001

Guy Leyland
WAFIC
Suite 6, 41 Walters Drive
Osborne Park WA 6017

Rachel Siewart
Conservation Council of WA
79 Stirling Street
Perth WA 6000

Director
Pearl Producers Association
PO Box 55
Mt Hawthorn WA 6016

Giz Watson
Marine & Coastal Community Network
3rd Floor, 79 Stirling Street
Perth WA 6000

Jim Creenan
Australian Nature Conservation Agency
GPO Box 636
Canberra ACT 2601

Dr Annabel Wheeler
Australian Heritage Commission
MTA House
39 Brisbane Avenue
Barton ACT 2600

Jeannie Lang
Department of Primary Industries & Energy
GPO Box 858
Canberra ACT 2601

Chris Murphy
Environmental Protection Agency
c/- Blackall Street
Barton ACT 2600

David Ryan
Department of Resources & Development
SGIO Building
St George's Terrace
Perth WA 6000

M Boardman
Ampolex Western Australia Inc.
26th Floor, QVI Building
250 St George's Terrace
Perth WA 6000

G A Allen
Kufpec Australia Pty Ltd
14 Richardson Street
West Perth WA 6005

P A Vingoe
Novus Petroleum Limited
Level 9, 321 Kent Street
Sydney NSW 2000

Mr K Tohyama/Mr J Staples
Marubeni Oil Australia Pty Ltd
20th Level, Allendale Square
77 St George's Terrace
Perth WA 6000

W R Herron
New World Oil & Developments Pty Ltd
Level 14, Maritime Centre
201 Kent Street
Sydney NSW 2000

C Greenway
Hardy Petroleum Ltd
Level 3, 40 Kings Park Road
West Perth WA 6005

Andy Young
Corsair Charters
Onslow WA 6710

Bob and Lita Way
Onslow Tourism and Progress Association
Onslow Sun Chalets
Second Avenue
Onslow WA 6710

Appendix 3

Description of the Environment

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A3.8 Aerial Photograph - South-west Fringing Reef

A3.9 Habitat Map, South-west Fringing Reef

A3.10 Historic Sites

A3.11 Commercial Resources

1. LOCATION

The Montebello Islands lie approximately 120 km west-north-west of the Port of Dampier. The Montebellos consist of more than 200 islands, most of which are rocky islets only a few metres in diameter. The largest islands are Trimouille (429 ha) and Hermite (939 ha) Islands (IUCN 1988). The islands are the remains of an old coastal landform separated from the mainland for more than 8,000 years.

2. TENURE HISTORY OF THE MONTEBELLO ISLANDS

Prior to 1992, the Montebello Islands were Vacant Lands administered by the Department of Defence on behalf of the Federal Government. In July 1992, the islands were returned to Western Australia and vested in the National Parks and Nature Conservation Authority as C-class reserves for the purposes of recreation and conservation (Reserves 42196 and 42197). Vesting extended to the low water mark.

Small sections of North West and Trimouille Islands were excised and were leased to the Commonwealth for lighthouse operations. Parts of the waters of Faraday Channel and an area near the south-west of Crocus Island were leased for a pearl cultivation operation (Deegan 1992).

3. PHYSICAL ENVIRONMENT

3.1 Bathymetry

Bathymetry of the project area is shown in Figures A3.1 and A3.2. The information presented is based largely on information obtained during seismic surveys, data from a recent scouting survey of seabed features undertaken by RACAL Survey Australia Ltd in May 1994 and limited navigational hydrographic survey data.

The water depth at the proposed drilling site is between 20 and 25 m (Figure A3.2). To the east of the site the seafloor rises from a depth of 25 m to 5 m over a relatively small distance (approximately 1 km). Much of the water surrounding the Montebello Islands and extending south to Barrow Island and the Lowendal Islands ranges in depth from intertidal to approximately 5 m.

To the west of the well site the seafloor slopes away more gradually to reach depths of 40 m over a distance of some 6 km.

3.2 Geomorphology

The site of Wonnich is located on a shallow submarine ridge which extends north from the mainland near Onslow and includes Barrow Island and the Montebello Islands (IUCN 1988). The ridge contains extensive areas of intertidal and shallow subtidal limestone pavement surrounding the numerous, mostly small islands which are found in the region.

The regional subtidal environment comprises predominantly limestone pavement at depths ranging from intertidal to in excess of 20 m. The pavements are frequently veneered by sheets and ribbons of calcareous sands varying in thickness from less than 5 cm to greater than 1 m. The sands are mobilised and dispersed as sand waves by water currents and, more dramatically, by storm events such as cyclones. Pavement in exposed areas is often continuously swept clear of sand.

The proposed well site lies on the eastern flank of this ridge, adjacent to the southern Montebello Islands. It occurs in a relatively open ocean environment where the high wave and current energy gives rise to extensive areas of exposed limestone pavement and reef, interspersed with patches of sand veneer overlying the limestone pavement.

The nearest landfall to the site is the Montebello Islands. The Western Australian Museum (WAM 1993) describes these islands and associated reefs which make up the Montebello group as "being arrowhead shaped, comprising a central 'chain' of islands with unusually irregular or convoluted coastlines lying on a north-south axis. These islands are in close proximity to one another and are separated by narrow channels". They are low lying and include 95 islands larger than 50 m in length and 170 smaller islets and reefs. They are composed of Pleistocene limestone and cross bedded sandstones, capped in places with consolidated or active sand dunes with elevations up to 40 m. However, most islands are bare rocky terrain without any beaches.

The total shoreline of intertidal land within the Montebello group is approximately 210 km in length and significantly longer if the margins of intertidal areas, particularly the western barrier reef, are included. An extensive shallow intertidal zone is therefore contained within a relatively small total area.

The major physical environmental units are lagoons, channels, intertidal embayments, intertidal shorelines, barrier reef and shallow open ocean (Table A3.1).

3.3 Climate

The climate of the neighbouring Lowendal Island region, which is some 20 km to the south of the Montebellos, has been described by LeProvost Environmental Consultants (LEC 1992) as arid subtropical with hot summer temperatures, occasional cyclones and associated summer rainfall. The climate at the Montebello Islands would be expected to be very similar. The annual average rainfall of the Lowendal Islands is approximately 330 mm, mostly as a result of tropical cyclones.

TABLE A3.1

MONTEBELLO ISLANDS: MAJOR PHYSICAL UNITS
(Source: WAM 1993)

PHYSICAL UNIT	DESCRIPTION
Lagoon	This may be divided into two sections: (1) shallow western lagoon, between the western barrier reef and central island chain; and (2) a deeper eastern lagoon between Trimouille Island and series of islets to the south of it, and the central island chain. Both the western and eastern lagoons are shallowest and most protected in the north and become progressively deeper and exposed to the south. The lagoons, particularly in the north, are characterised by relatively high turbidity and low wave and current energy, resulting in extensive areas of sand substratum. Rubble substrates are also present in the more exposed areas.
Channels	These are mostly between the central island chain, connecting the eastern and western lagoons. Stephenson Channel is the exception in that it is a blind channel, approximately 8 km in length, leading into the interior of Hermite Island. The channels are characterised by high turbidity and very high current energy, resulting in coarse sand and rubble substrates with extensive exposures of limestone pavement when scouring occurs.
Intertidal embayments	These are subject mainly to tidal energy and are characterised by fine, soft, sandy substrates, generally of low organic content.
Intertidal shorelines	Shorelines are rocky or sandy, depending on their degree of exposure to wave and/or current energy. Rocky shores predominate at the Montebellos and typically have a double erosion notch.
Barrier Reef	This is characterised by very high wave energy. The outer reef slope is not steep and, where examined was not dissected by spur and groove formation, but became progressively more broken with depth. The crestal area is indistinct; in some places it has boulder accumulations, but there is no rubble crest. A typical reef flat, largely composed of consolidated coral slabs interspersed with sand, drops off steeply in parts where patch reefs occur. Several large breaks in the reefs form deep channels.
Shallow open ocean habitat	Relatively high wave and current energy gives rise to extensive areas of exposed limestone pavement and reef, interspersed with patches of sand veneer overlying the pavement.

Winds blow consistently for most of the year except during April and May, which is a transitional period. During winter (June - August), moderate to strong south-easterlies and easterlies prevail (Figure A3.3), while during summer, moderate southerly, south-westerly and westerly winds dominate (Figure A3.4). The 0900 and 1500 wind regimes for Barrow Island for April, May and June, the proposed drilling period, are presented in Figures A3.5 to A3.7.

Tropical cyclones may occur any time between November and April. The annual average frequency of cyclones passing within 360 km of the project area is 2.4.

The frequency of occurrence of tropical cyclones is an important physical environmental factor influencing the marine fauna, particularly corals, in shallow water at the Montebellos. Examination of cyclone tracks provided by the Bureau of Meteorology showed that, in the 16 years between 1977/78 and 1991/92, a total of nine cyclones passed within approximately 90 km of the islands. Recent cyclone damage, evident in shallow areas of the lagoons, may have resulted from cyclones "Ian" (February/March 1992), "Ilona" (December 1988) and/or "Orson" (April 1989) and "Bobby" (1994).

3.4 Tides and Currents

Water movement in the survey area is dominated by wind-modified tidal currents. Tides are semi-diurnal, that is, there are two high and two low tides in each 24 hours, with water movement during spring tides far more influenced by tidal currents than by local wind stress. The spring tidal range is approximately 3.3 m. Tidal currents of up to 4 knots can be experienced in the shallow channels of the Montebello group (Steedman Science & Engineering 1989).

The Leeuwin Current, which flows along the Western Australian coastline, persistswith greatest strength from February to July (Holloway & Nye, 1985), although this timing can vary from year to year.

The water temperatures at the Montebellos range from 20°-33°C which, in terms of biogeographical provinces, places the Montebellos within the Dampier or Northern Australian Tropical Province (Wilson & Allen 1987, in WAM 1993).

The water in the Montebellos is frequently turbid due to the combination of wave action, relatively high tidal range and the shallowness of the area (WAM 1993). Despite their distance offshore, the Museum considered the turbidity conditions and the fauna of the Montebellos to be more typical of the mid-continental shelf than of the outer shelf edge, such as found at the Rowley Shoals, which are typically oceanic.

4. FLORA AND FAUNA

The Montebello Islands form the perimeter of a shallow lagoon and the indented islands form further sheltered embayments and channels which are not replicated elsewhere on the northwest coast (IUCN 1988).

The shallow waters and intertidal areas of the region support a range of habitats and wildlife. These include macroalgal and seagrass beds, coral reefs, and mangroves.

The water column supports a range of marine mammals, reptiles, pelagic and benthic fish, drift species and plankton. The sea surface also supports some species of seabirds which feed at sea.

4.1 Rocky Shores

Notched limestone cliffs and intertidal platforms are a feature of most of the islands and rocky outcrops. The rock faces are encrusted with rock oysters (*Saccostrea* spp), barnacles (*Tetraclita porosa* and *Chthamalus*), turfing algae, chitons, limpets, *Leptograpsus* crabs and cryptic crustaceans such as shrimps, isopods and amphipods.

4.2 Sandy Shores

Sandy beaches occur between the rocky headlands on most of the larger islands. They support a limited range of resident fauna, principally small burrowing fauna such as polychaete worms, bivalve molluscs and amphipod crustaceans [LeProvost Semeniuk & Chalmer (LSC) 1986].

The sandy beaches and adjoining limestone pavements provide feeding grounds for wading birds and nesting sites for species of birds such as the pied oystercatcher and beach thick-knee, as well as seabirds like the caspian, bridled and fairy terns. During summer, four species of turtles use these beaches for nesting.

4.3 Mangroves

Associated with the sand and mudflats in the bays of the Montebello Islands are mangals ranging in size from isolated mangrove trees to areas of more than 15 ha. These are most common on the east side of Hermite Island. At least four species are present with *Avicennia marina* occurring alone or in mixed assemblages in association with *Bruguiera exaristata, Ceriops tagal* and/or *Rhizophora stylosa* (Marine Parks and Reserves Working Group, 1994). The Crocus Island stand is reported to include the river mangrove *Aegiceras corniculatum* (WAM 1993).

Mangrove communities are normally associated with high biological productivity. Mud crabs, turtles, rays, fish and bird life are supported by the mangrove stands along with a myriad of invertebrate animals.

4.4 Macroalgae and Seagrasses

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.

Seagrasses are flowering plants with roots and stems, and are important as sediment stabilisers and fauna habitats.

Macroalgae are abundant on the exposed limestone pavement and knolls surrounding the Montebello Islands. Brown algae belonging to the genera *Sargassum* and *Padina* and the green algae of the genera *Caulerpa* and *Cladophora* have been noted (WAM 1992). These algae are also widely distributed around Barrow and the Lowendal Islands.

Six seagrass species are known to occur in the area: *Cymodocea angustata, Halophila ovalis, Halophila spinulosa, Halodule uninervis, Thalassia hemprichii* and *Syringodium isoetifolium* (Kirkman & Walker 1989). They mostly occur in areas of sandy seafloor ranging from intertidal to shallow subtidal. They tend to form small patches from 1 to 10 m in diameter and are generally reported to be sparsely distributed.

The distribution of seagrass meadows in deeper waters is unknown, however, at least one species, *Halophila spinulosa,* is known to occur to depths of 20 m.

The first in situ collection of an endemic Australian seagrass, *Cymodocea angustata* Ostenfeld, was made in the Montebello Islands in 1979 (McMillan et al. 1983). This species was found on the western side of Hermite Island at a depth of 5 m.

Seagrass beds, and possibly algae beds, are important feeding grounds for green turtles and dugongs, both of which are found in the area. They are also important as nursery grounds for many fish and crustaceans.

Much of the extensive area of shallow (<5 m) water occurring between the well site and the Montebellos and extending southward to Barrow Island is sand-veneered pavement predominantly with algae. These, along with sparse patches of seagrass, may provide feeding sites for the green turtles and dugong which have been observed in this area.

4.5 Corals

A total of 141 species of 54 genera of corals were recorded during the WAM 1993 survey of the Montebello Islands and a further nine species were added from previous records. A comparison of hermatypic (reef-building) corals at various coral reefs off Western Australia is shown in Table A3.2. It is considered likely that more species may be found at the Montebellos when the reefs are more completely surveyed (WAM 1993).

The coral reefs of the Montebello Islands, like those of the Dampier Archipelago are subject to extensive damage by cyclones through physical disturbance and sedimentation (Heinsohn & Spain 1974; Van Woesik et al. 1991) and therefore may be seen at different stages at different times. In August 1993, the Museum reported that they appeared to be in fairly advanced recovery stage in some very large tabular *Acropora* plates in back, reef areas. Fast growing *Acropora* species can recover from severe damage in a few years while slow growing massive species may take up to 30 years to recover from major damage (WAM 1993).

Coral spawning usually occurs in March and April. In 1996, the major spawning is predicted to occur on 11 - 14 April with a smaller one occurring between 12 - 15 March (C. Simpson pers. comm.).

The coral fauna includes a suite of five genera characteristic of turbid inshore waters but most corals are characteristic of moderately clear water conditions. The coral fauna is most similar to that of the Dampier Archipelago. These belong to the genera *Caulastrea, Moselaya, Trachyphyllia, Catalaphyllia* and *Duncanopsammia* while *Euphyllia* and *Turbinaria* spp., which although not confined to turbid water, are more abundant in such conditions.

The proposed Wonnich drilling site lies approximately 1 km to the west of the southern section of the Montebello fringing reef system, an aerial photograph of which is shown in Figure A3.8. The following description of this segment of the fringing reef which occurs closest to the well site is drawn from a survey of the reef conducted on 30 and 31 October 1995 by Michael Forde of Bowman Bishaw Gorham. A map of the habitats described by Forde is presented as Figure A3.9.

Table A3.2

Number of Coral Genera/Species
(Source: WAM 1993)

LOCALITY	GENERA	SPECIES
Barrow Island	17	32
Abrolhos Islands	42	184
Montebello Islands	54	150
Ningaloo Reefs	54	217
Scott/Rowley Reefs	56	255
Ashmore Reef	56	255
Dampier Archipelago	57	216

In describing the reef, Forde divided it into five sub-habitats as follows:

- reef crest and fore-reef;
- southern margin of the reef;
- the coral community on the south-eastern side of the reef;
- deep central channel and fringing reef edges;
- coral community on the north-eastern side of the reef; and
- back reef on the northern side and directly behind the reef crest.

In addition, a deeper (~4 m) coral community was located some 300 m to the north of the main reef complex (Figure A3.9).

Forde's description of each of these sub-habitats is as follows:

4.5.1 Reef crest

The reef crest is composed of low profile limestone, heavily bored by sea urchins below the intertidal, with bare limestone present within the intertidal. Stunted macroalgae, particularly *Halimeda* sp., become dominant with increasing depth along the fore-reef. Live coral is generally restricted to approximately 5% cover and consists of encrusting species. Coral cover was observed to increase to approximately 20% in one area where reef relief was greater, with *Porites* being dominant.

4.5.2 Coral community (south side of reef)

A coral community occurs along the southern side of the reef, composed of complex assemblages on limestone or coral patch reefs raised above a sand substrate. Coral cover was estimated at 30%, with *Porites*, *Acropora* and the hydrocoral *Millepora* being the most common genera. Soft corals are also very common. *Porites* 'bommies' and *Acropora hyacinthus* plates, each of 3 m diameter, were the largest corals seen. Large fish were abundant in this area, with Red Bass (*Lutjanus bohar*), Coral Trout (*Plectropomus* sp.), Tusk Fish (*Choerodon* spp.) Flowery Cod (*Epinephelus fuscoguttatus*), Chinaman (*Symphorus nematophorus*) and Spangled Emperor (*Lethrinus nebulosus*) being observed.

Immediately adjacent to the reef are flat patchy coral communities dominated by arborescent *Acropora* alternating with sand patches, exposed bare limestone and small seagrass, *Thalassodendron ciliatum*, patches. These patches are approximately 10 m^2 in area.

The shallow reef flat is bare of flora other than turf algae. Numerous large green turtles were observed feeding in this zone on the high tide.

4.5.3 Coral community (south-east side of reef)

A large coral community occurs east of the shallow reef flat and was investigated at three different locations during the survey. The community is an extensive, diverse assemblage dominated by arborescent *Acropora* and the hydrocoral *Millepora*. Other common genera include *Galaxea, Favia, Favites, Montipora, Merulina, Pectinia* and *Porites*. The southern part of the coral community appears to have been affected by a recent storm event: much of the substrate consists of coral rubble and many of the *Acropora* appear to have generated through fragmentation.

A notable observation in this community was the abundance of Crown-of-Thorns starfish (*Acanthaster planci*). These were common at each location investigated and were observed feeding on most of the scleractinian coral. Coral deaths which could be attributed to *Acanthaster* were not abundant and, in combination with the relatively small size of the starfish, suggests that the abundance of seastars is a recent phenomenon. Evidence of the presence of *Acanthaster* and *Drupella* was observed on some of the coral reefs by LEC in 1992.

4.5.4 Deep channel

The deep channel which bisects the reef was investigated at two sites. The floor of the channel is comprised of sand and is bare of coral or other attached benthos. The fringes of the channel support large *Porites* 'bommies' and other massive corals such as *Lobophyllia* and *Oulophyllia.* Coral cover increases as water depth decreases with *Millepora* becoming dominant. Coral cover decreases towards zero further into the reef flat, apparently because it is mainly intertidal.

4.5.5 **Coral community** (north side of the channel and east of the reef flat)

The coral community on the northern side of the deep channel and east of the reef flat is not as prolific as in the corresponding community on the southern side of the channel. The community appears to be strongly depth determined, with the shallow reef top (which is probably intertidal) being devoid of attached benthos other than very occasional small corals. The slightly deeper surrounds support approximately 20% live coral of low diversity. Dominant genera include *Favia, Leptoria, Montipora, Galaxea* and *Acropora* scleractinian coral genera, along with the hydrocoral *Millepora.*

The pavement immediately beyond the shallow, sloping reef supports a *Sargassum* (algae) community with very few live corals.

4.5.6 **Back reef** (north-western end of the reef complex)

The back reef area at the north-western end of the reef complex was found to support dark-coloured turfing algae with live coral being virtually non-existent. Large areas of exposed back reef could be observed at low tide. This area appeared to dry well before low water, and parts would probably be exposed on most low tides. Coral communities in these areas appear most unlikely. However, large green turtles (*Chelonia mydas*) were observed to be feeding in the area during high tide and the area may be regionally significant for this purpose.

4.5.7 **Coral 'bommie' community** (north of the reef complex)

An extensive reef community occurs in about 4 m of water approximately 300 m north of the reef complex. This is a *Porites* 'bommie'-dominated community with soft corals being sub-dominant. Other corals occurring were mainly found in association with the *Porites*, and included *Coscinaraea, Leptoria,* corymbose and tabular *Acropora, Goniastrea* and, on the sand/rubble substrate, *Sandalolitha.* Fish are common throughout this coral community, with large Coral Trout (*Plectropomus* sp.) and Flowery Cod (*Epinephelus fuscoguttatus*) being observed.

4.6 Molluscs

Six hundred and thirty-three species of molluscs are recorded from the Montebello Islands and, of the majority of those species whose distributions are known, the great majority are widespread Indo-West Pacific species (WAM 1993). The molluscan assemblage at the Montebellos is described as characteristic of the continental coastline rather than the offshore atolls.

Two commercially important species of bivalve molluscs occur within the waters of the Montebello Islands. Pearl oysters live on the sea bed from the low water mark to a depth of 85 m, inhabiting a range of substrates from mud and sand through deepwater reefs (Kailola et al. 1993). The largest species, *Pinctada maxima* is harvested at depths from 10 m to 37 m between Exmouth Gulf and King Sound. Collected shell is farmed to produce cultured pearls. A pearl farm is operated within the Montebello Islands by Morgan & Co. Pty Ltd.

The western saucer scallop, *Amusium balloti,* also occurs in waters between 10 m and 75 m. There is no commercial fishing for scallops within the Montebellos, although there is a fishery based in Dampier.

In addition, there is one species of gastropod which is endemic to the area between Barrow Island and the Montebello Islands. This is the direct developing volutid *Amoria macandrewi* and its endemicity may indicate that this area has been isolated from other marine ecosystems for some time (Marine Parks and Reserves Selection Working Group 1994).

Drupella cornus, a coralliverous species known to cause considerable damage to corals along the Ningaloo Reef Tract in Western Australia, are present at the Montebellos, but no damage to coral populations was found during the survey conducted in 1993 (WAM 1993).

4.7 Crustaceans

A number of decapod crustaceans occur in the waters surrounding the Montebellos Islands and some of these are fished commercially. The western king and tiger prawns are the main component of the catch. Both species burrow into the sediments, but the western king prawn prefer relatively coarse sediments while tiger prawns select muddy areas. Other species may be harvested as by-catch include white banana prawns and the bay lobster or mud bug. Another species of lobster, the painted spiny lobster *Panulirus ornatus* is the target of a small localised dive fishery around the islands and reef chains between the Muiron and Montebello Islands (Kailola et al. 1993).

4.8 Fish

A diverse range of fish is found in the area. This includes commercially significant species such as sharks, snapper, Spanish Mackerel and Red Emperors, recreational species including sea perch and rock cod, together with a variety of tropical reef species inhabiting coral areas. LSC (1986) described the fish fauna of the Montebello Islands as abundant around areas of limestone and coral reef, and moderate to low in seagrass patches and over limestone pavement.

The survey carried out by the Museum details fish species found in the Montebello Islands. It reports that a total of 457 fish species in 76 families are found in the area. Most of the species, with the exception of a few north-west regional endemics, have relatively wide distributions in the Indo-west Pacific Region. Nearly all species have either pelagic eggs or larvae and therefore are recruited as juveniles from areas outside the Montebello Islands (WAM 1993). Many of the species are found in the shallower reef areas.

4.9 Turtles

Four species of turtle populate the waters between the Lowendal and Montebello Islands: the green turtle (*Chelonia mydas*), loggerhead (*Caretta caretta*), flatback (*Chelonia depressa*) and hawksbill (*Eretmochelys australis*). Nearly all of the sandy beaches in the region are used for nesting during the summer months, where depending on species and age, between 110-125 eggs may be laid by each nesting turtle.

The green turtle feeds on seagrass and algae, and numbers have been observed in the shallow waters on the west side of Hermite Island and the shallows between the Montebellos and Barrow Island.

All species nest from late spring through summer (November-March) and may be seen together on beaches. Data indicates that turtles may be decades old before they first breed, and individual females may not breed every year.

All four species of turtles are classified as endangered on a world wide basis and Australia is one of the few countries still to have relatively large turtle populations (Limpus 1990). Despite this, the numbers of loggerhead turtles in Australia is believed to be in decline (Limpus & Couper 1994). All four species are migratory and subject to exploitation in traditional fisheries in northern Australia and neighbouring countries. They may also incur significant mortality as a by-catch of commercial fishing in Western Australian waters (Prince 1990).

4.10 Marine Mammals

Marine mammals, including dolphins, whales and dugongs, frequent the waters of the region.

Species known to occur include six species of toothed and three species of baleen whales, and the dugong. Of notable interest, Humpback Whales migrate through the North West Shelf in the winter months between June and October. These migrate northward from the Southern Ocean into the region, passing the west and north coasts of Barrow Island and the Montebello Islands.

The following cetacean species are likely to be sighted in the region:

Toothed Whales (*Odontoceti*)
- Bottle Nosed Dolphin
- Common Dolphin
- Striped Dolphin
- Short-finned Pilot Whale
- False Killer Whale
- Killer Whale

Baleen Whales (*Mysticeti*)
- Tropical Bryde's Whale
- Southern Minke Whale (winter only)
- Humpback Whale (winter only)

Humpback turtles take about 10 years to reach maturity and are able to breed every other year. Gestation takes 11-12 months and usually only one calf is born. Dolphins are generally mature by 6 years old with a calving interval of two years.

Dugong (*Dugong dugon*) are known to occur in the shallow, warm waters around the islands, although not in the large concentrations seen further south in the Exmouth Gulf or Shark Bay (Prince 1989). This animal is entirely herbivorous and feeds on the seagrass and algae meadows. Current knowledge on the size and distribution of dugong populations and their migratory habits in the region between North West Cape and the Dampier Archipelago is limited. Dugongs are slow maturing, slow breeding, long lived animals with a minimum pre-reproductive life of 9 - 10 years (Prince 1989). The gestation period is about 13 - 14 months and calving appears to occur at intervals of 3 - 7 years. Dugongs are considered rare and endangered and are protected in Western Australia.

4.11 Seabirds

Seabirds are those birds which feed in the waters of the area and use the islands for roosting and nesting. Some of the birds which use the islands for nesting include the Wedge-tailed Shearwater, Osprey, White Breasted Sea Eagle, Caspian Terns, Crested Terns, Pied Cormorants, Bridled Terns, Silver Gulls and Brahminy Kites (Dinara Pty Ltd 1985; LEC 1992). None of these species is restricted in their distribution to the Montebello Islands.

Wedge-tailed Shearwaters and Bridled Terns have the largest breeding populations on the North West Shelf islands (J. N. Dunlop, pers. comm.). Both species are offshore feeders with extensive foraging habitats.

Wedge-tailed Shearwaters are present in local waters for much of the year although there is evidence for a partial migration in the eastern Indian Ocean to a wintering area north of 12° South Latitude (Dunlop et al. 1995). The regional population is difficult to estimate, but is probably of the order of 100,000 breeding pairs (Storr 1984; CALM 1990; Astron Engineering 1995).

Shearwaters usually return to their breeding burrows in late August. On the North West Shelf, the laying period of 2-3 weeks begins in late October or the beginning of November. The chicks start hatching around the third week in December and fledge around mid-April. The fledglings may be deserted for a week or so before departure (Astron Engineering 1995).

Adult Wedge-tailed Shearwaters have been observed to gather at dusk in rafts at sea, some kilometres offshore from their colonies. This behaviour could render them vulnerable during an oil spill incident. In April, fledgling chicks may also spend more time on the water and would also be relatively exposed.

Bridled Tern colonies seem to be present on almost all of the 27 islands and rocks of the Lowendal Group. Bridled Island alone had 3-4,000 pairs in February 1995 (Dunlop in press) and overall the group could be supporting around 10,000 pairs. Colonies are also reported from islets south of Hermite Island in the Montebellos and from the Dampier Archipelago (Haycock, Elphick Nob, Lady Nora, Brigadier Goodwyn, Kendrew, Collier Rocks - Storr 1984; J. N. Dunlop pers. obs.). A regional population of 15-20,000 pairs would be a reasonable estimate.

Bridled Terns breeding on the Western Australian coastline are migratory wintering in the Indo-Pacific north of the equator (Dunlop & Johnstone 1994).

On the Lowendals, and most likely, Montebello Islands, egg laying begins in late December which is considerably later than the latest dates recorded in south-western Australia. Based on December egg laying, the first chicks would fledge in early to mid March. The post breeding exodus on the migration probably occurs in May.

For many seabirds, only one egg is laid per year.

5. SOCIAL ENVIRONMENT

5.1 Aboriginal History

An extensive search for Aboriginal artifacts has found evidence of occupation in small caves on Campbell Island, located in the central part of the island chain (Figure A3.10). The occupation appears to date from time prior to the most recent sea level rises (± 7,000 years before present). There is no evidence of Aboriginal occupation more recently than this (Veth 1993).

5.2 European History

The English ship *Tryal* (also known as the 'Trial') was wrecked on what are now known as the Tryal Rocks just north of the Montebello Islands in 1622 (Figure A3.10). This ship wreck is protected by the *Marine Archaeological Act* 1973 and has 'National Estate' status.

A further uncharted wreck, that of the 19th century ship the *Wild Wave,* is understood to be located close to rocks south-west of the Montebellos. Its exact position is unknown.

Three other identified wrecks lie in or near the Montebello Islands: Parkes' Lugger, *Curlew* and *Van Uden*.

Between 1903 and 1913 a pearling lease was held over waters in the Montebellos by a Mr Thomas Haynes. Campbell Island was reserved at that time for the "Water Pearling Industry" and remnants of Haynes' buildings and other structures may still be seen there (Figure A3.10).

In 1952 and 1956, three British nuclear weapon tests were exploded on and near the Montebello Islands (Figure A3.10). One of these was on a vessel, the HMS Plym, moored close to the western shore of Trimouille Island, while the other two took place on land, at the northern tip of Trimouille Island and on Alpha Island (Australian Ionising Radiation Advisory Council 1979). Remains of activities include scrap steel, relics of the nuclear tests and the former British operational headquarters foundations on the south of Hermite Island. Continuing radiation hazards limit the recommended length of occupation times on Trimouille and Alpha Islands.

5.3 Present Land Use

Present uses of the Montebello Islands include pearl cultivation (Figure A3.11) and occasional recreational fishing and diving cruises.

The main commercial fishery in the near vicinity of the islands is a line and trap fishery for reef fishes which mainly occurs about five nautical miles from the Montebellos in depths of 30 - 100 m. Coral reefs and shallow waters are generally avoided by trap fishermen. Currently the level of line fishing is thought to be low (WAM 1993).

Oil and gas production is presently undertaken from the Harriet Oilfield and Campbell and Sinbad gasfields located to the south on the east side of the Montebellos. Gas and oil produced from these two fields is pumped via subsea pipelines to production and storage facilities located on Varanus Island.

The sheltered waters of the islands are also used on occasion as a protected mooring area during the passage of cyclones.

There is no permanent resident population on the islands although the pearling operation run by Morgan & Co. Pty Ltd. maintains an active presence between Hermite and Campbell Islands.

5.4 Conservation Value

Effective from 7 July 1992, the Montebello Islands were vested in the National Parks and Nature Conservation Authority as two C class reserves (infra-tidal land 42196 and intertidal land 42197) for the purpose of a Conservation Park (CALM Act 1984). The surrounding waters are not included in the vesting. Prior to this they were Vacant Crown Land administered on behalf of the Federal Government by the Department of Defence. A condition of the transfer of vesting to the State Government was that the State should reserve and manage the lands and waters of the Montebellos for conservation.

The marine conservation value of the area has been recognised in a recently released report *A Representative Marine Reserve System for Western Australia* (CALM 1994). With respect to the Montebello Islands, the Working Group considered that "... appropriate protection and management can be achieved by reservation of parts of the area, combined with designation of the remainder as an environmentally sensitive area needing special management."

The marine waters surrounding the Montebello Islands are currently being evaluated by the Australian Heritage Commission for listing as National Estate. The adjacent waters surrounding the Lowendal Islands have also been nominated.

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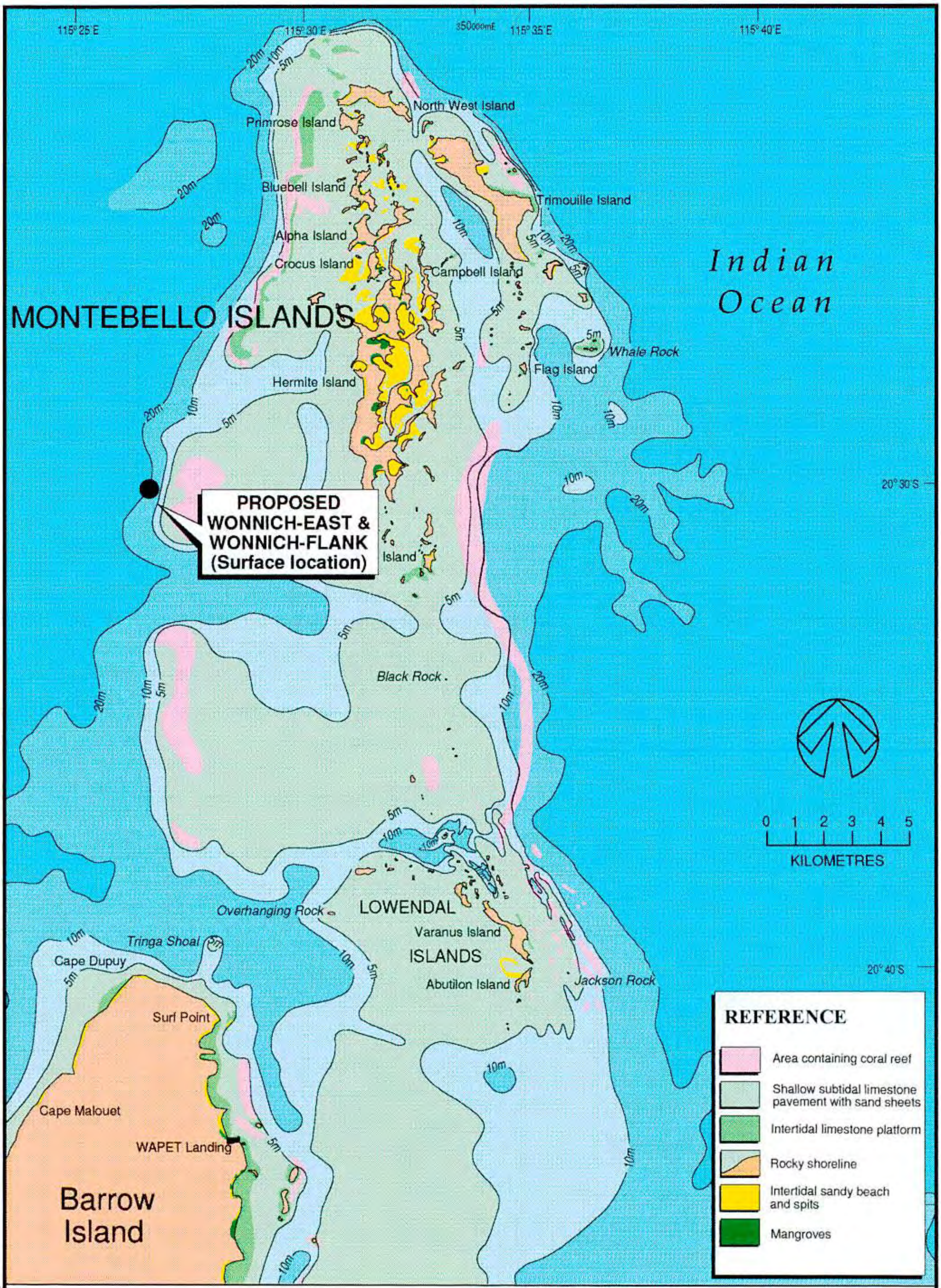
Appendix 3

Figures



LePROVOST DAMES & MOORE

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WONNICH APPRAISAL DRILLING CER

REGIONAL BATHYMETRY AND HABITATS

Figure A3.1

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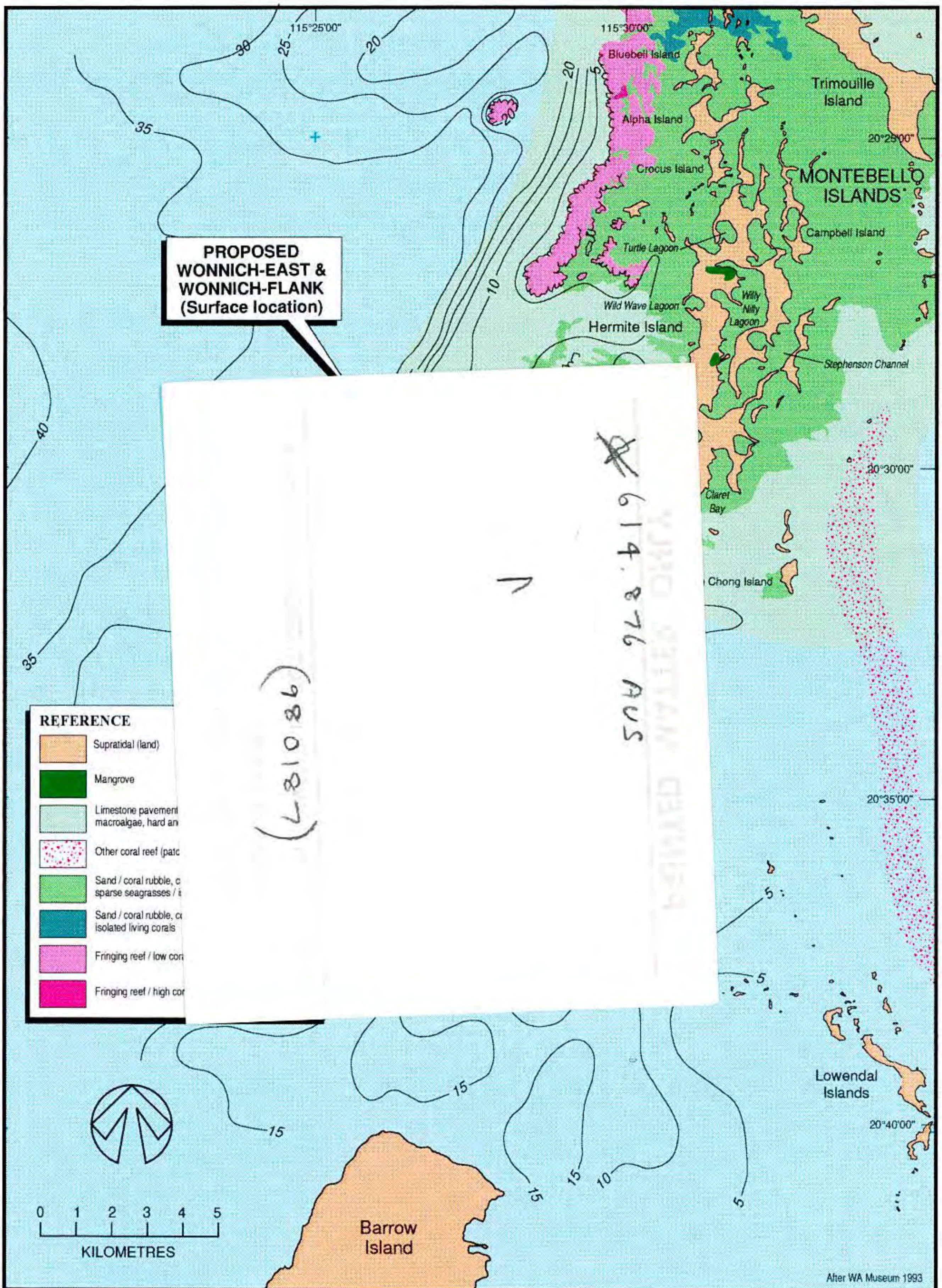


Environmental Drafting (09) 40 8105

LEPROVOST DAMES & MOORE

Apache Energy Limited
WONNICH APPRAISAL DRILLING CER

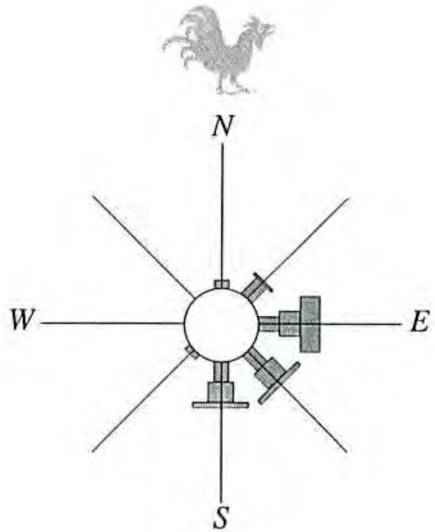
MARINE HABITATS - WONNICH

Figure A3.2

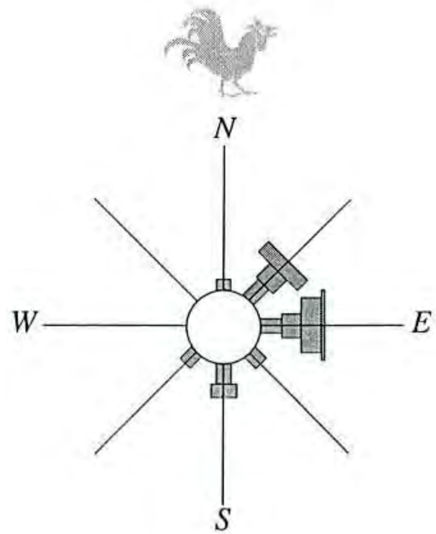
31479-002-367 R583 FIGA3_2.DGN 12/95

Apache ENERGY

WINTER: WIND ROSE DIAGRAM
Barrow Island

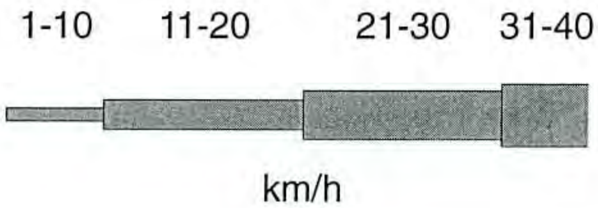


Winter
(9am)



Winter
(3pm)

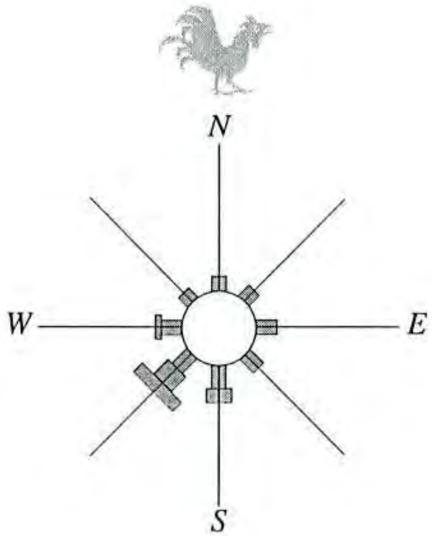
SEASONALLY



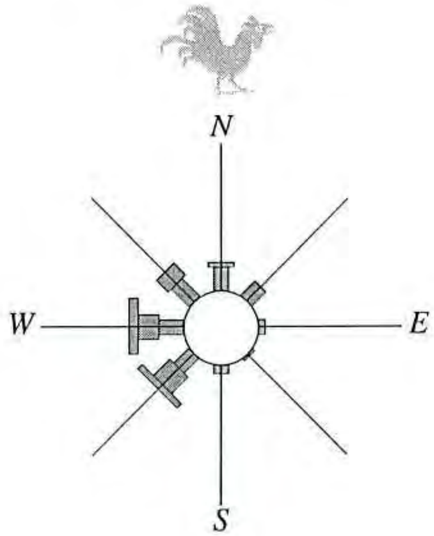
10 May 1995 IS.m2162

Figure A3.3

SUMMER: WIND ROSE DIAGRAM
Barrow Island



Summer
(9am)



Summer
(3pm)

SEASONALLY

1-10 11-20 21-30 31-40

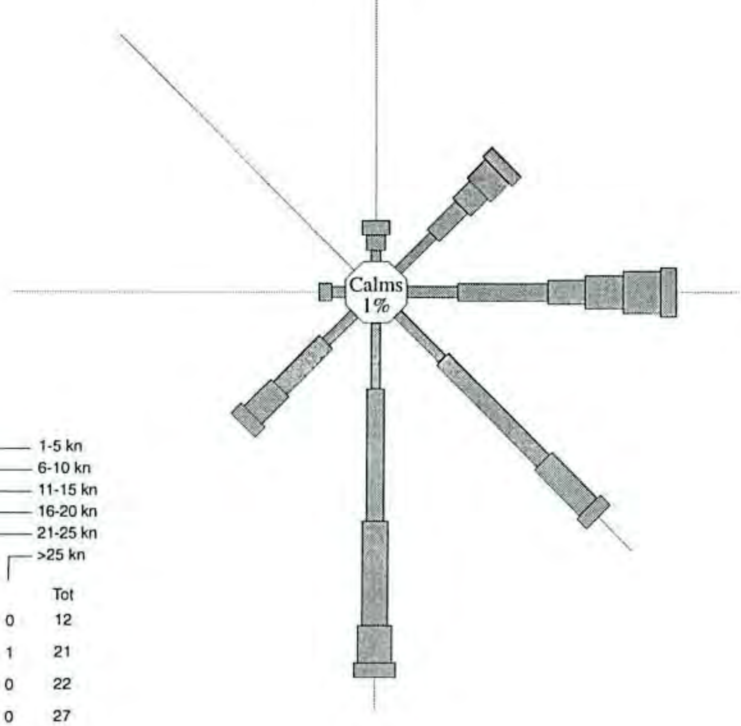
km/h

10 May 1995 IS.m2161

Figure A3.4

APRIL: WIND ROSE DIAGRAM
Barrow Island

N

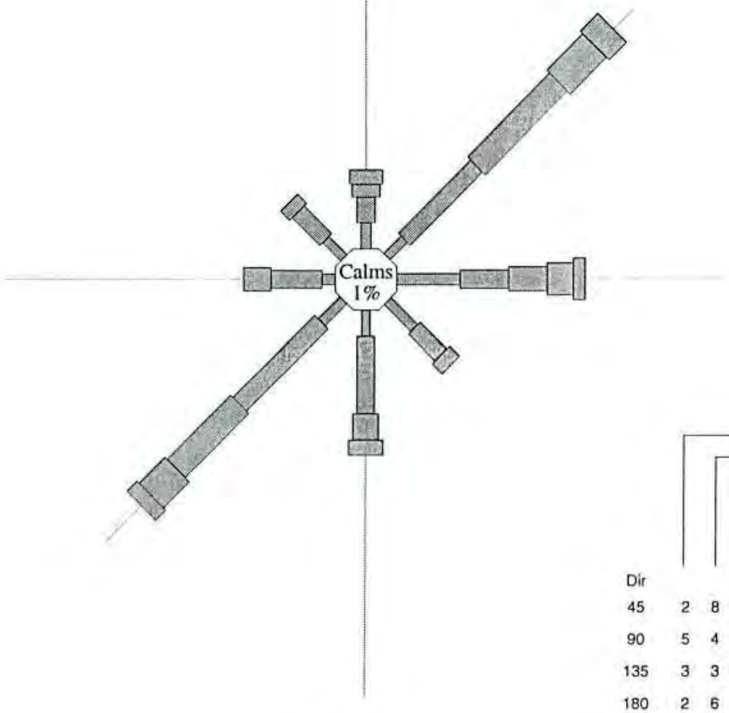


APRIL
(9 am)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	4	3	2	2	1	0	12
90	4	7	3	3	3	1	21
135	5	11	5	1	0	0	22
180	5	10	8	3	1	0	27
225	3	5	3	1	0	0	12
270	1	1	0	0	0	0	2
315	0	0	0	0	0	0	0
360	1	1	1	0	0	1	1
Tot	23	38	22	10	5	1	100

Percentage

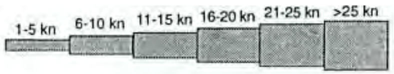
N



APRIL
(3 pm)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	2	8	9	4	2	0	25
90	5	4	3	2	1	0	15
135	3	3	1	0	0	0	7
180	2	6	2	1	0	0	11
225	2	9	7	3	1	0	22
270	1	4	2	0	0	0	7
315	2	3	1	0	0	0	6
360	2	2	1	1	0	0	6
Tot	19	39	26	11	4	0	100

Percentage



Box height defines the wind speed range

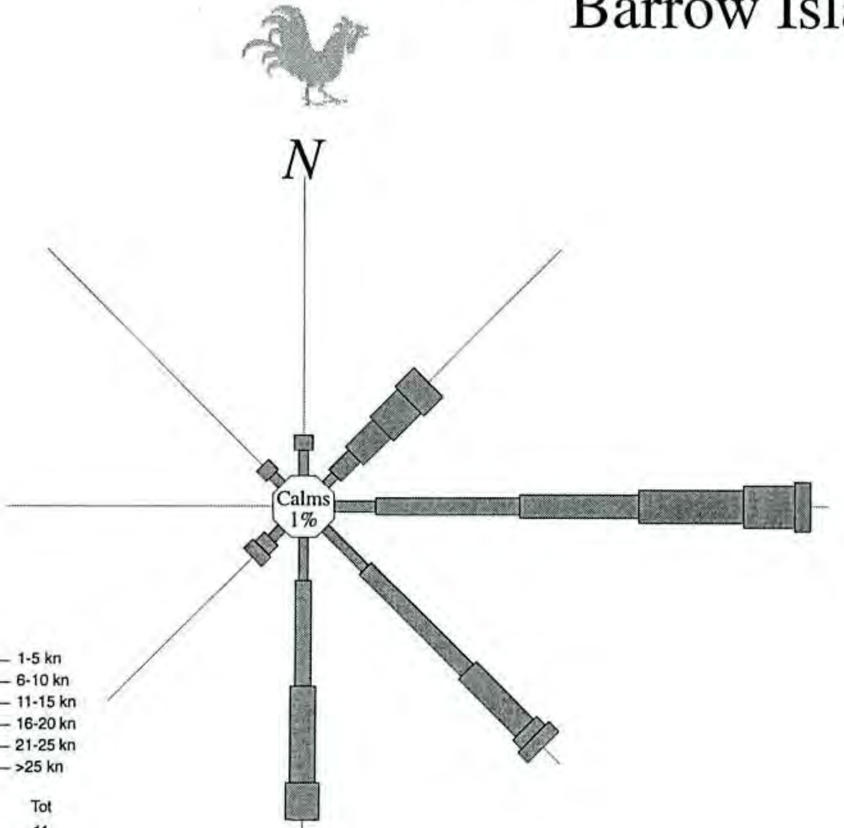
Box length is proportional to relative % frequency (see Table)

29 December 1995 IS.m3196

Figure A3.5

Apache ENERGY

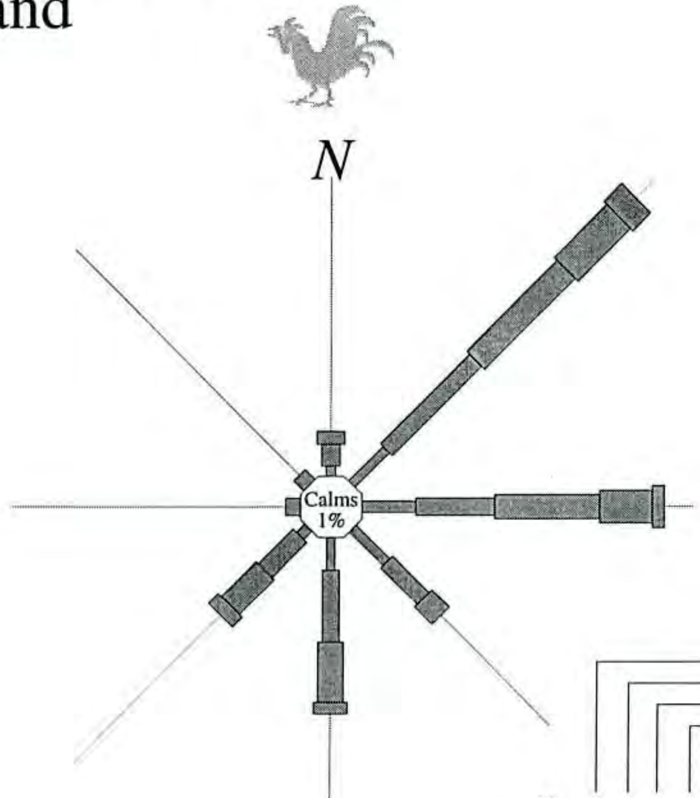
MAY: WIND ROSE DIAGRAM
Barrow Island



MAY
(9 am)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	1	2	3	3	2	0	11
90	3	11	9	8	4	1	36
135	4	11	6	1	1	0	23
180	3	8	7	3	0	0	21
225	1	1	1	0	0	0	3
270	0	0	0	0	0	0	0
315	1	1	0	0	0	0	2
360	2	1	0	0	0	1	3
Tot	15	35	26	15	7	2	100

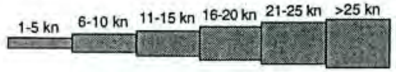
Percentage



MAY
(3 pm)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	4	10	10	6	2	0	25
90	4	6	8	4	1	0	15
135	4	4	2	0	0	0	7
180	3	6	5	1	0	0	11
225	1	4	4	1	0	0	22
270	0	1	0	0	0	0	7
315	0	1	0	0	0	0	6
360	1	2	1	0	0	0	6
Tot	17	34	30	12	3	0	100

Percentage



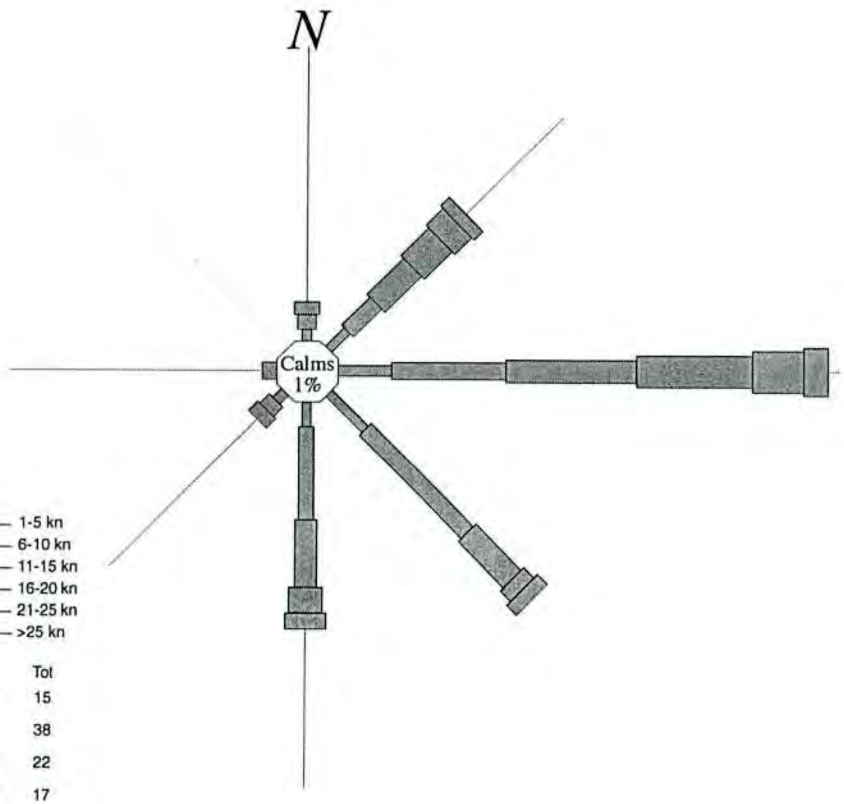
Box height defines the wind speed range

Box length is proportional to relative % frequency (see Table)

29 December 1995 IS.m3197

Figure A3.6

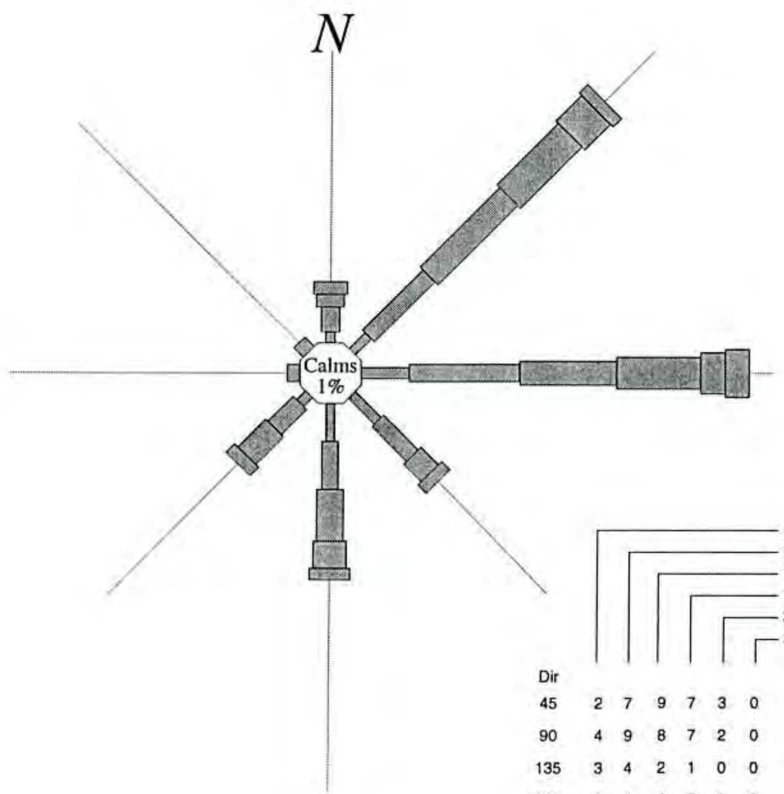
JUNE: WIND ROSE DIAGRAM
Barrow Island



JUNE
(9 am)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	2	3	4	3	2	1	15
90	4	9	10	9	4	2	38
135	4	11	5	1	1	0	22
180	2	7	5	2	1	0	17
225	1	1	1	0	0	0	3
270	0	1	0	0	0	0	1
315	0	0	0	0	0	0	0
360	1	1	1	0	0	3	3
Tot	14	33	26	15	8	3	100

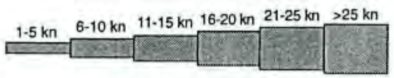
Percentage



JUNE
(3 pm)

Dir	1-5 kn	6-10 kn	11-15 kn	16-20 kn	21-25 kn	>25 kn	Tot
45	2	7	9	7	3	0	29
90	4	9	8	7	2	0	31
135	3	4	2	1	0	0	10
180	3	4	4	2	1	0	14
225	1	3	3	1	0	0	8
270	0	1	0	0	0	0	1
315	0	1	0	0	0	0	1
360	1	2	1	1	0	2	5
Tot	14	31	27	19	8	2	100

Percentage

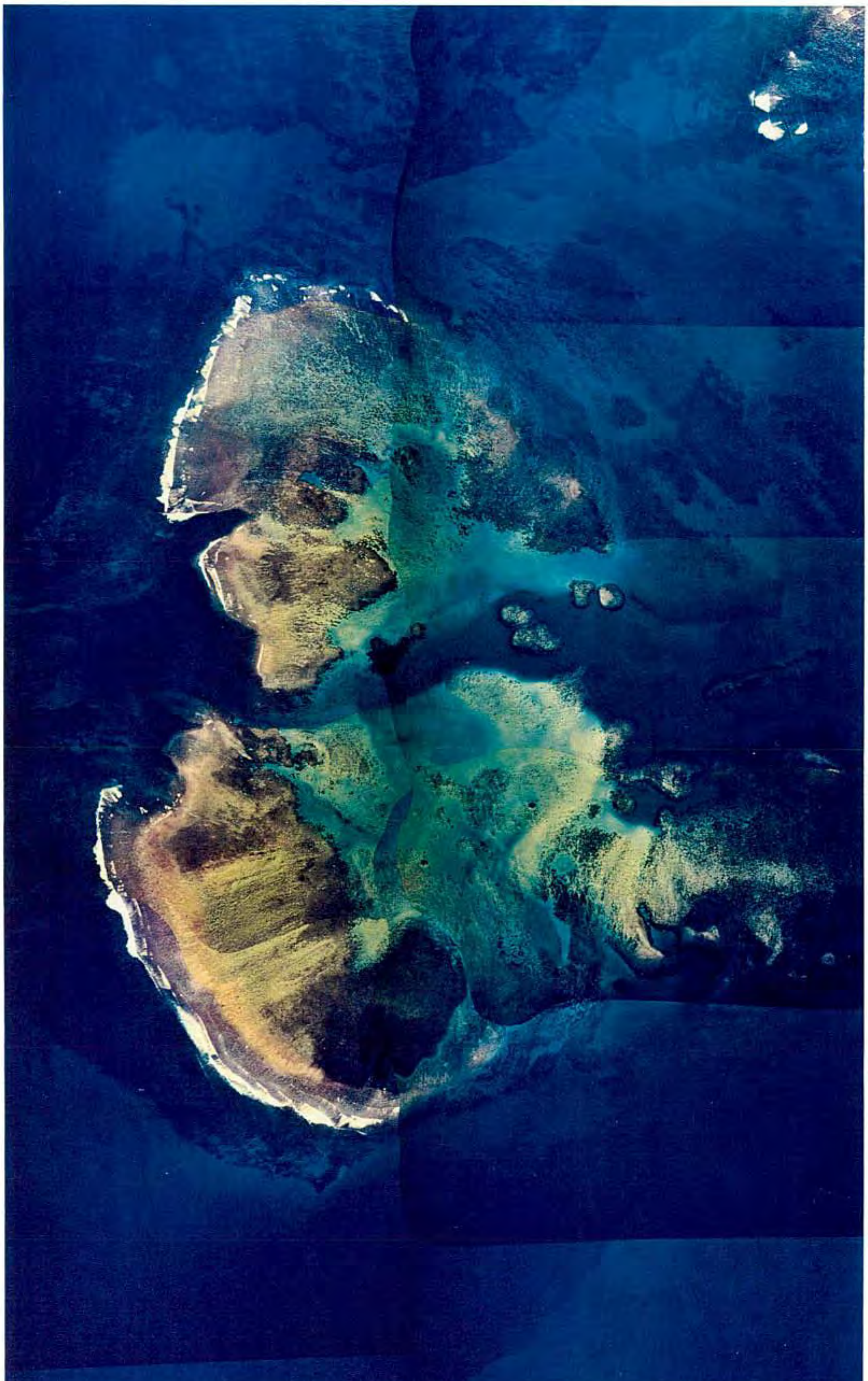


Box height defines the wind speed range

Box length is proportional to relative % frequency (see Table)

8 January 1996 IS.m3204

Figure A3.7



Aerial Surveys Australia
192 Cambridge Street
Wembley 6014
Western Australia

WONNICH 1
PRE — DRILLING SURVEY
Date of photography 6-7-1995

0 500m
RF 1:10000

Environmental Drafting (09) 40 8105

Apache Energy Limited
WONNICH APPRAISAL DRILLING CER

SW MONTEBELLO FRINGING REEF

LePROVOST DAMES & MOORE

Figure A3.8

31479-002-367 R583 FIGA3_9.DGN 12/95

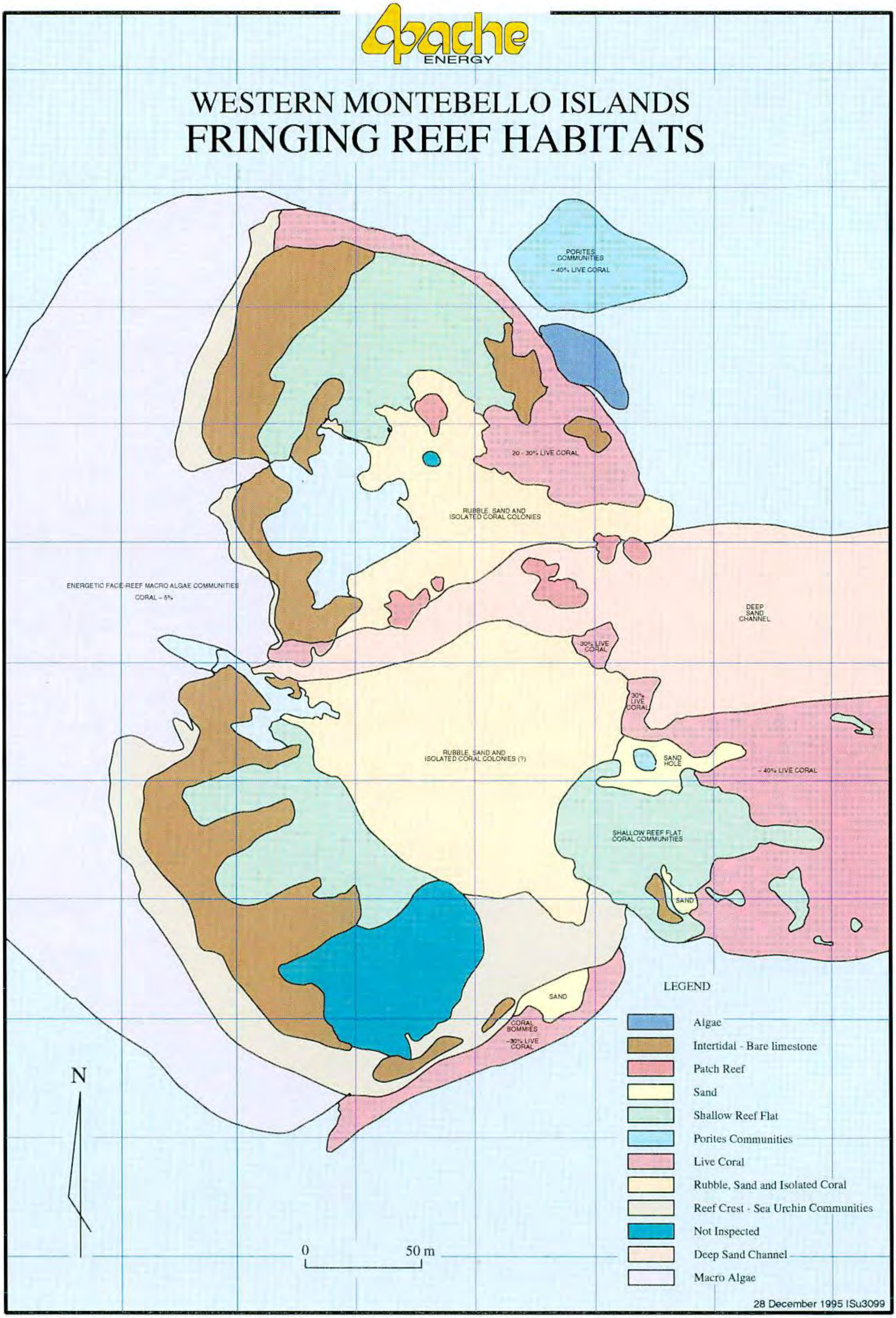
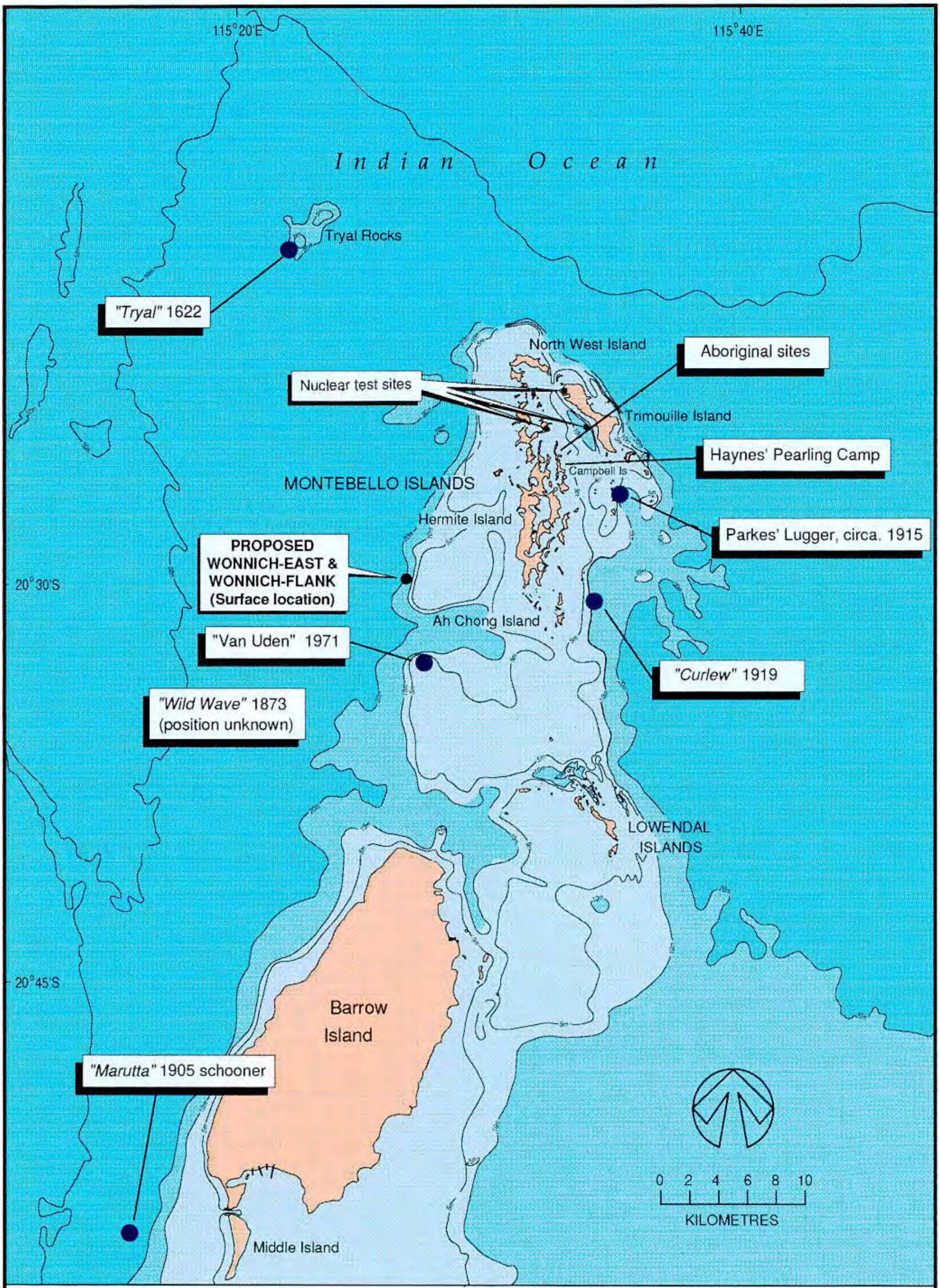

Apache
ENERGY
WESTERN MONTEBELLO ISLANDS
FRINGING REEF HABITATS
PORITES COMMUNITIES
~40% LIVE CORAL
20 - 30% LIVE CORAL
RUBBLE, SAND AND ISOLATED CORAL COLONIES
ENERGETIC FACE-REEF MACRO ALGAE COMMUNITIES
CORAL ~ 5%
DEEP SAND CHANNEL
30% LIVE CORAL
30% LIVE CORAL
RUBBLE, SAND AND ISOLATED CORAL COLONIES (?)
SAND HOLE
~40% LIVE CORAL
SHALLOW REEF FLAT CORAL COMMUNITIES
SAND
SAND
CORAL BOMMIES
~30% LIVE CORAL
N
0
50 m
LEGEND
Algae
Intertidal - Bare limestone
Patch Reef
Sand
Shallow Reef Flat
Porites Communities
Live Coral
Rubble, Sand and Isolated Coral
Reef Crest - Sea Urchin Communities
Not Inspected
Deep Sand Channel
Macro Algae
28 December 1995 ISu3099

Figure A3.9



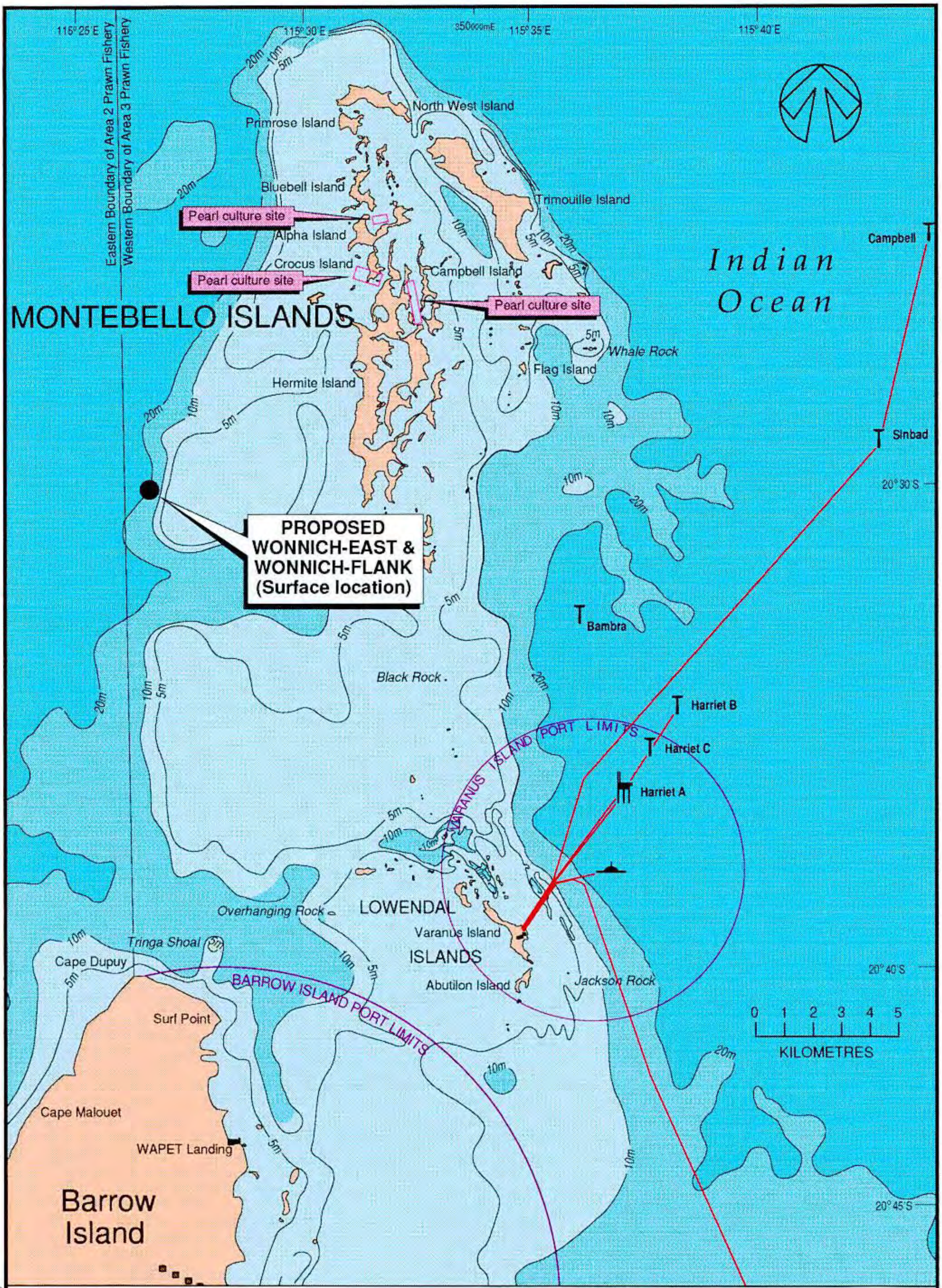
LePROVOST DAMES & MOORE

Apache Energy Limited
WONNICH APPRAISAL DRILLING CER

HISTORICAL SITES

Figure A3.10

31479-002-367 R583 FIGA3_11.DGN



LePROVOST DAMES & MOORE

Apache Energy Limited

WONNICH APPRAISAL DRILLING CER

COMMERCIAL RESOURCES AND INFRASTRUCTURE

Figure A3.11

Environmental Drafting (09) 40 9105
31479-002-367 R583 FIGA3_12.DGN 12/95

Appendix 4

Characteristics of Drilling Fluids

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 material such as barite when circulation is interrupted - as when adding a new joint of drill-pipe (Hinwood et al. 1994).

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.

Two drilling fluid systems will be used during the drilling of the Wonnich Appraisal Wells. Wonnich - Flank, a horizontal well, will be drilled using a conventional water-based drilling fluid system, while Wonnich - East will be drilled using the synthetic ester-based drilling fluid, 'Petrofree'.

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 poses no health risk to workers under normal conditions of exposure.

'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. 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) (Attachment 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) (Attachment 2).

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 (Attachment 3) 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 the following table.

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

A Static Sheen Test by the American company Envirotest of Lafayette, Louisiana, USA, found that a sample of drilling mud containing Petrofree produced no surface sheen when mixed with water (Attachment 4).

3 WATER-BASED DRILLING FLUID

The main constituents of water-based drilling fluid systems most commonly used in Australian waters are: potassium chloride; barite; bentonite; powdered, partially hydrolysed polyacrilamide polyanionic cellulose; Xanthum gum; soda ash; and caustic soda.

The following table shows the composition of the drill fluid at an average composition.

PRODUCT	CHEMICAL DESCRIPTION	% w/w
KCI	Potassium Chloride	2.1
Barite	$BaSo_4$ - inert	1.1
Bentonite	Montmorillonite Clay - inert	2.0
Modified Starch	Modified Polysaccharide	0.1
PAC	Polyanionic Cellulose	0.1
Soda Ash	Na_2CO_3	0.04
Caustic Soda	Na0H in solution	0.01
Lime	Ca0	0.02
Sodium Sulphite	NA_2SO_3	0.01
Mica	Muscovite - inert	-
Thinner	Lignosulphonate	-
Magco A-303	Water-soluble filming amine	0.01
XCD Polymer	Xanthum gum	0.03
Polyplus (PHPA)	High molecular weight anionic polymer	0.09
Water & Formation Drilling Fines		94.0
Oil/Diesel		
Total (rounded)		100.0

During drilling, the fluid composition may be changed by the use of various additives to alter the physical or chemical properties of the fluid in order to better control the well and the drilling operation.

Toxicity testing classifies water/KCL drilling fluid as almost non-toxic to non-toxic to marine organisms (Hinwood et al. 1994).

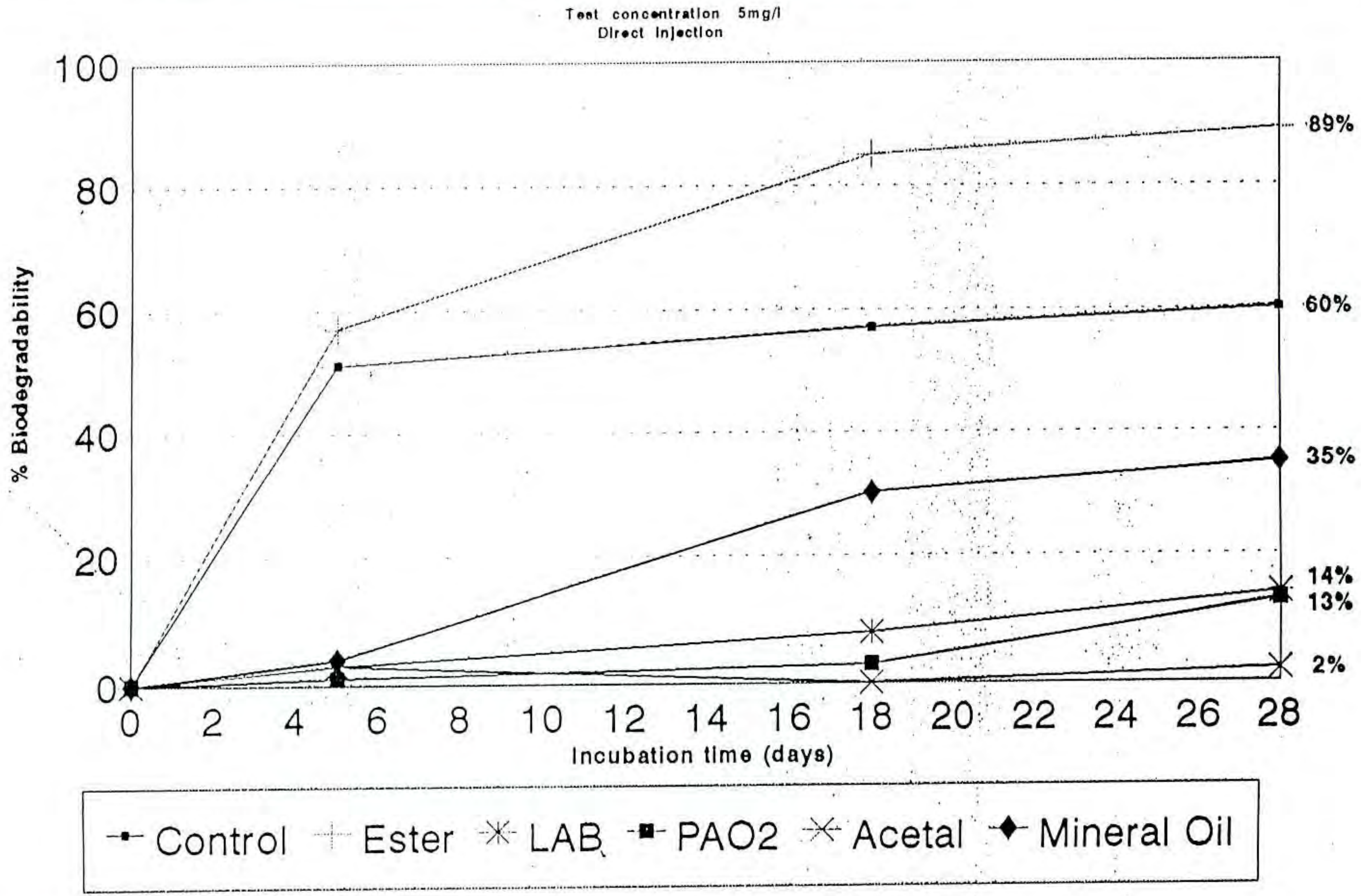
Table 1: Anaerobic biodegradability of test chemicals examined in the ECETOC No. 28 screening test.

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

BIODEGRADABILITY OF SYNTHETIC BASE FLUIDS

Aerobic Method 28 day Test



January 1994 Test protocol: US EPA 40 CFR 796.3200

PETROFREE - TOXICITY TESTING

ECOTOXICOLOGY STUDIES USING TROPICAL & SEMI-TROPICAL MARINE ORGANISMS

A substantial number of marine toxicity tests have been conducted on PETROFREE laboratory and field muds using temperate water species.

In order to ascertain the potential toxicity of PETROFREE discharges in the tropical marine environment additional ecotoxicological tests have been carried out using tropical and semi-tropical water species, in Australia and in the US.

1. Baroid internal bioassay testing

   Mysid shrimp *Mysidopsis bahia*

   96 hour LC_{50} (Suspended Particulate Phase - SPP) >1,000,000 ppm

2. Testing carried out at the Centre for Petroleum Engineering, University of NSW

   Amphipod crustacean *Allorchestes compressa*

   96 hour LC_{50} (SPP) 691,500 ppm
   96 hour LC_{50} (Liquid Phase - LP) 1,278,300 ppm

   Sand snail *Polinices conicus*

96 hour LC_{50} (SPP)	579,500 ppm
96 hour LC_{50} (LP)	706,900 ppm
30 mins EC_{50} (SPP)	988,600 ppm
30 mins EC_{50} (LP)	919,600 ppm
24 hour EC_{50} (SPP)	240,900 ppm
24 hour EC_{50} (LP)	320,600 ppm

   MICROTOX (Bacteria - *Photobacterium phosphoreum*)

15 min LC_{50} (SPP)	233,700 ppm
15 min LC_{50} (LP)	255,900 ppm

3. In order to obtain additional ecotoxicity data for the PETROFREE mud system on tropical species common to marine environments of the North West Shelf, Baroid Australia has recently submitted samples of PETROFREE mud to the Curtin Ecotoxicology Program for acute toxicity tests. This bioassay testing is comprised of :

   - 96 hr LC_{50} test on Tiger prawn - *Panaeus monodon*
   - 96 hr EC_{50} test on planktonic alga - *Isochyrsis* sp.
   - 96 hr EC_{50} test on symbiotic coral alga - *Symbiodinium kawagutii*

These tests are being carried out on water accommodated fractions (WAF's) of the mud prepared according to a European protocol designed for poorly water-soluble mixtures such as invert emulsion drilling fluids. This preparation method involves mixing samples of mud with seawater for 20 hours, followed by a 4 hour phase separation. The aqueous phase is decanted off and designated as the WAF. This technique for preparing WAF's of drilling muds is considerably more stringent than the standard method used for the U.S. EPA bioassay tests - in this case a suspended particulate phase (SSP) of the drilling mud is prepared by mixing mud with seawater for 5 minutes, followed by a 1 hour phase separation.

It is apparent that the former protocol involving much longer periods of mixing and phase separation is more likely to result in a higher proportion of the water-soluble components in the mud actually being included in the test solutions.

FORMULATION - 11.2 ppg; 80/20 ester : water ratio

PRODUCT	bbl conc		Metric conc	
PETROFREE ester	0.656	bbls	0.104	m^3
EZ MUL NTE	8.0	ppb	22.82	kg/m^3
DURATONE HT	8.0	ppb	22.82	kg/m^3
GELTONE II	6.0	ppb	11.41	kg/m^3
Lime	1.0	ppb	2.85	kg/m^3
Water	0.153	bbl	0.02	m^3
$CaCl_2$	25.8	ppb	73.61	kg/m^3
OMC 2	1.0	ppb	2.85	kg/m^3
OMC 42	2.0	ppb	5.71	kg/m^3
RM-63	0.5	ppb	1.43	kg/m^3
Barite	173.2	ppb	494.14	kg/m^3

RESULTS

Tiger prawn *Panaeus monodon* (juveniles)

96 hour LC_{50} (Water Accommodated Fraction) > 256,000 mg/l

Planktonic alga *Isochyrsis* sp.

96 hour IC_{50} (Water Accommodated Fraction) 177,000 mg/l

Symbiotic coral alga *Symbiodinium kawagutii*

96 hour EC_{50} - Testing in progress

Baroid Australia's participation in the Curtin Ecotoxicology Program, as one of the supporting sponsors, is a positive indication of the company's commitment to improving our environmental performance and also of our support of moves to minimise the environmental impacts from offshore oil and gas exploration and production here in Western Australia.

CURTIN ECOTOXICOLOGY PROGRAM

BIOASSAY SUMMARY

Toxicant: Petrofree Drilling Fluid

Species Tested: *Penaeus monodon* (15 Day Post Larval)

Test Temperature: 27 °C

Test Dates: 14 - 18 February 1995

Results of 96 Hr *P. monodon* Acute Test

Petrofree Concentration (mg/L)	% Mortality
0	0
8,000	5
16,000	5
32,000	0
64,000	0
128,000	15
256,000	20

The LC_{50} of Petrofree drilling fluid for juvenile *P. monodon* is greater than 256,000 mg/L.

CURTIN ECOTOXICOLOGY PROGRAM

BIOASSAY SUMMARY

Toxicant: Petrofree Drilling Fluid

Species Tested: *Isochrysis* sp.

Test Temperature: 27 °C

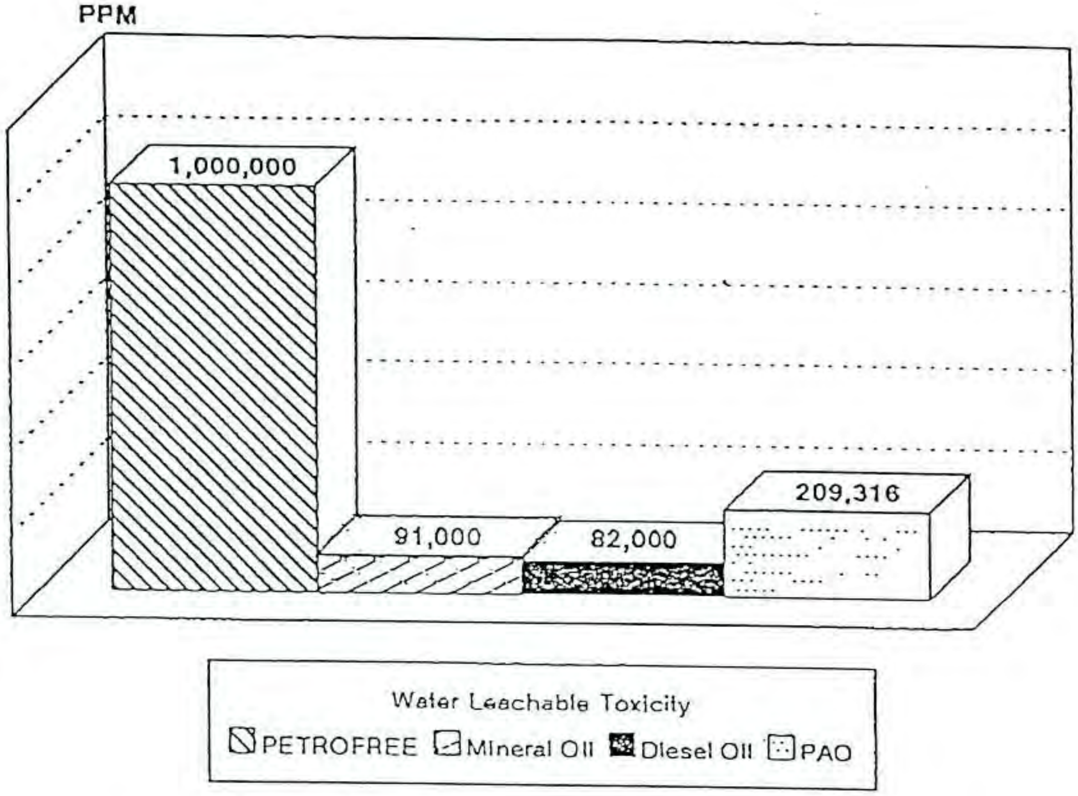
Test Dates: 25 - 29 January 1995

Results of 96 Hr *Isochrysis* sp. Growth Test

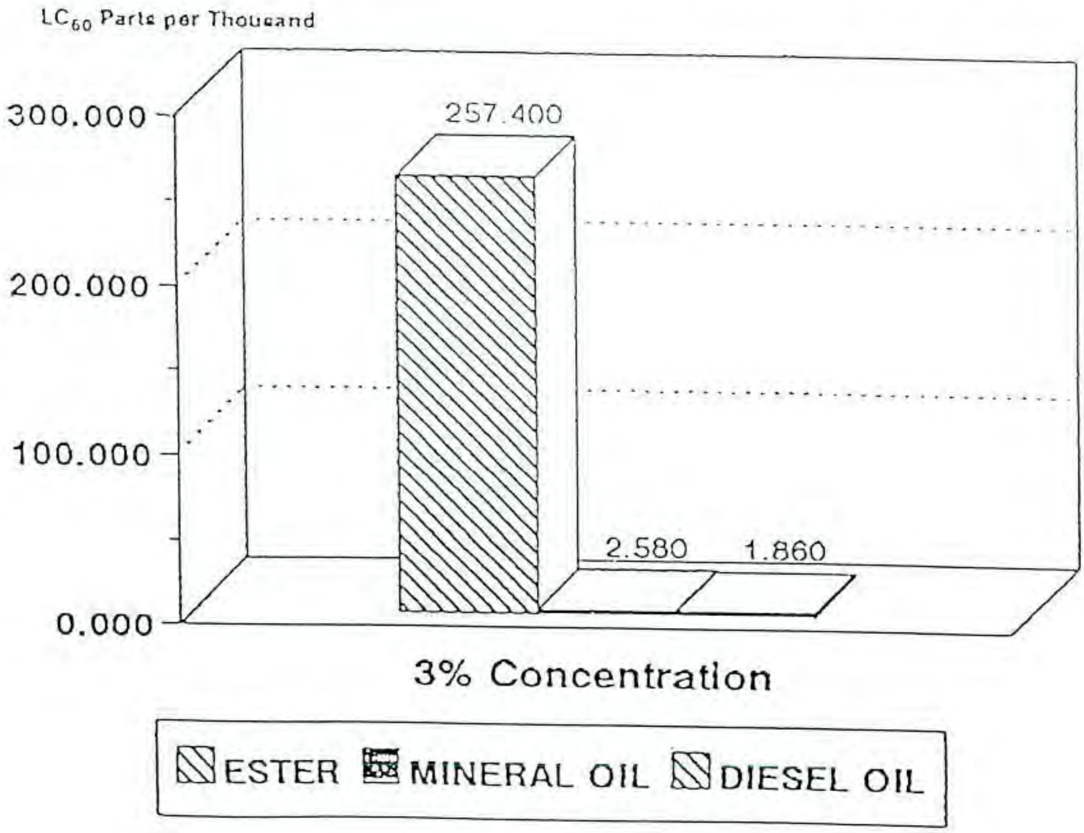
Petrofree Concentration (mg/L)	% Inhibition of Algal Growth Rate
0	----
28,700	19.8
47,900	20.4
84,000	24.0
132,000	45.2
218,000	95.3

IC_{50} (95 % confidence intervals): 177,000 mg/L (128,000 - 259,000 mg/L)

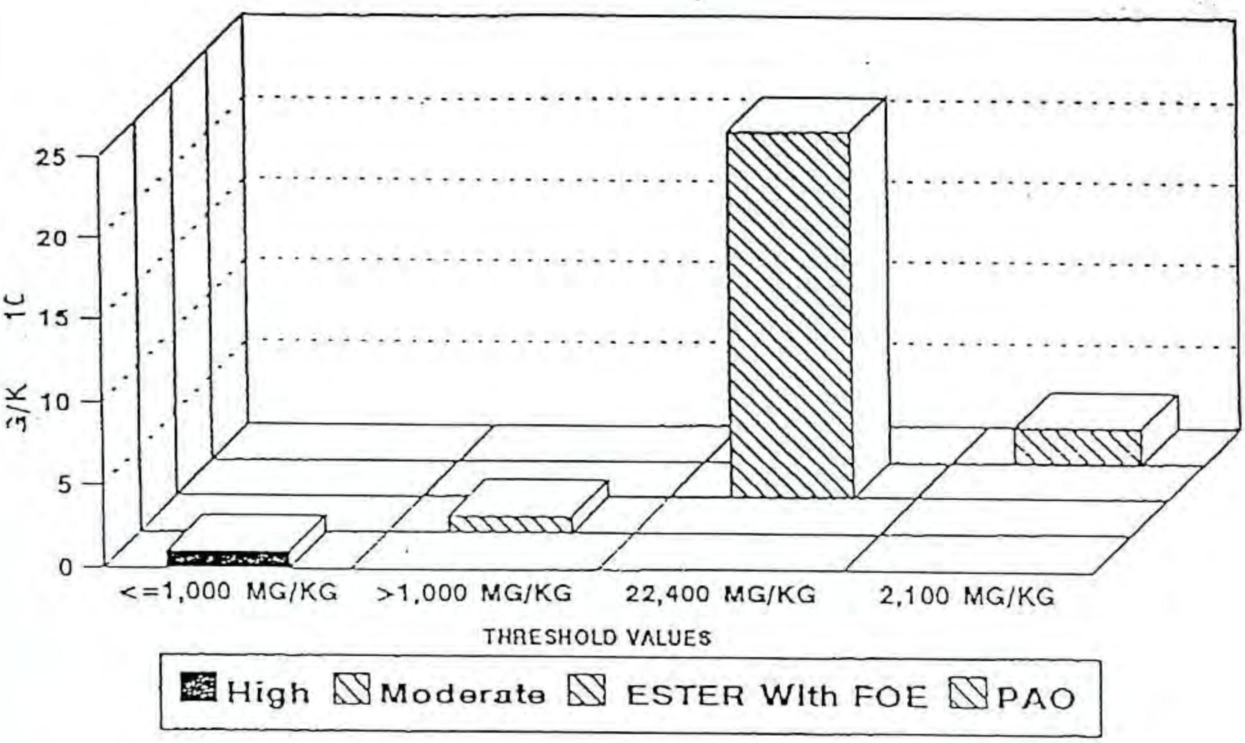
Drilling Fluid Toxicity Comparison
LC50 SPP



Base Fluid Toxicity Comparison
LC 50 TESTS IN A GEN#7 MUD SYSTEM



TOXICITY TO *SKELETONEMA COSTATUM*
EC_{50} VALUES



PETROFREE TOXICITY

TEST	PETROFREE ESTER
Acute Oral Toxicity Wistar Rats 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 # 406	Negative
Mutagenicity - Ames bacterial OECD # 471	Not Mutagenic
Dermal Study Dermatological 129-37-46 (1964)	Not Irritant
Dermatological Test	
-Burckhardt Test	-no reaction
-Closed epicutanious	-very good skin compatibility
Pre-Manufacture Notification	Not Mutagenic

NVIROTEST

P.O. Box 32464
Lafayette, La. 70593-8464
(318) 984-1626

STATIC SHEEN TEST REPORT

TEST NUMBER: 111-E91

COMPANY: KERR-MCGEE

PRODUCT: BAROID PETROFREE

DATE TESTED: 6-29-91

DATE OF SAMPLE: 6-21-91

TIME OF SAMPLE: 1500

****

TEST VESSEL: Open 5 gallon bucket

RECEIVING WATER: Lab-prepared Seawater

AMOUNT OF MUD USED: 120 mls

TYPE OF LIGHT: Fluorescent

RESULTS: After stirring vigorously in an unsuccessful attempt to achieve a homogeneous mixture, the mud was allowed to settle for 20 minutes. At that time observation was made and no sheen was present.

Appendix 5

Quantitative Risk Assessment of Spills

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A5.2 Total Spill Frequency of Wonnich #2 & #3

A5.3 Individual Spill Size vs Frequency Distribution Curves (drilling mud handling, diesel transfer, use and storage)

A5.4 Individual Spill Size vs Frequency Distribution Curves (well drilling, blowouts and other known spill frequencies)

1. INTRODUCTION

Risk assessment emerged as a formal discipline in the 1940s and 1950s as a means of ascertaining the dangers associated with the newly emerging nuclear industry. Traditionally, risk assessment was used for safety hazard and health analysis, but recently has been applied for ecological resources.

Risk assessment is defined as the process of determining the frequency of occurrence of an event and the probable magnitude of adverse effects - economic, human safety or health, ecological - over a specified period of time (Kolluru, 1994).

The process of identifying the risks and liklihood of given events, and the magnitude of their occurrence consists of four interrelated steps (Figure A5.1):

- Risk identification: recognizing that hazards exist and defining their characteristics.
- Risk determination: determining the characteristics of risks, either qualitatively or quantitatively. These may include frequency, magnitude, spatial scale, duration and intensity of adverse consequences.
- Risk evaluation: making judgments about the significance and acceptability of risk probabilities and consequences. Comparing the risks against benefits.
- Risk control: setting up a management system with standards, procedures, guidelines, etc. to decrease or eliminate risk.

There are two main methods to determine the level of risk:

- Quantitative: using experience, judgment, intuition; and
- Quantitive: using modelling, probability and statistical analysis

In safety risk assessment, the endpoint is usually defined as fatalities, injuries and economic loss: the impact is immediate and the cause-effect relationship is usually clear. Health risk analysis is less certain due to multifactorial causes, long latency periods and tenuous cause-effect relationships (Rowe 1979). Ecological risks are by far the most complex and the most uncertain. Unlike safety or health assessment, which deal with a single species, environmental assessment can involve various levels of biological organisation (i.e. populations, communities, etc.) which inherently are very variable. However, environmental consequence assessment is a component of the process of determining the risk from a potentially hazardous situation (Figure A5.1).

A spill risk assessment for appraisal well drilling operations using a jack-up drilling rig was carried out by DNV Technica (1996). The purpose of the assessment was to quantify the frequency and spill size distribution for reservoir based hydrocarbons, diesel and drilling fluid spills. Specifically:

- identify the sources of spills ; and
- calculate the spill size frequency.

The quantitative risk assessment data gives the frequency of various spill sizes originating at the drill site due to some event (i.e. a hose breaking, tank rupture), but does not take into account what the environmental consequences may be. This aspect must be defined in the environmental risk assessment.

Environmental risk assessment is still a developing technique. Modeling of the probability of oil hitting a particular resource at a stage when the oil is still toxic and can do the most damage is very complex given all the variables involved (e.g. type of habitat, weather conditions, tides, currents, air temperature, resource sensitivity) and is still in the developmental stage. Oil spill trajectory models take several of these variables into account and are able to give an estimate of the chances of oil hitting a resource and the time it will take to impact. The consequences of oil impacting particular resources is based on field research and laboratory experiments. What is of utmost importance, is not to assign a number to describe the impact of an oil spill, but to insure that management plans are in place to prevent a spill from happening in the first instance.

If applied properly, the total concept of risk assessment will enable risk acceptors (decision makers, public) to identify the various types of technological risks and to recognize the merits and disadvantages of management measures used to reduce the risk.

2. METHODOLOGY

The following methodology was used to determine the frequency and spill size distribution curves for the Wonnich-East and Wonnich-Flank appraisal wells.

Step 1: Identify the sources of spills of oil, diesel and drilling fluid resulting from drilling.

Step 2: Refer to a world wide analysis of oil spill data from 1975 to 1990 via the Oil Spills Risk Database (OSRD) to obtain generic coefficients based on the spill sources identified in step 1.

Step 3: Specify a range of spill sizes in barrels (bbls), based on the limits which the historical spill data covered.

Step 4: Combine the data in Steps 2 and 3 to create Spill Frequency Distribution Curves as presented in Figures A5.2 to A5.4.

3. OIL SPILL RISK DATABASE (OSRD)

DNV Industry was commissioned by the Dutch Ministry of Housing and the Environment (VROM) to develop a quantitative database to evaluate the risk of oil spillage from the North Sea offshore oil industry. The primary motivation for the study was to use the database as part of the Management Analysis of the North Sea (MANS) software system. MANS is a sophisticated risk assessment tool which has been developed and is currently being used by the Dutch authorities to review and optimise the Dutch North Sea sector oil spill contingency plan. A description of the development of the Oil Spills Risk Database is presented below.

Spill data for the UK Sector of the North Sea between 1975 and 1990 comprising over 750 platform years was obtained from operator spill reports to the now defunct UK Department of Energy.

Spill data from the US offshore industry was obtained from the United States Coast Guard for the years 1982-1990, making up over 14,500 oil and gas installation years. For the purposes of the VROM study, only spills of 0.7 bbls or greater were analysed, as the majority of spills reported in the United States were below 0.7 bbls, leaving a residual between the number of spills reported and the number of spills analysed.

Danish oil spill data between 1980-1990 were obtained from Miljostrelsen (Minister of the Environment). Miljostrelsen is the responsible authority for reporting oil pollution incidents in Denmark.

Dutch spill data between 1984-1990 was obtained from Staatstoezicht op de Mijen (Ministry of Economic Affairs, State Supervision of Mines).

Norwegian spill data between 1980-1990 was obtained from Statens Forurensingstilsyn (the State Pollution Agency) which is responsible for the control of oil spills on the Norwegian Continental Shelf.

Since the UK and US oil spill data were the statistically most significant, they were used to develop the oil spill risk model that is the basis of OSRD. The Dutch, Danish and Norwegian data were then used to validate the model and to investigate its sensitivity.

Analysis of the spill data from the OSRD database has identified that most spills are associated with oil processing on platforms. Well drilling, production and workover spills are associated with the well manifold and well head and are considered separately from processing spills.

4. INTERNATIONAL DATA vs AUSTRALIAN DATA

Caution must be used when extrapolating overseas data to Australia. Operational procedures, weather conditions, equipment and regulatory systems are different between countries and will result in different frequencies of spills. Australia has a very strict safety regime which must be adhered to by industry and this is reflected in the low number of spills which have occurred in Australian waters.

There is also a difference in the number of wells drilled overseas versus the number drilled in Australia which would affect the frequency rates. For example, the US oil industry drills over 2,000 wells per year. In Australia, about 1,100 offshore wells have been drilled between 1964 to 1994, an average of 37 wells per year.

There is a lack of data to quantitatively assess the risk of oil spills from the Australian oil and gas industry. This is not due to lack of reporting, but simply that spills occur infrequently and are relatively small. In nearly 30 years of operations, nearly 3,100,000 barrels of oil have been produced and the estimated volume of oil spilled into the marine environment was 900 bbls.

Worldwide, about 80 billion barrels of oil have been produced; offshore drilling and production contributes 2% of the 3.2 million tonnes of oil entering the sea worldwide in an average year, which includes both spills and the release of produced water. Municipal and industrial inputs make the largest contribution of oil to the marine environment (30%), followed by tanker operations (22%), other transport (13%), tanker accidents (13%), atmospheric fallout (9%), natural sources (8%) and refinery wastes (3%) (Volkman et al. 1994). In Australia, the oil and gas industry contributes less than one half of a percent (0.5%) of the volume of oil spilled to the Australian environment.

From the Commonwealth records, five spills totalling 10 bbls (1,600 L) of oil and up to 77 bbls (12,400 L) of drilling fluid have occurred as a result of exploration drilling activities (Volkman et al. 1994). In Western Australia, four spills have occurred totalling up to 20 bbls (3,200 L).

The majority of these spills were caused by human error rather than mechanical or equipment failure, and management procedures were modified to reduce the chances of re-occurrence.

5. ACCEPTABLE LEVEL OF RISK

The determination of acceptable levels of risk associated with an activity is a process which involves the balancing of costs, risks and benefits. Hence, environmental risk assessment involves balancing or trading social benefits and environmental risk. The difficulty with the cost-benefit approach is that the two sides of the equation cannot necessarily be compared quantitatively.

The benefits of the oil and gas industry to the Australian society include: royalties and income taxes; import replacement; employment; products from oil; cheap fuel for transport and energy; scientific research and knowledge; and infrastructure.

The risks of the industry are the consequences of an oil spill on the conservation, recreational and scientific value of the Montebello Islands and adjacent waters.

One mitigating factor that applies to this drilling program is that the predominant winds are from the north-east and east during the proposed time for drilling. These winds would take any spilled oil away from the fringing reef and islands. However, the results of the trajectory modelling (Apendix 6), and evaporation and spreading studies indicate that given the right tide and wind conditions, small spills (100 L) may reach the west fringing reef in about two hours. Larger spills (>1,000 L) may reach Hermite Island in about 8-9 hours. However, the oil found in the Wonnich reservoir is a light oil which evaporates quickly so only a portion of the oil will remain on the water (which may reach the shore) and the toxic components will have dissipated. The west side of the Montebello Islands is a high energy area which will help disperse the oil, minimizing the chances of reaching the shoreline. Drilling for the

Wonnich program will be carried out during a time when winds have shifted and there is an increased chance that the winds will not carry the oil towards the reef and islands. Thus, it is concluded that although there is a risk of small spills occurring, the risk is low due to management procedures put into place, and the consequences to the marine environement will be low. The areas of highest consequence in the event of a very large spill (>1,000 bbls) would be the southern section of the west fringing reef and the mangroves located in Turtle Lagoon.

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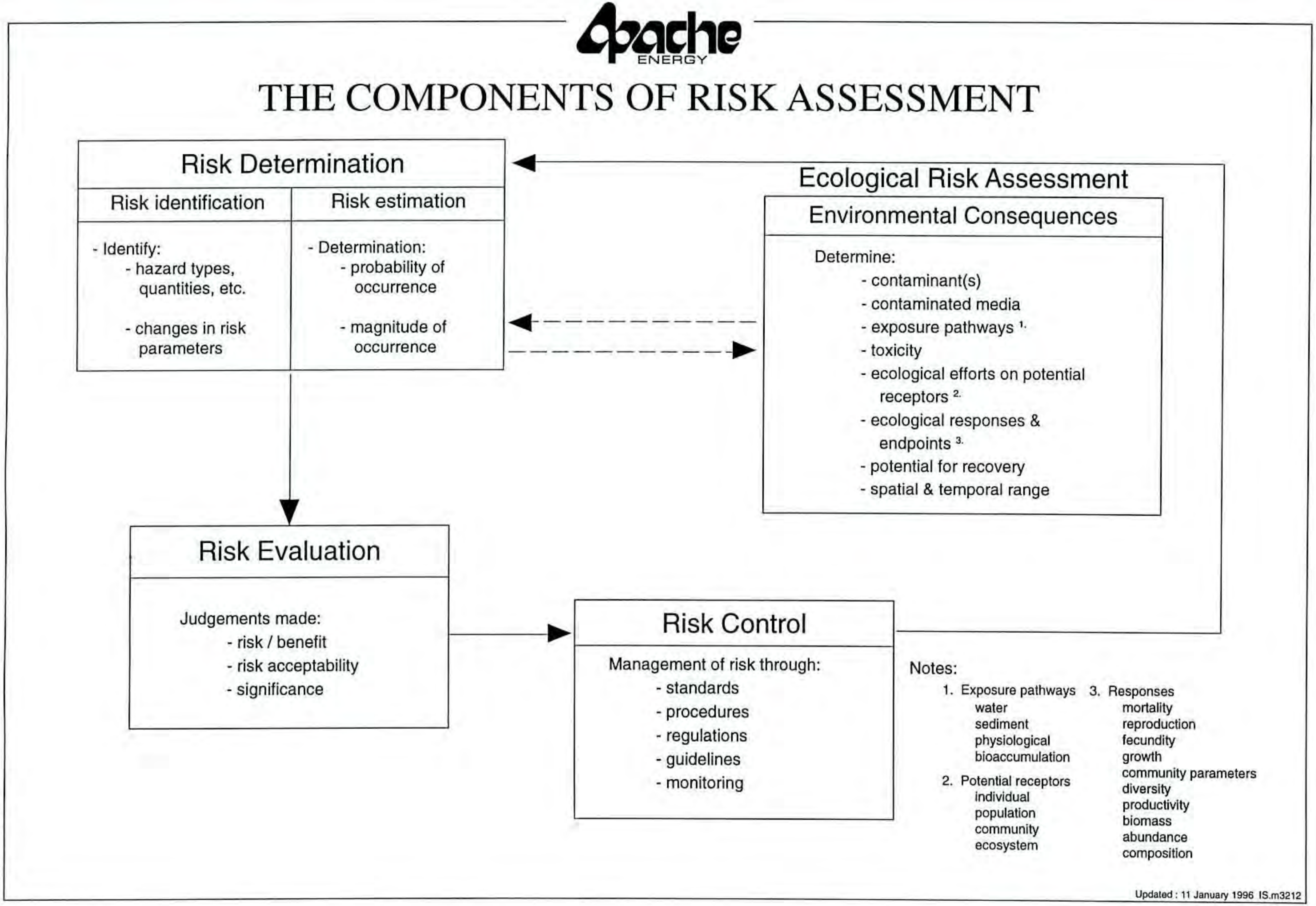
Appendix 5

Figures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ENERGY
THE COMPONENTS OF RISK ASSESSMENT
Risk Determination
Risk identification
Risk estimation
- Identify:
- hazard types, quantities, etc.
- changes in risk parameters
- Determination:
- probability of occurrence
- magnitude of occurrence
Ecological Risk Assessment
Environmental Consequences
Determine:
- contaminant(s)
- contaminated media
- exposure pathways 1.
- toxicity
- ecological efforts on potential receptors 2.
- ecological responses & endpoints 3.
- potential for recovery
- spatial & temporal range
Risk Evaluation
Judgements made:
- risk / benefit
- risk acceptability
- significance
Risk Control
Management of risk through:
- standards
- procedures
- regulations
- guidelines
- monitoring
Notes:
1. Exposure pathways
water
sediment
physiological
bioaccumulation
2. Potential receptors
individual
population
community
ecosystem
3. Responses
mortality
reproduction
fecundity
growth
community parameters
diversity
productivity
biomass
abundance
composition
Updated : 11 January 1996 IS.m3212

Figure A5.1

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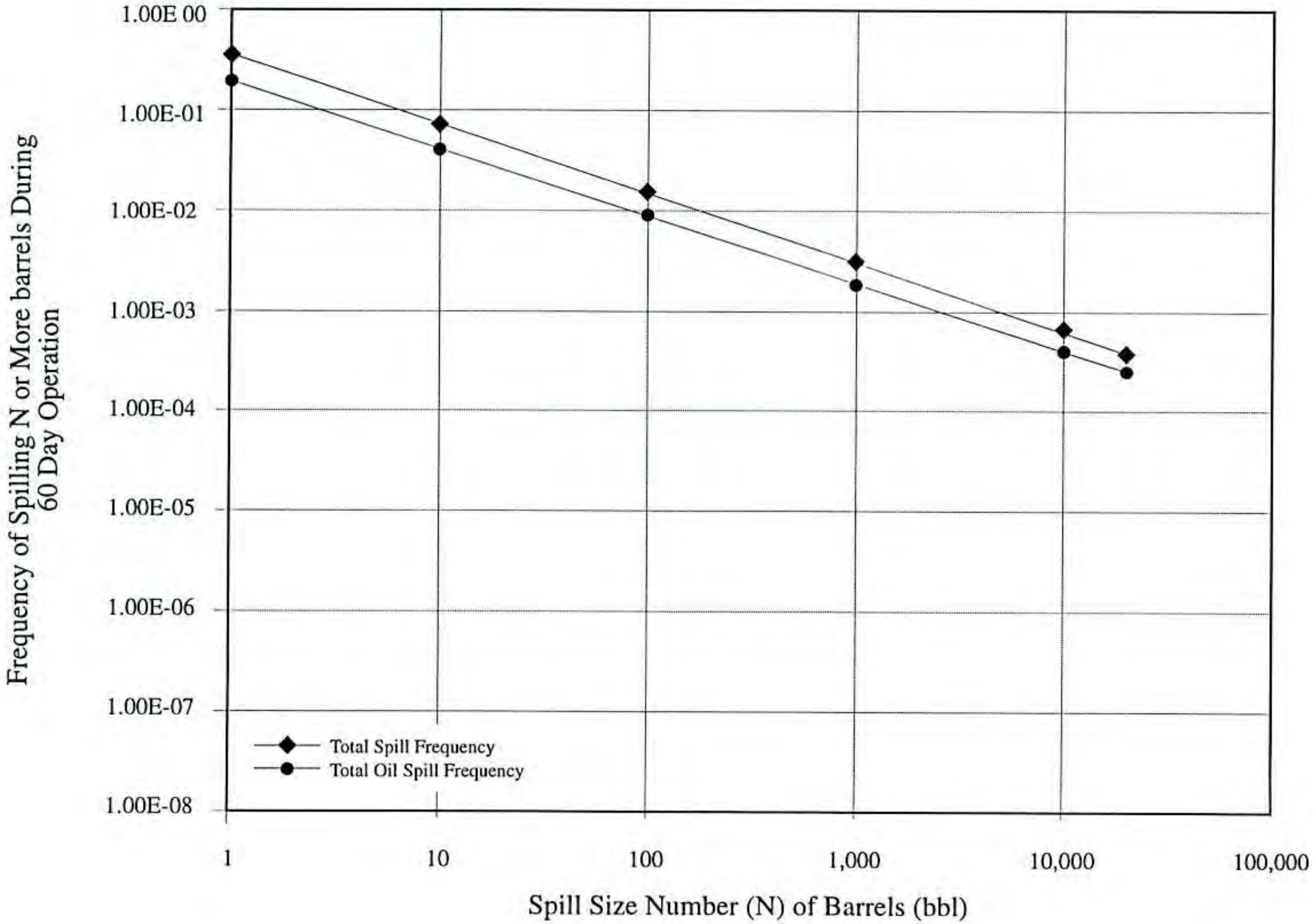
TOTAL SPILL FREQUENCY OF WONNICH #2 & #3



Updated : 11 January 1996 IS.m3208

Figure A5.2

ENERGY

TP/8

INDIVIDUAL SPILL SIZE vs FREQUENCY DISTRIBUTION CURVES

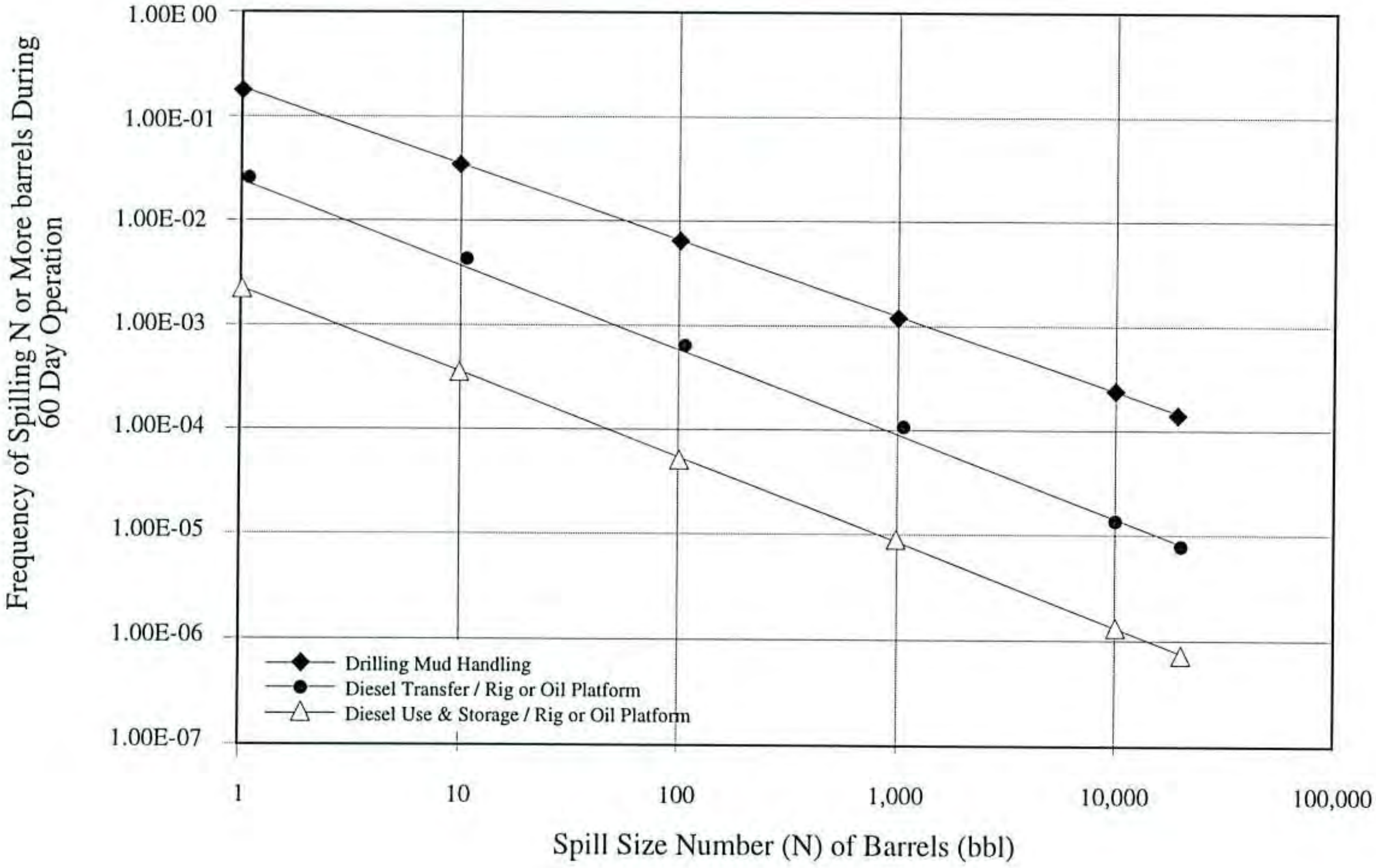


Figure A5.3

Updated : 11 January 1996 IS.m3209

Apache ENERGY

TP/8
INDIVIDUAL SPILL SIZE vs FREQUENCY DISTRIBUTION CURVES

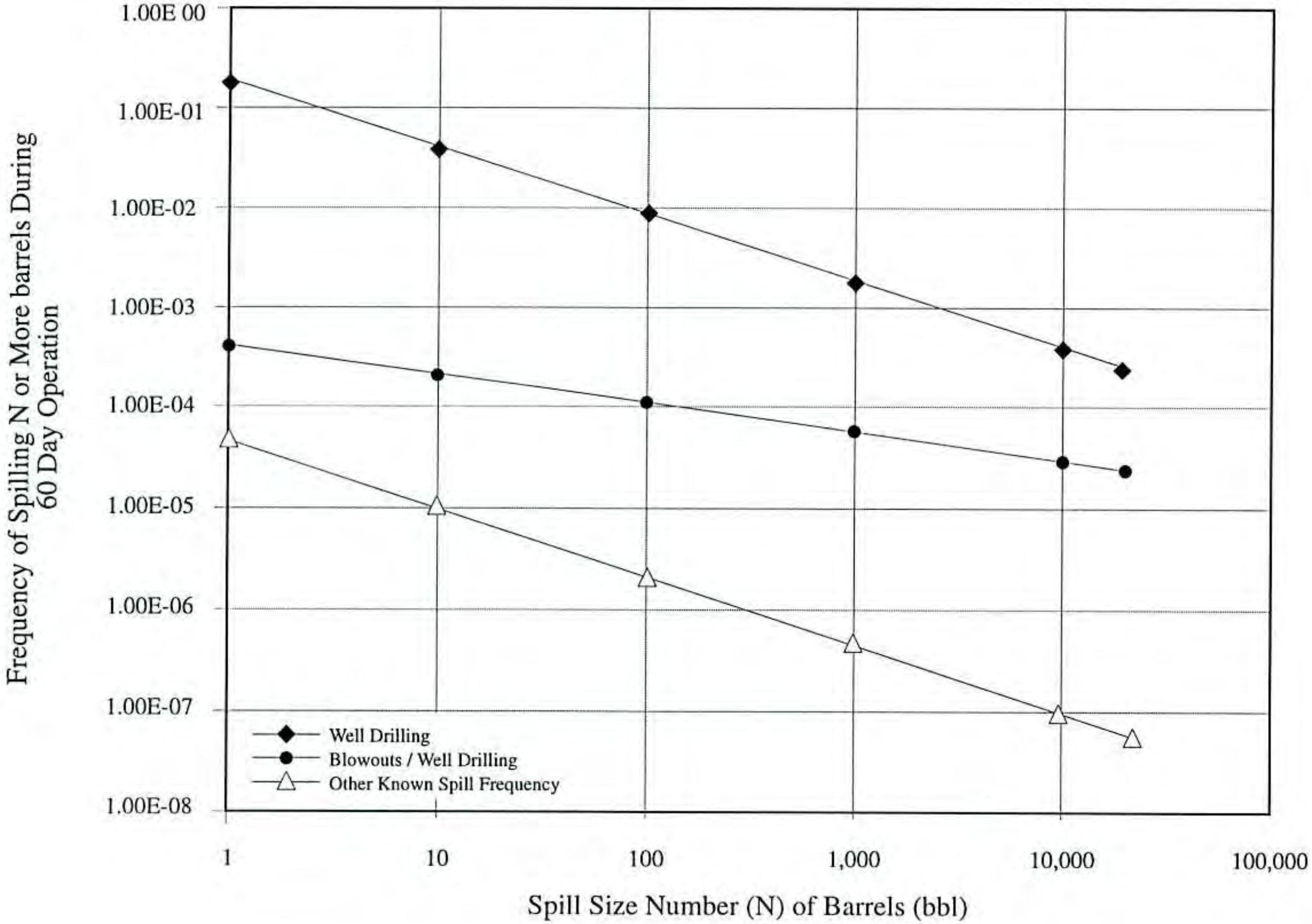


Figure A5.4

Appendix 6

Oil Spill Trajectories and Predicted Impact Times

Estimation of Spill Trajectories using OILTRAK/OILMAP

OILTRAK is a fully three-dimensional ocean model with a proven capability of predicting surface ocean currents around the continental shelf. OILTRAK focuses on predicting the particle trajectory path produced by the surface ocean currents during an oil spill.

OILMAP does not attempt to model the ocean physics, but relies on surface ocean currents as input to map the path of the oil spill and incorporates spreading and evaporation components, and environmental resource data. OILMAP includes an interactive graphical display system linked to a Geographical Information System which provides an inportant decision support system for oil spill response and contingency planning .

The oceanographic and climatic features of the Montebell Islands were described in Appendix 3.

A number of oil spill trajectories using OILMAP/OILTRAK were run based on wind speed and direction scenarios expected for May-June (Appendix 3, Figures A3.5-A3.7). The wind speeds chosen were ones which occurred >30% of the time while the directions were ones which occurred >20% of the time (Table A6.1). The projected time to impact was also determined (Table A6.2).

The trajectories given are after the spill has been on the water for 48 hours.

The currents and tidal systems around the Montebello Islands are very complex (Figure A6.1) and there is a lack of detailed information. The data used for the following trajectories are estimates and have not yet been validated in the field. Field validation and current readings are scheduled to be carried out prior to the start of drilling.

Table A6.1

Wind and tide scenarios used for oil spill trajectories. Origin of trajectories is the proposed Wonnich drilling location. Unless marked otherwise, a 5,000 L spill was used for the trajectories except scenario 15 which was based on a 10,000 L spill. Wind speeds selected based on occurrences >30% of the time for April, May and June data. Wind direction based on occurrence 20% of the time.

	Time	Wind speed (knots)	Wind direction (coming from)	Tide
1		none		flood
2		none		ebb
3	0900	10	east	flood
	1500		northeast	
4	0900	10	east	ebb
	1500		northeast	
5	0900	10	east	flood
	1500		southeast	
6	0900	10	east	ebb
	1500		southeast	
7	0900	10	southeast	flood
	1500		southwest	
8	0900	10	southwest	ebb
	1500		southwest	
9	0900	10	south	flood
	1500		northeast	
10	0900	10	south	ebb
	1500		northeast	
11	0900	10	south	flood
	1500		southwest	
12	0900	10	south	ebb
	1500		southwest	
13	0900	20	southwest	flood
	1500	10	south	
14	0900	20	southwest	ebb
	1500	10	south	
15	0900	20	south	flood
	1500	10	southwest	

Table A6.2

Estimated Time to Impact
from Wonnich Drilling Site to Selected Locations

	Wind and tide scenario (see Table A6.1)														
Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Islands															
Ah Chong	8												7		
Hermite - SW	29				28		19				8				8
Hermite NW											26				14
Hermite - Haynes Pt.											18				
Crocus	48										17		18		18
Alpha							43				42		16		16
Bluebell							42				43	38	17		17
Brook	42						30				17		20		17
Kingup and Gardenia													23		23
North West														>54	
Trimoulle											37		34		35
Barrow															
Varanus															
West Fringing Reefs															
north							54					50	22		
central north							25				14	13			
central south							16	25	29	24	9		9		9
south	2		2		2		2	11	2	10	2				
Other reefs															
west of Black Rocks			17												
Tryal Rocks														>50	
Lagoons															
Wild Wave Lagoon											9		8		8
Turtle Lagoon															18
Claret Bay											10		10		

WONTRAJ.XLS
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Table A6.3: Montebello Island resources at risk from an oil spill based on current knowledge.

	Rocky intertidal	Sand beach	Mud flats	Seagrass	Algae	Coral	Mangal	Pearl farm	Recre -ation	Social	Turtle	Marine mammals	Sea birds
Islands													
Ah Chong	x	x			x						x	x	x
Hermite	x	x	x	x	x		x	x	x				x
Crocus	x	x	x				x	x					
Alpha	x	x					x	x		x [1]			
Bluebell	x	x					x						
Primose	x	x			x	x							
Brook	x												
Kingup	x	x											
North West	x	x			x	x					x	x	x
Trimoulle	x	x			x	x				x [1]	x	x	x
Barrow	x	x	x	x	x	x	x			x [2]	x	x	x
Bridled	x	x	x	x	x	x	x			x [2]	x	x	x
Varanus	x	x		x	x	x	x				x	x	x
Fringing reef													
west					x	x					x	x	

1. Nuclear testing
2. Oil and gas facilities

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CURRENT REGIME AROUND THE MONTEBELLO ISLANDS

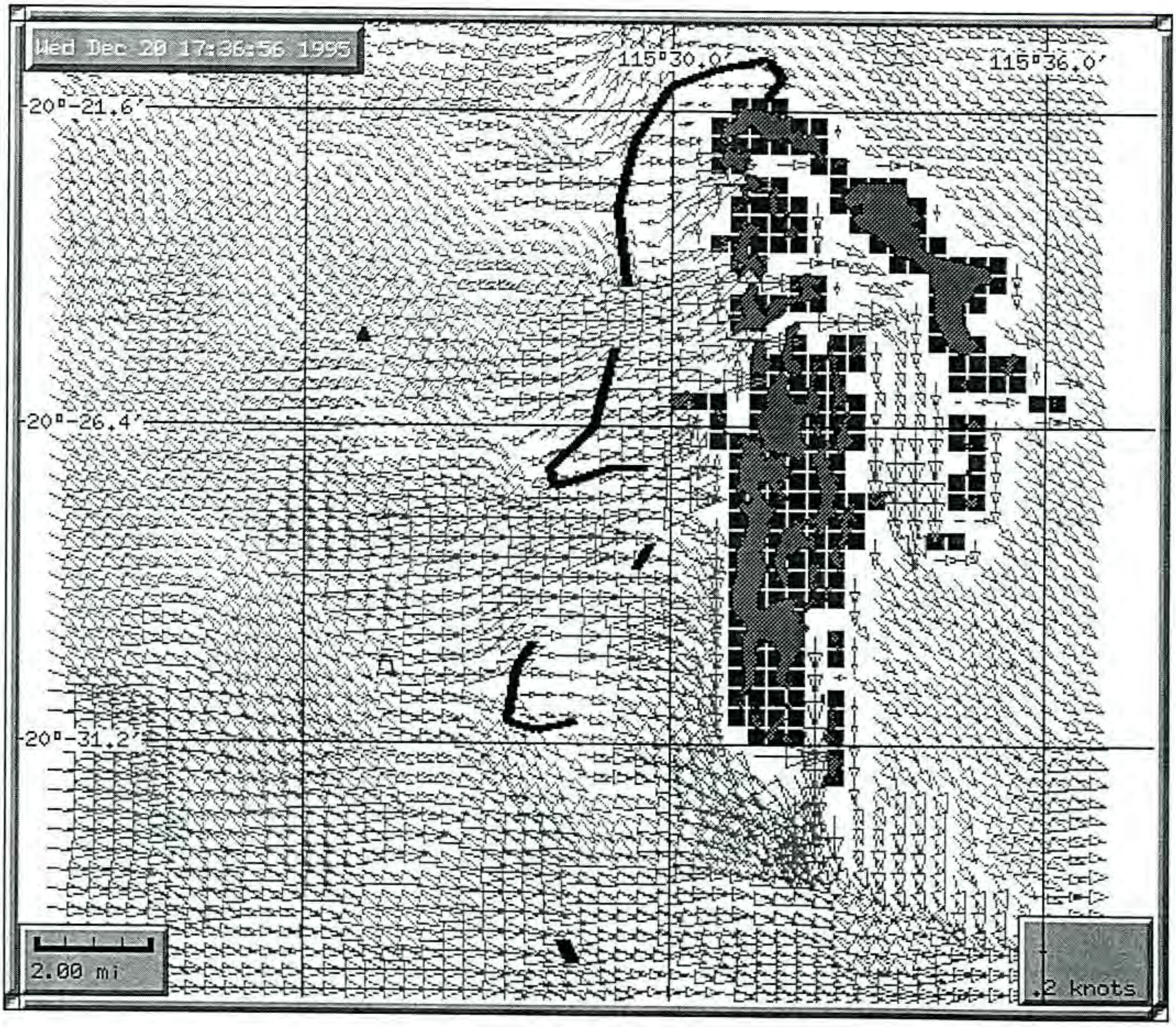
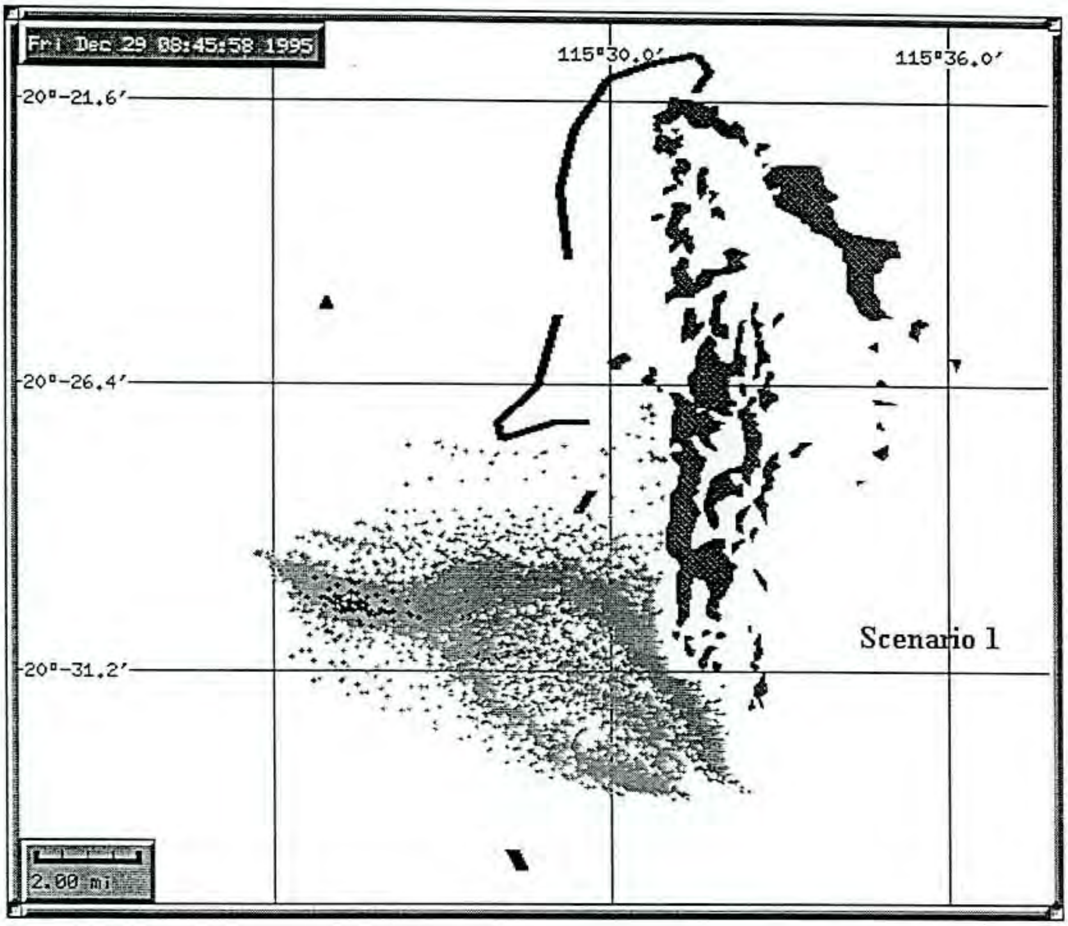


Figure A6.1



Fri Dec 29 08:45:58 1995
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115°36.0′
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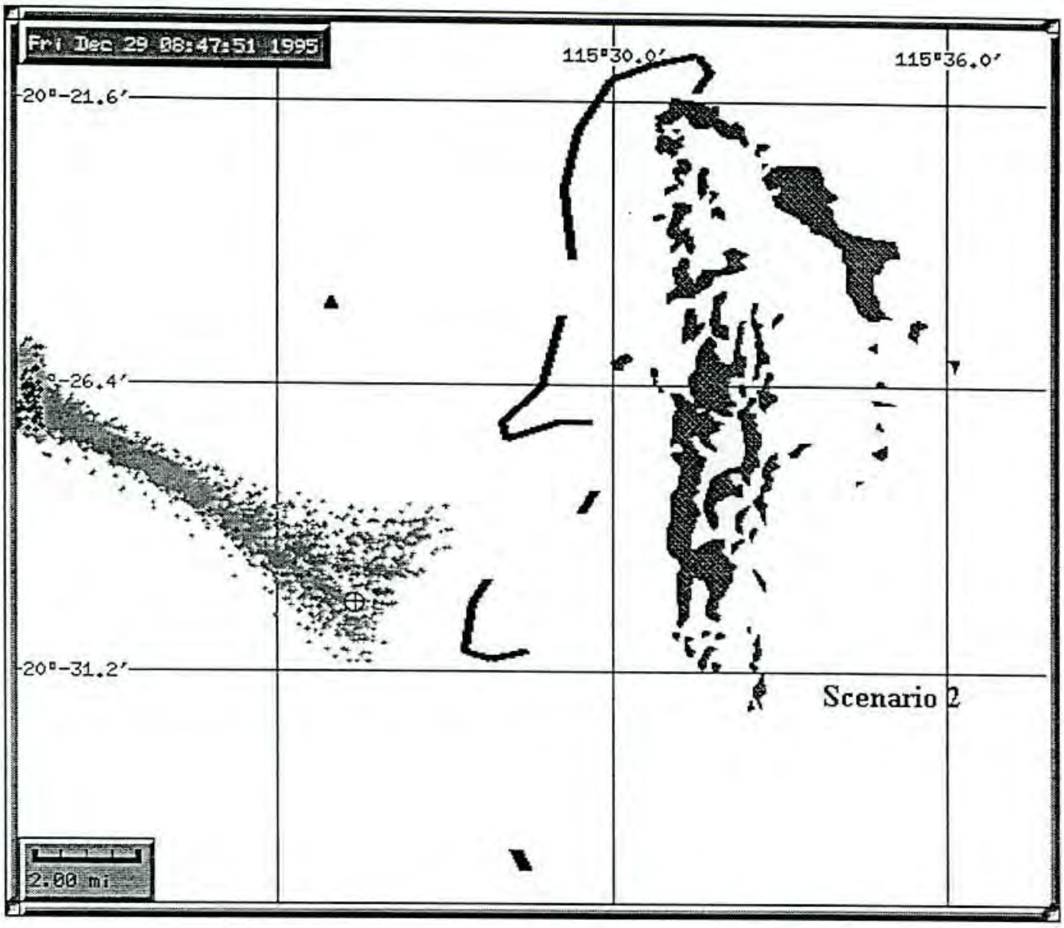
20°-26.4′
20°-31.2′
Scenario 1
2.00 mi



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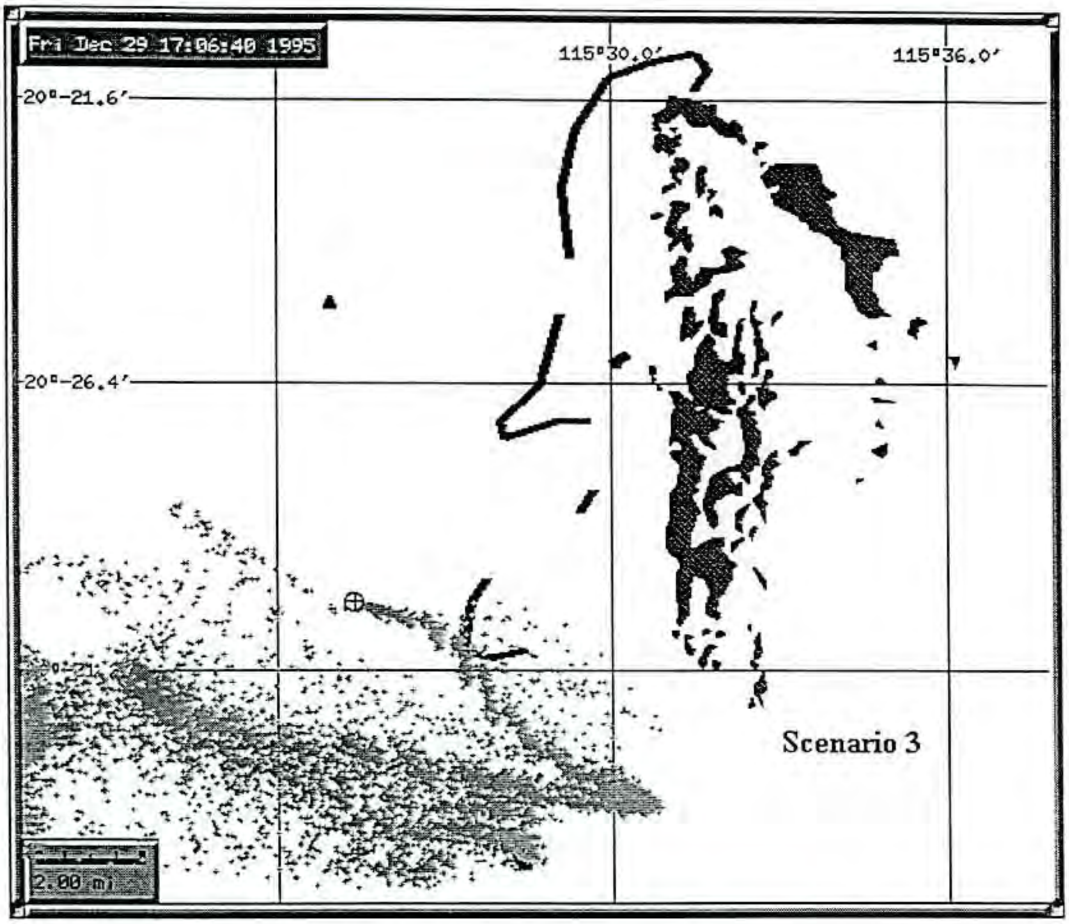
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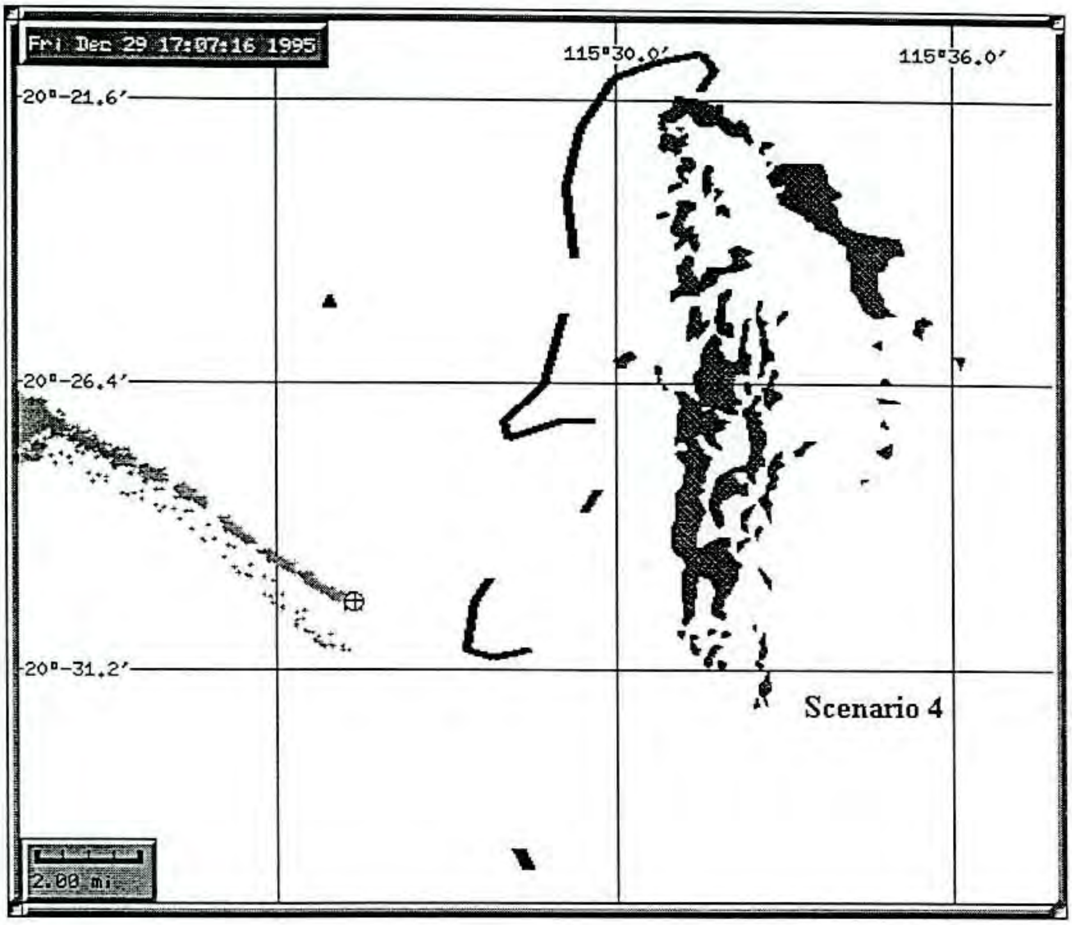
2.00 mi
Scenario 3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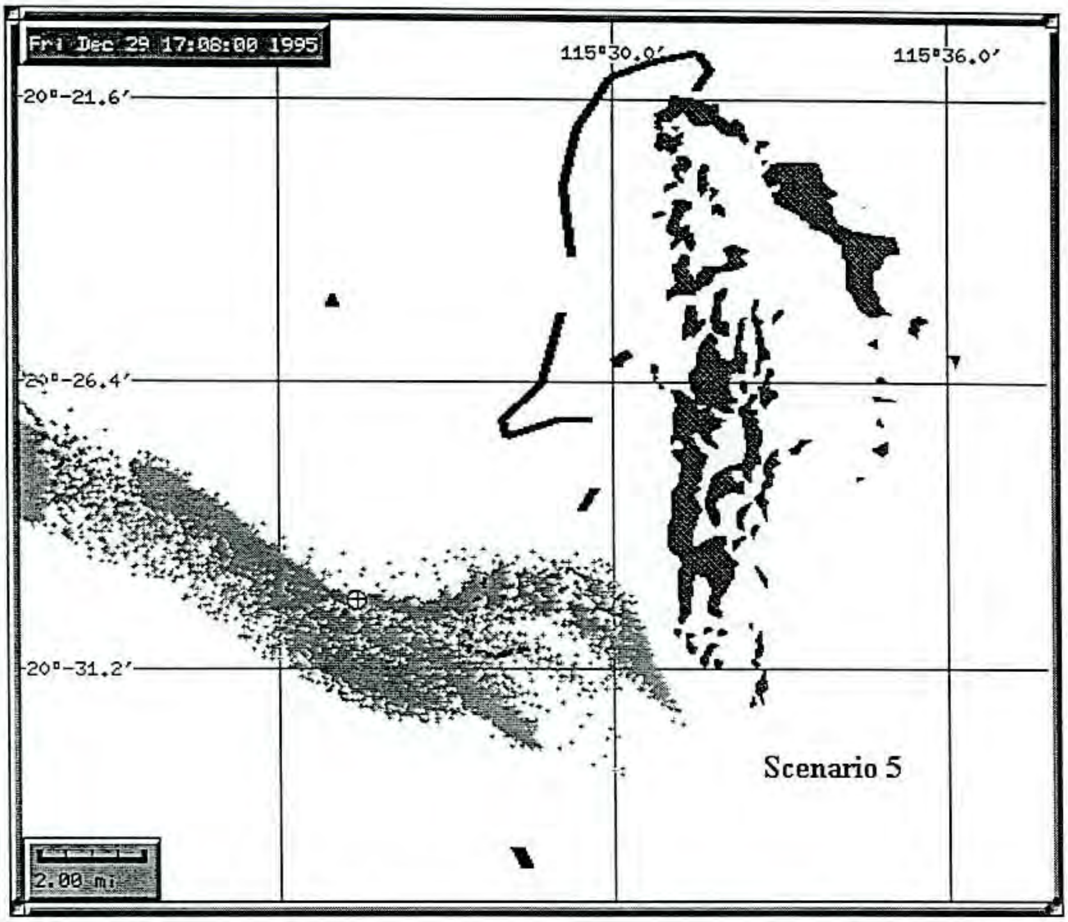
2.00 mi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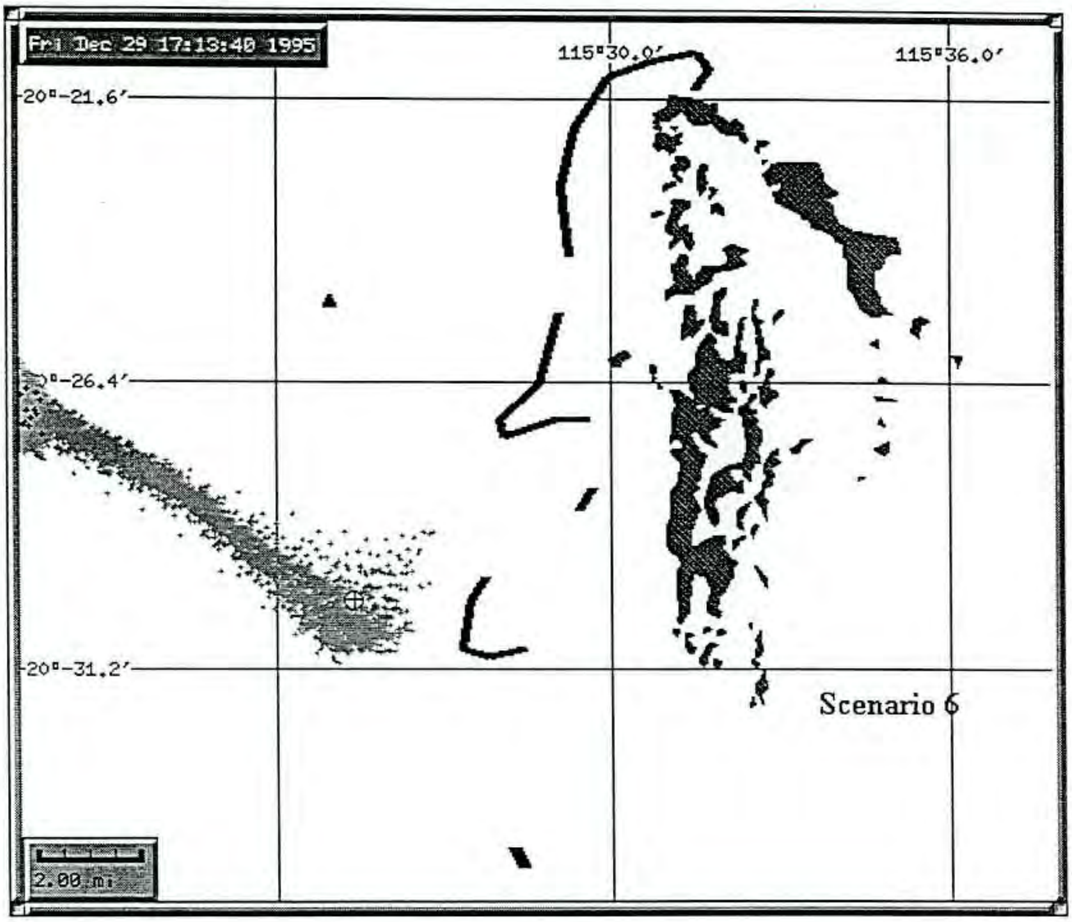
2.00 mi

Scenario 5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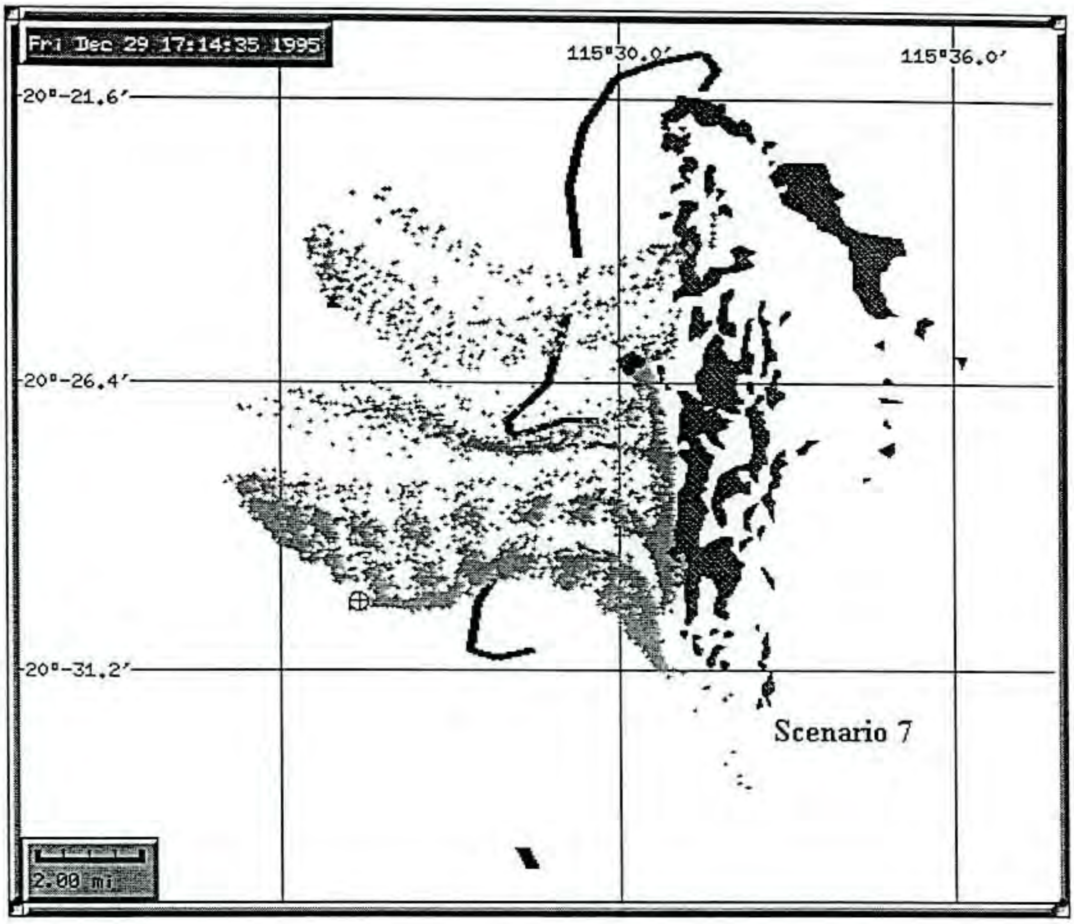
Scenario 6
2.00 m.



Fri Dec 29 17:14:35 1995
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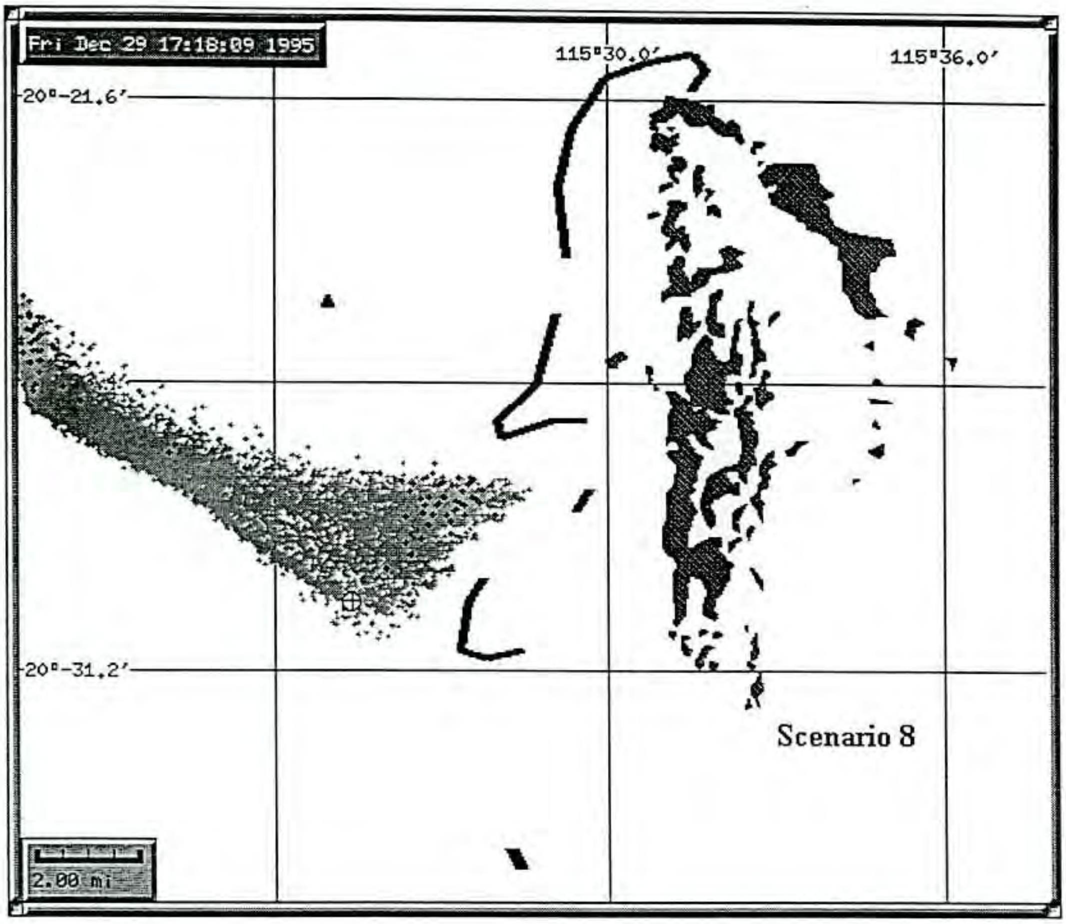
2.00 mi

Scenario 7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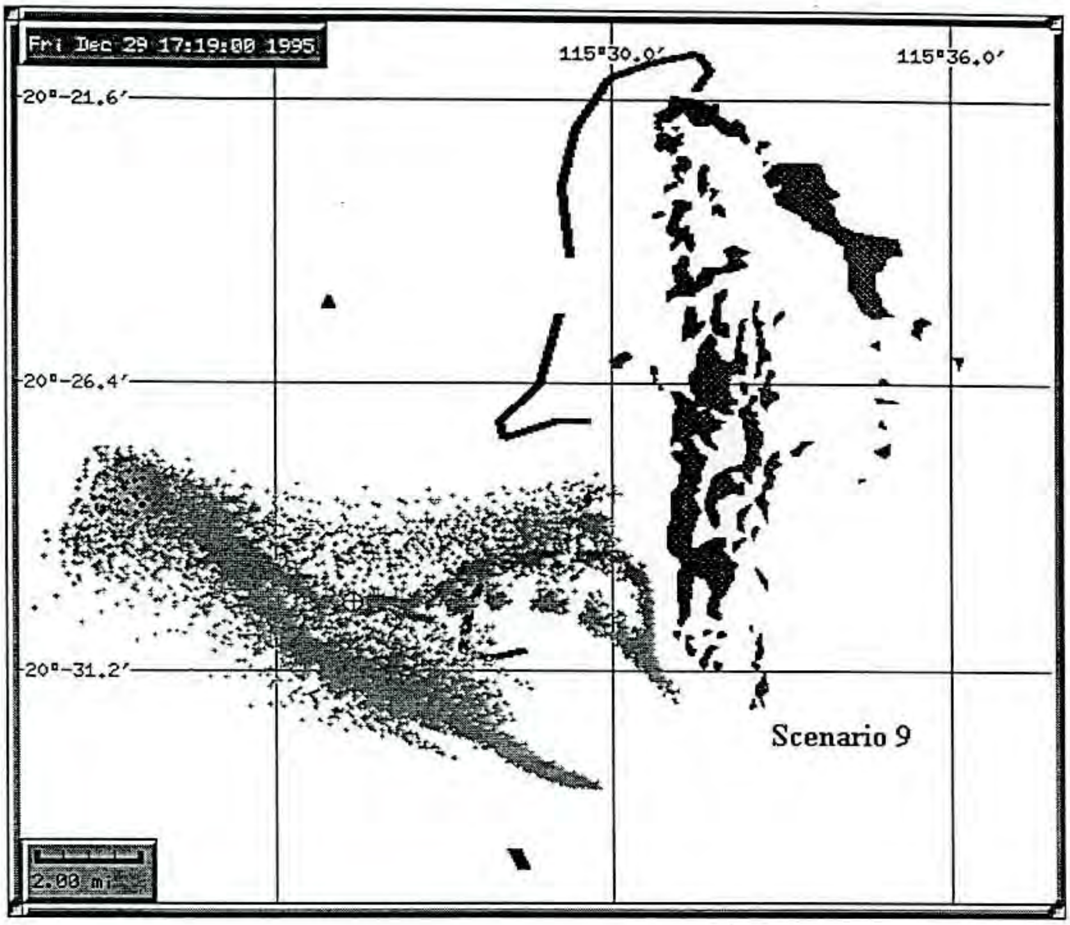
Scenario 8
2.00 mi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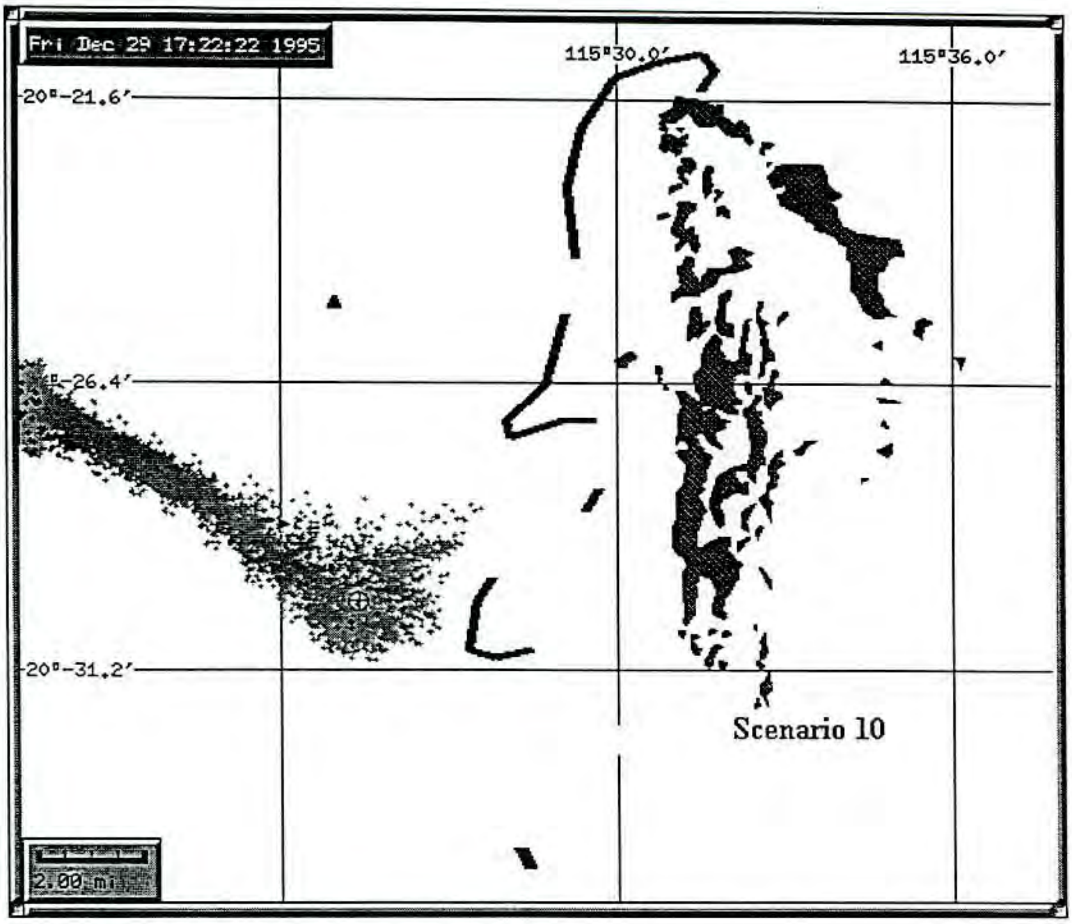
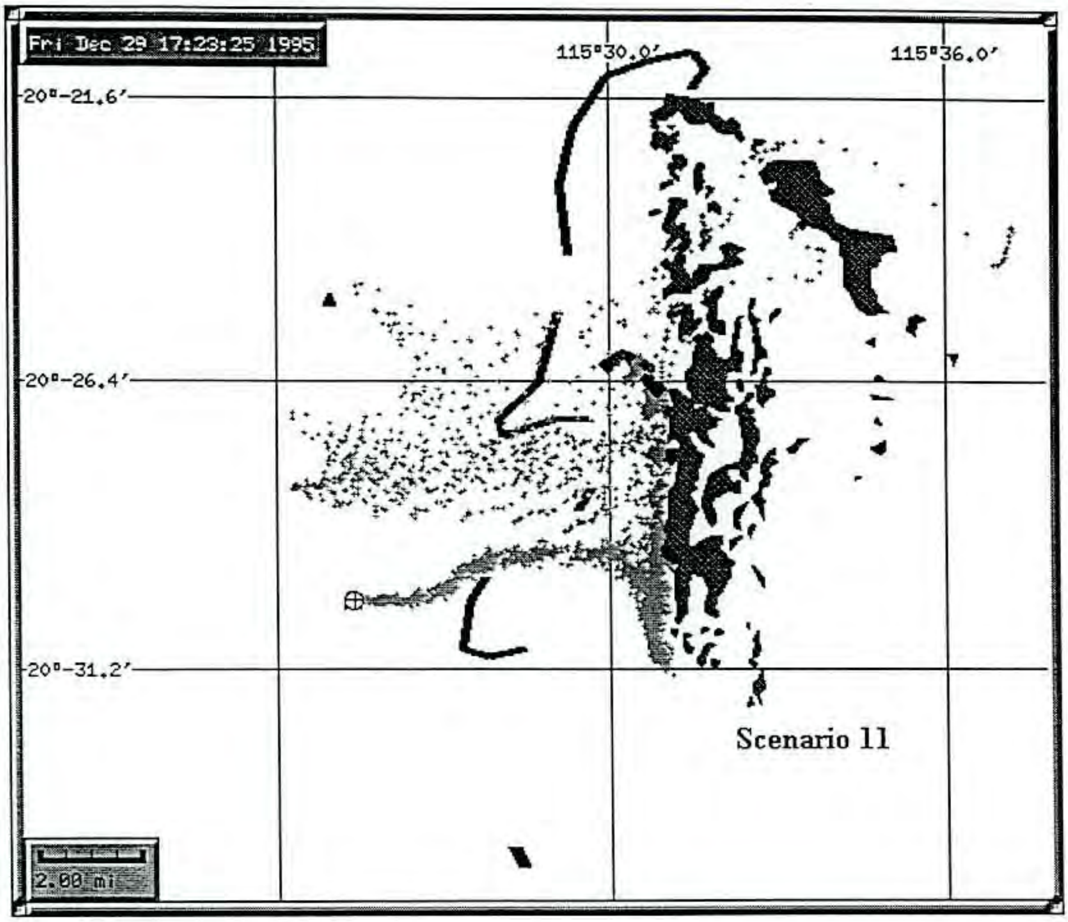
2.00 mi



Scenario 10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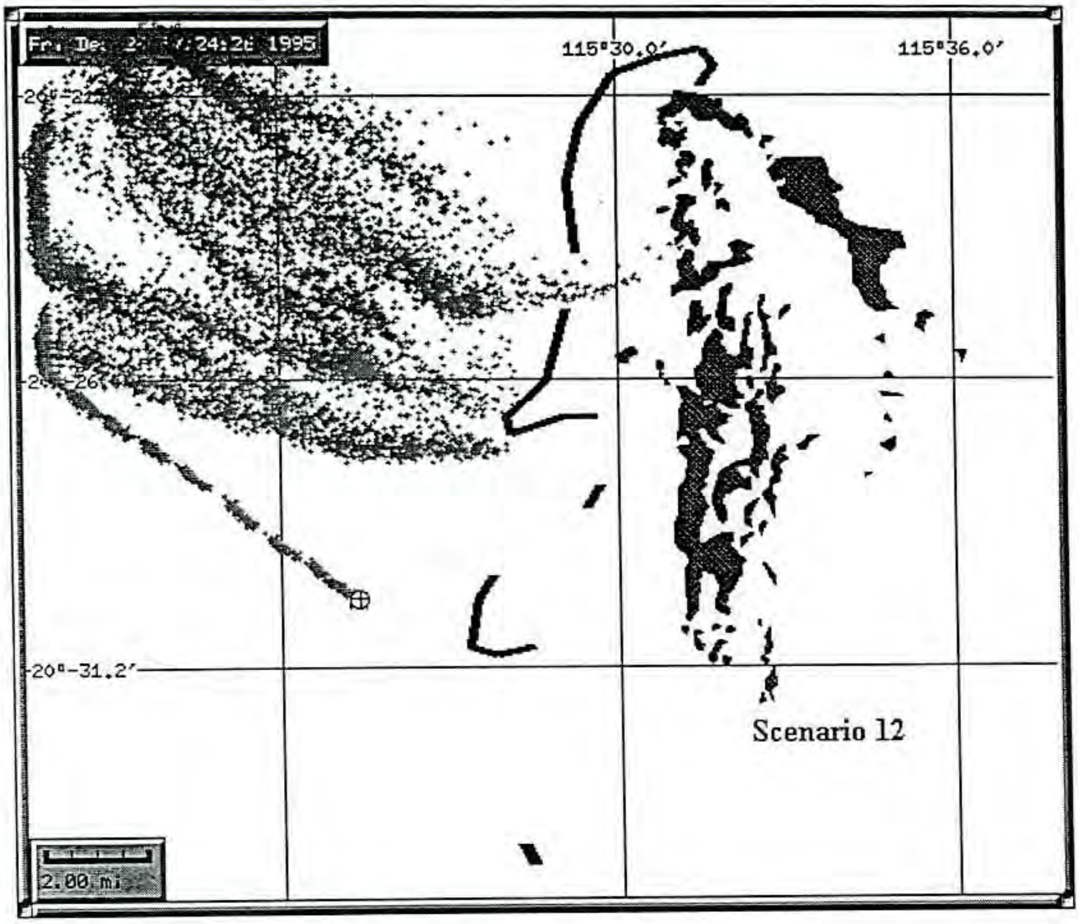
2.00 mi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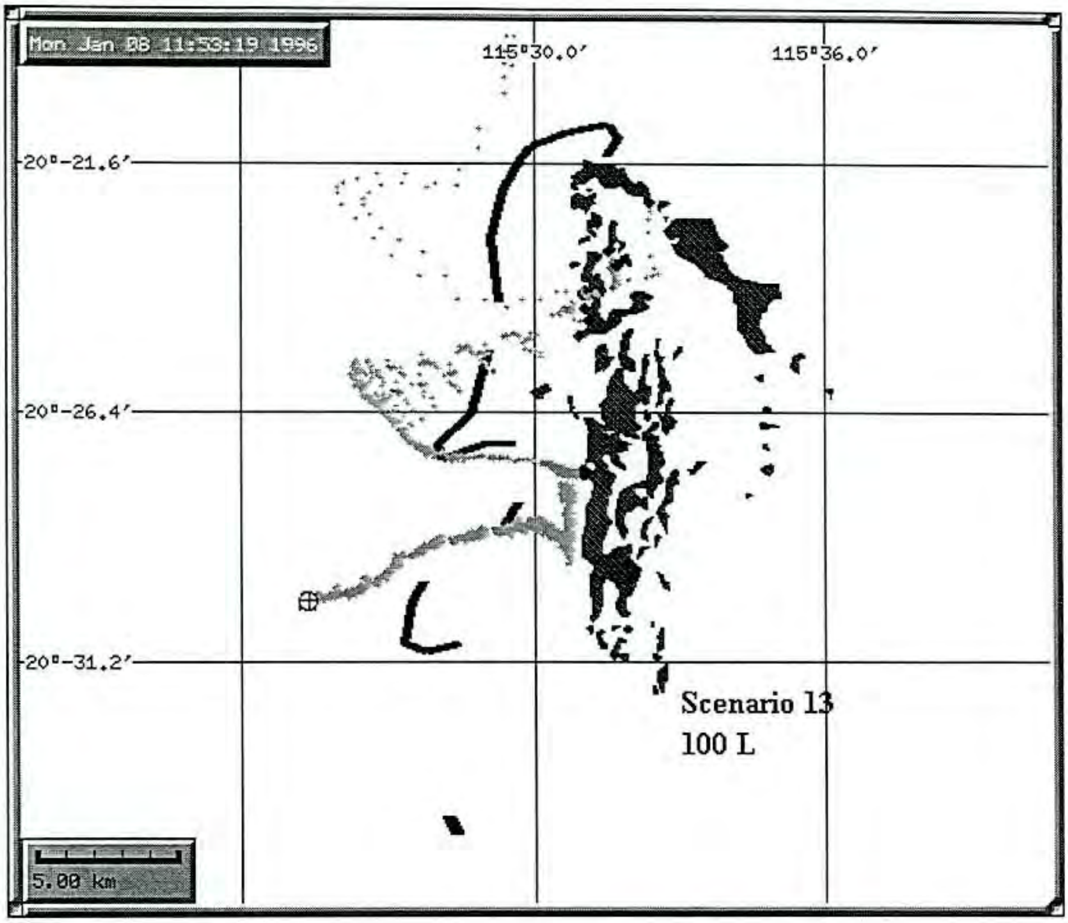
Scenario 12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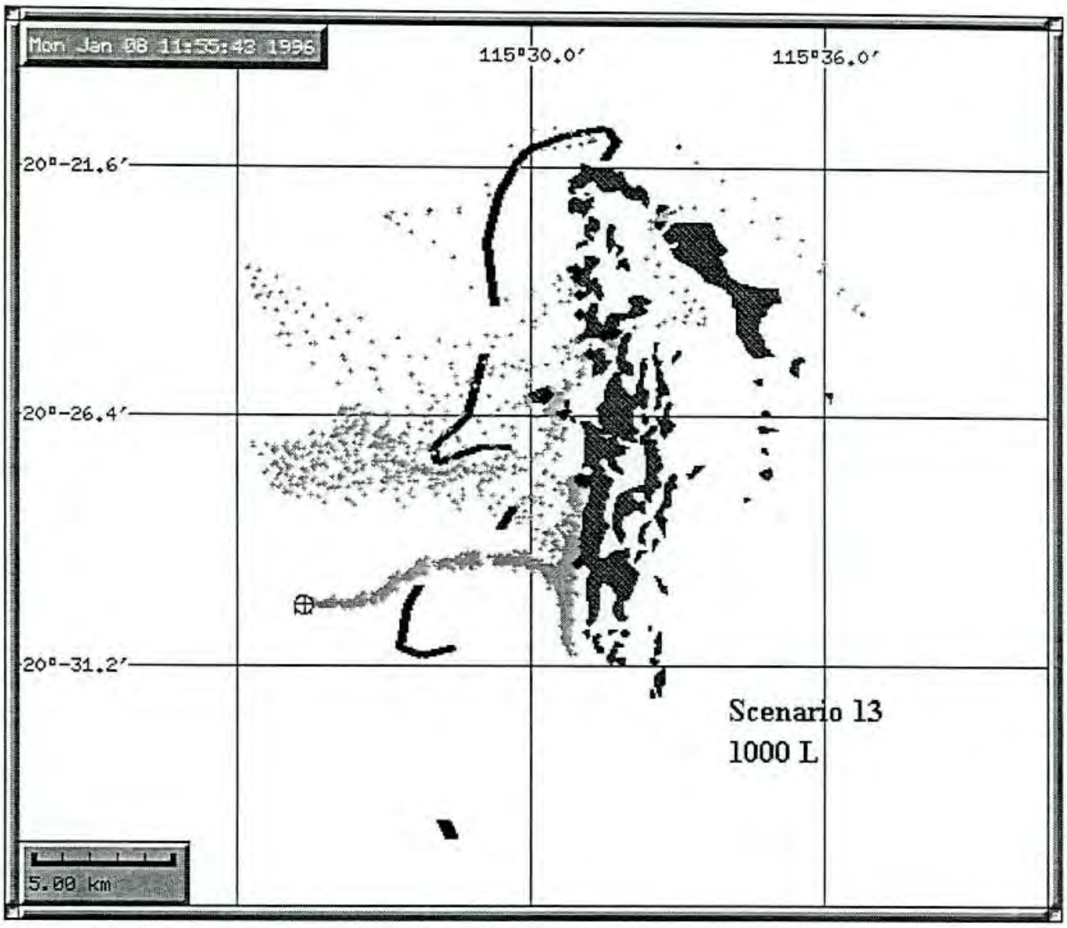
Scenario 13
100 L
5.00 km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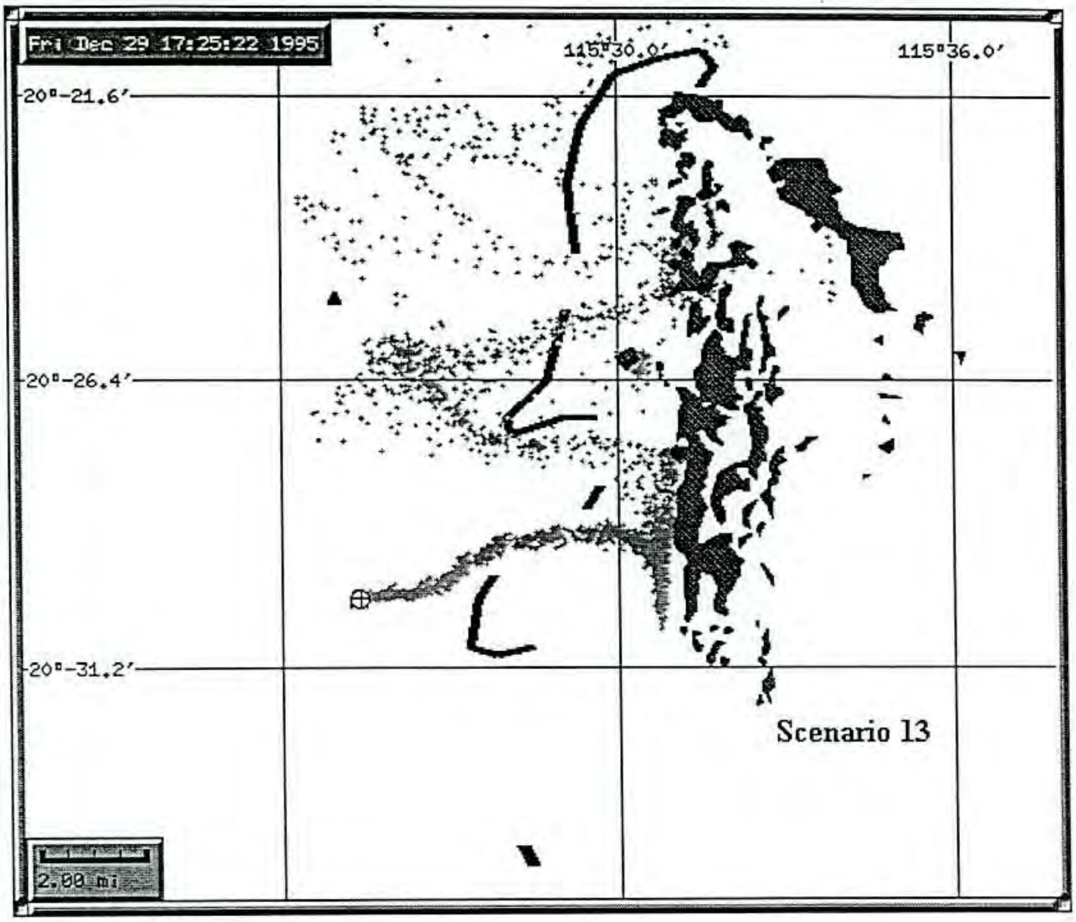
Scenario 13
1000 L
5.00 km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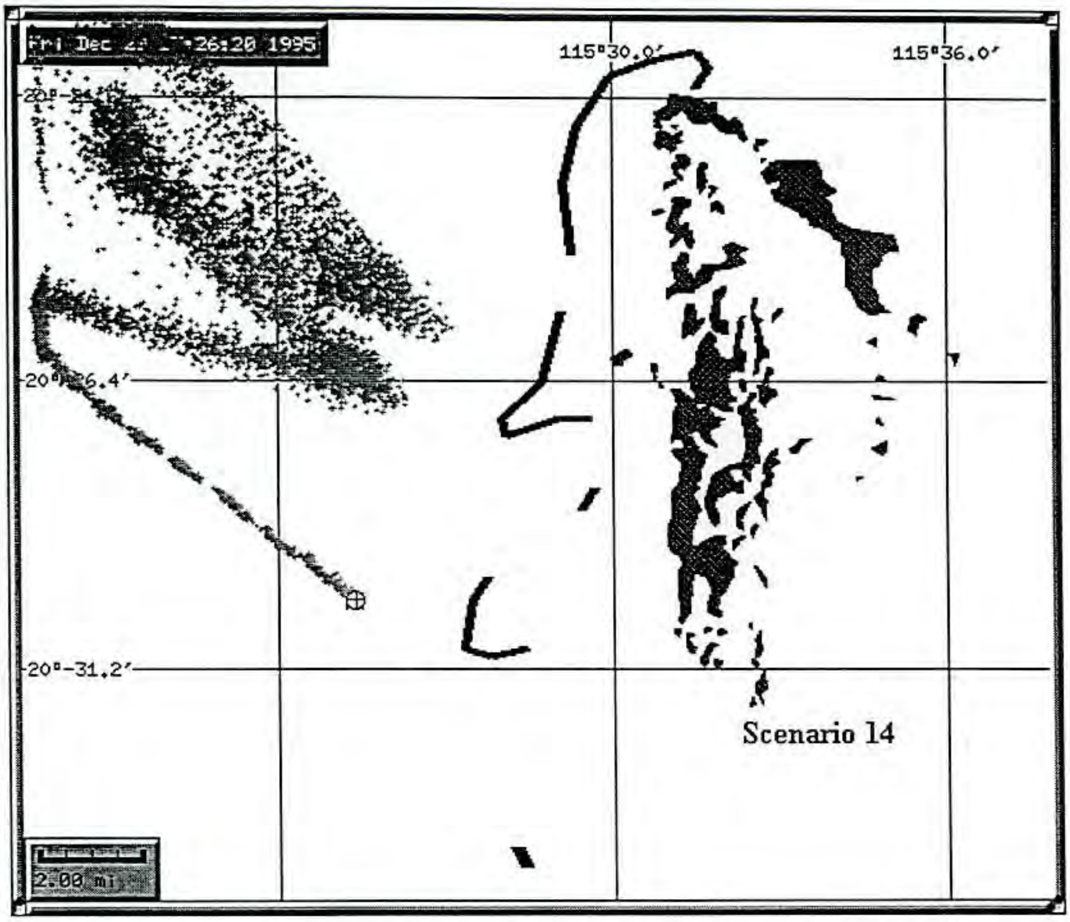
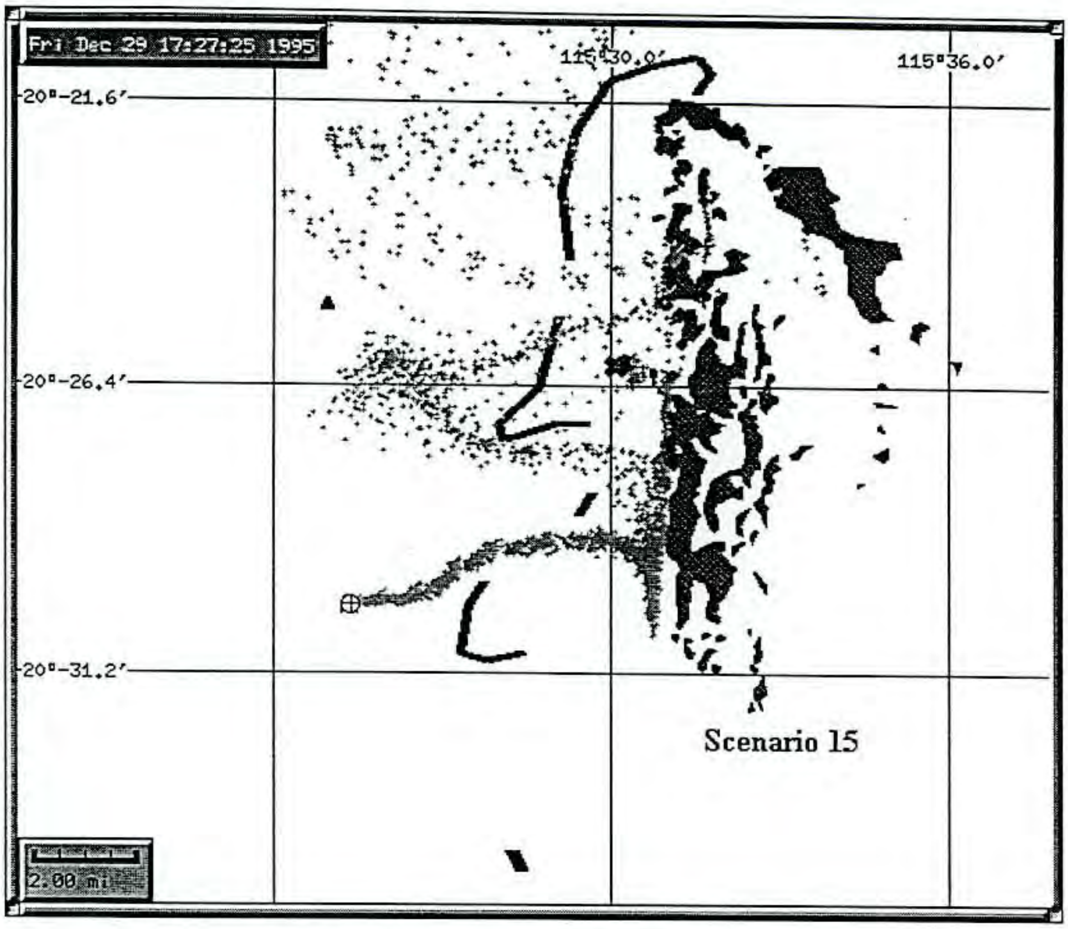
2.00 mi

Scenario 13



Scenario 14


Fri Dec 29 17:27:25 1995
115°30.0'
115°36.0'
20°-21.6'
20°-26.4'
20°-31.2'
2.00 mi

Scenario 15

Appendix 7

Effects of Oil on Natural and Social Resources

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TABLE

A7.1 Overview of the consequences of an oil spill on natural and social resources. A light crude oil is used as the source of impact.

A7.2 Man induced and natural impacts and stressors Montebello Islands

1. INTRODUCTION

There is no clear-cut correlation between the size of the spill and extent of damage it may cause. 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 for sediment penetration, location of the spill, climate and sea state, 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 and 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 oil on various resources is presented in Table A7.1.

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, predictions for the potential impact of spills on the local marine communities can only be based on the limited toxicity data available and the results of post-spill field studies undertaken overseas.

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 and it is against these variables that the consequences of an oil spill must be compared.

Potential anthropomorphic and natural sources of disturbance are listed in Table A7.2.

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. Generally, the effects increase in intensity and persistence from pelagic (open ocean) to subtidal to intertidal communities.

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 due to an oil spill, 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 number of the initial colonisers. In time, the flora and fauna characteristic of the area are 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 sand wave 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 the prediction or assessment of the impact of spilt 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 which have developed inter-relationships between themselves and the physical environment which surrounds them (air, water, sediment). An oil spill could cause a major disruption to this relationship resulting in changes in the composition and functioning of the ecosystem, or 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 recolonising organisms, biological interactions and climatic variables, food availability, survival of recruits and 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 are present and are 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. IMPACT 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 petroleum on marine life include:

- lethal toxic affects -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 phsiological and/or behavioral 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 the oil;
- direct smothering and suffocation; and
- physical or chemical alteration to a habitat resulting in a change in population or community structure.

4.1 PLANKTON

Plankton is the name applied to the group of mostly small, single and multicellular plants and animals which live within the water column. They are often the juvenile stages of larger organisms, including fish, crustaceans and corals, and form the basis of many food chains in the marine environment, providing 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 which 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 review of the literature, Volkman et al. (1994) concluded there was general agreement that oil toxicities to plankton showed minimal or transient effects in both experimental and field experiments.

4.2 INTERTIDAL AND 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 of the animals of the rocky shore 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, both temporally and spatially (Underwood & Chapman 1995).

The effect of oil on the rocky shore tends to be minimal and recovery rates are rapid (two 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.

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 which turn the sediment over (bioturbation) will help to decease the time it takes for the oil to degrade.

Macroalgae and Seagrasses

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 of seagrasses to oil spills appears to vary considerably (Thorhaus 1987).

Seagrass beds and algae will survive a spill provided that no actual coating occurs. 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).

Corals are recognised as requiring protection from oil spills due to their sensitivity to oil pollution, their slow rate of recovery and their importance in providing habitat for a high density of marine organisms. Chronic oil pollution and coating will kill corals, but corals can survive oil spills if they are fully submerged and the conditions are such that oil does not become entrained in the water column. Entrainment is more likely to occur when the spilt oil is heavy, when chemical dispersants are used, when the seas are high and physical dispersal has occurred, or when corals are in shallow water or areas of extreme tidal range (AGC Woodward-Clyde 1992). Evidence from spills and laboratory studies suggest that there may be longer term, sublethal effects on growth and reproduction of corals 1 to 6 m deep, with deeper corals seemingly unaffected (Loya & Rinkevich 1980; Jackson et al. 1989; Burns & Knap, 1983; Guzman & Holst 1993).

Mangroves

Mangrove communities are potentially the most sensitive of the marine environments to coating by oil (Lai et al. 1984; Wardrop 1987). Oil spills generally 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) on 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). Oil retained in sediment may inhibit the germination of mangrove propagules.

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 tide 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).

4.3 FIN FISH

The death of adult fish has been attributed to toxic effects of ingestion and to suffocation caused by clogging of the gills. 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 Valdez* spill, there was a record catch of pink salmon. The reason for this increase was attributed to the oil acting as a fertiliser, 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.

4.4 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* due to the range of juvenile and larval fish, crustaceans and terrestrial insects which 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 potential 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 is not the deaths brought on by oiling, but the number and fate of the survivors. Recovery of a population depends either on the existence of a reservoir of young breeding adults from which breeding colonies can be replenished or a high reproductive rate. Animals with a high breeding potential may rapidly regain their losses. Mortality is only significant if it results in a substantial decrease in the breeding population.

4.5 MARINE REPTILES AND MAMMALS

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. Other effects could include damage to the gastrointestinal tract due to ingestion of oil and damage to the lungs from inhalation. 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. Although 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. 1990). 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 10 species of marine mammals in eastern Canada, implying that PAHs can accumulate in mammalian tissue. However, the data must 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. Preen (1991) reported that dugongs of the Persian Gulf were not affected by the oil spills which occurred during the Gulf War.

5. EFFECTS OF OIL SPILLS ON THE SOCIAL ENVIRONMENT

5.1 COMMERCIAL FISHERIES

A large oil spill could have significant effects on local fisheries but, because most fishing activity occurs south of the permit area and most surface water movement is offshore, this risk is minimal. The pelagic larval stages and the benthic juvenile and adult stages of prawns are more sensitive to oil than finfish 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.

In the event of an oil spill under appropriate conditions, there could be some impact on pearl farming to the north-east of the drilling location. 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 spreading to the south and/or east of the drilling location may have a temporary effect on the operations of charter boats and recreational fishing. The actual fishing stocks are unlikely to be affected as game fish are highly mobile and so able to avoid the effects of a spill. An oil spill spreading to the Lowendals or Barrow Island would similarly disrupt recreational fishing and charter trips to those areas.

6. BACTERIA

This group of organisms is given separate recognition due to their natural occurrence 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 break down 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. Micro-organisms contributed to the natural degradation of oil after the Amoco Cadiz spill (Ward et al. 1980). Extensive bioremediation techniques were developed after the *Exxon Valdez* spill and results have been very promising (Hoff 1993). However, the technique still needs refining before it can be used as a large-scale clean-up technique.

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Table A7.1

Overview of the consequences of an oil spill on natural and social resources. A light crude oil is used as the source of impact.

RESOURCE	IMPORTANCE	IMPACT	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 high reproductive capacity 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 component of the 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 colonising 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 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. Abundances highly variable. High reproductive capacity.
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. Majority of invertebrates have high reproductive capacity and therefore high potential for recolonisation

Table A7.1 (cont'd)

Overview of the consequences of an oil spill of natural and social resources. A light crude oil is used as the source of impact.

RESOURCE	IMPORTANCE	IMPACT	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 is 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 heavily impacted.	Algae: 1 year Seagrass: 1 year - decades
Corals	Provide habitat for high density and diversity of animals. Nurseries for many fish. Important for tourism.	Minimal impact of 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 Growth rate and longevity of life is variable and species specific.
Mangroves	Highly productive. Source of food and shelter for wide diversity of organisms. Nursery grounds for some marine species. Stabilise shoreline.	Oil may persist for long time in sediment, especially where penetration has occurred (i.e. down animal burrows). Response range from defoliation, chlorosis and death of trees due to toxic impact. Infauna may be decimated by oil due to its toxicity.	Trees: 5-50 years Some species can grow very rapidly but take years to reach sexual maturity. 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. High reproductive capacity.

Table A7.1 (cont'd)

Overview of the consequences of an oil spill on natural and social resources. A light crude oil is used as the source of impact.

RESOURCE	IMPORTANCE	IMPACT	RECOVERY TIME
Seabirds	Conservation and recreation (bird watching). Add to biodiversity of area.	Damage to plumage and ingestion.	Slow to medium recovery depending on reproductive potential.
Turtles	Add to conservation status and biodiversity to area. Food source to indigenous people.	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.	Very slow recovery.
Marine mammals	Add to conservation status and biodiversity of area.	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.	Very slow recovery.
Commercial fisheries	Economic value.	Decimation of stocks may result in economic impact.	Slow to medium.
Tourism	Economic value.	Access to oiled beaches to be avoided, fishing may be restricted and some natural resources used for diving may be restricted for access.	Medium

Table A7.2

Potential Man-induced and 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 Islands.
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 runoff from land.

Appendix 8

Apache Energy Environmental Management 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, Managing Director

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Appendix 9

Summary of Insurance Coverage

SUMMARY OF INSURANCE COVERAGE

The Joint Venture Participants set out in summary for the main aspects of the insurance in place, but stress that the statements contained herein should be taken as statements of broad principles, rather than a binding commitment on their part:

1. **Control of well** - In the very unlikely event of loss of absolute control of any well being drilled such as the unintentional release of oil or gas from the well or around the well which cannot be stopped, it may be necessary to undertake expensive operations to regain control. This insurance would cover these costs whether the well was out of control on the surface or below the surface and covers wells which get out of control as a direct result of the well insured getting out of control.

2. **Redrill/Relief wells** - One of the means which could be utilised to bring a well under control in extreme circumstances if the flow of petroleum from the insured well cannot be stopped by surface equipment or drilling fluid is to re-enter the bore of the out of control well at a subsurface level by a new well drilled from a nearby location and deviated into the out of control well. The insurance would cover the cost of drilling the relief well(s).

   The operator will carry not less than $50 million 100% interest per occurrence for: (1) control of well; and (2) drill relief wells.

3. **Seepage and Pollution, Clean up and Contamination** - This section of the insurance provides cover for:

   (a) all sums which the JVP shall be liable at law or under terms of the permit or contract are liable to pay for the cost of remedial measures and or as damages for bodily injury and/or loss of, damage to or loss by third parties of use of property, business interruption and loss of profits (including without limitation, fishermen and aquaculture) caused directly or indirectly by seepage, pollution or contamination arising from any operations connected with insured wells; and

   (b) the cost of, or any attempt at, removing, nullifying or cleaning up seeping, pollution or contaminating substances emanating from the proposed wells, including the cost of containing and/or diverting the substances and/or preventing the substances reaching the shore.

   The operator will have insurance in the amount not less than $50 million per 100% interest per occurrence for this section.

Non insured losses: While the JVP do have insurance for the matters described in the event of a spill, they will take all reasonable measures to ensure that there is no loss. The loss record will be taken into account when the insurance is renewed so any claim could result in substantial increases in subsequent renewals.

The JVP are very aware of the consequences of an oil spill not only on the physical environment but also on the industry and the public perception of the industry. They realise that if there were a spill, it would seriously jeopardise any further applications to drill in environmentally sensitive areas, of which there are many along the NWS. The JVP are interested in finding petroleum, at the lowest practical cost, not only for their own purposes but also for the Australian economy. Any loss would be extremely prejudicial to the goodwill of the companies and would result in the companies losing a considerable sum of money directly from the oil spill not to mention loss of revenue from petroleum that would otherwise be produced, and refined and benefit obtained by the Australian public.