Major Marine Oil Spills - Risk and Response

Report

This study examines the risk associated with major oil spills (over 1000 tonnes) in open water anywhere on the Australian coast. This differs from previous work which has focused on the more numerous, smaller spills associated with ship operations in ports and sheltered waters. The study also examines the logistic constraints on providing rapid response along the whole length of the coast.

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risk and response

Report 70

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FOREWORD

This study was commissioned in 1990 by the Maritime Operations Division of the Department of Transport and Communications. It has been presented to the new Australian Maritime Safety Authority (AMSA), which has taken over the relevant operational responsibilities.

The analysis was carried out by Franzi Poldy and Anthony Carlson. The Bureau wishes to acknowledge the invaluable assistance provided by the staff of the Maritime Operations Division and AMSA, Kit Filor, Mike Julian, Mike Hawes and, most especially, Don Brodie.

It should be noted that this study was completed before the oil spill from the tanker *Kirki* off the Western Australian coast in July 1991. Fortunately, in this case, weather conditions and the nature of the oil were such that only relatively minor pollution occurred. The incident did, however, provide an early test of the response capability of the Oil Spill Response Centre which was established by the Australian Institute of Petroleum during the course of the study. In particular, the Centre is now more confident of the ability of available commercial aircraft to implement the first stage of moving response equipment (from Melbourne to a major airport nearest to the spill).

This single incident does not significantly change any of the study conclusions. After full investigation, it may, however, provide further information relevant to spill response and prevention.

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ABSTRACT

This study examines the risk associated with major oil spills (over 1000 tonnes) in open water anywhere on the Australian coast. This differs from previous work which has focused on the more numerous, smaller spills associated with ship operations in ports and sheltered waters. The study also examines the logistic constraints on providing rapid response along the whole length of the coast.

Extrapolating from international oil spill rates and anticipated Australian exposure, the probability of one or more major oil spills occurring in Australian waters, from tankers, could be as much as 48 per cent in the next five years and 93 per cent in the next 20 years.

For platforms and pipelines the probability estimates were based upon US data. If the same determinants apply to the present Australian situation, the probability of one or more major oil spills occurring could be 39 per cent in the next five years and 83 per cent in the next 20 years. These estimates are subject to a number of qualifications; the extrapolation from overseas experience will yield pessimistic risk evaluations to the extent that the current Australian disciplines and conditions are better than historical overseas circumstances.

The main limitations on rapid response are the availability and positioning times for suitable transport aircraft. Little is gained by having stockpiles close to high risk or sensitive areas if the aircraft to transport their equipment have to come from the other side of the continent.

SUMMARY

Australia has a *National Plan to Combat Pollution of the Sea by Oil* which provides a framework for coordinating the activities of the authorities responsible for responding to oil spills in different areas. Under its auspices stockpiles of material and equipment are maintained, training workshops and exercises are conducted and contingency plans coordinated.

As the vast majority of oil spills involve small to medium quantities and are associated with ship operations in ports and oil terminals, the National Plan has been designed to deal with moderate spills (up to about 1000 tonnes) in these identified high risk areas.

The National Plan has not been designed to cope with major spills in open waters away from the identified high risk areas. Recent major spills, together with increased public concern about the environment, have raised questions about how Australia would respond to such incidents.

This study investigates the risk of major spills (over 1000 tonnes) in Australian waters and examines aspects of the response logistics. Because of the very limited Australian experience of major spills, the risk estimates are based on rates derived from worldwide data, together with estimates of Australian exposure. The logistic assessment focuses on the constraints in providing rapid response to remote locations on the Australian coast.

Oil spill risk

Extrapolating from international tanker oil spill data and anticipated Australian exposure, the probability of one or more major oil spills (over 1370 tonnes) occurring in Australian waters, from tankers, could be as much as 48 per cent in the next five years and 93 per cent in the next 20 years.

For platforms and pipelines the probability estimates were based upon US data. If the same determinants apply to the present Australian situation the probability of one or more major oil spills (greater than 1000 tonnes) occurring could be as much as 39 per cent in the next five years and 83 per cent in the next 20 years. Considering the nature of the qualifications required for such an analysis, there is some reason to believe that these figures are pessimistic.

Probability estimates of this kind are important background information, but the study emphasises the technical and policy limitations on their use.

Shipping and tanker traffic and movements of crude oil and petroleum products suggest that the highest risk areas would be in Bass Strait and more generally in the south and east between Brisbane and the South Australian Gulfs.

Shipping accident rates per unit of shipping traffic are highest on the Inner Route of the Great Barrier Reef, where there is some evidence that the use of pilots may prevent groundings.

Oil spill response

The main limitation on rapid response is the availability of suitable transport aircraft and the time required for them to be positioned to an airport near the stockpile of response equipment. Little is gained by having stockpiles close to high risk or sensitive areas if the aircraft to transport their equipment have to come from the other side of the continent.

The availability of sufficient numbers of suitable aircraft (helicopters or fixed wing) and spraying equipment may be a limitation on the rate at which dispersants can be applied.

This study was not primarily concerned with the effectiveness of response operations at the site of the spill. Nevertheless, it is important to note that there is some uncertainty regarding response effectiveness. Variations in sea and weather conditions can have a significant effect upon the effectiveness of response equipment, regardless of the size of the spill.

Although information regarding the risk of an oil spill occurring (larger than a given volume) provides useful background for the decision to invest in response equipment, its practicality is limited since it cannot provide a meaningful expectation of the economic and environmental costs of a spill occurring. This is particularly so in Australia's case, where the probability of a spill occurring may be considered low, but where a spill may occur anywhere along a significantly long coastline with varying degrees of environmentally sensitive regions.

Consequently, the decisions of the oil industry and governments to invest in a response capability will probably be based upon qualitative judgments. Since the *Exxon Valdez* incident it may be argued that the oil industry in general has become more risk-averse and increasingly sensitive to community environmental expectations as well as to the firms' commercial liabilities.

CHAPTER 1 INTRODUCTION

BACKGROUND

The grounding of the *Exxon Valdez*, and the spilling of 30 000 tonnes of crude oil in Prince William Sound, Alaska in March 1989 focused attention on the risks to the environment associated with the transport of large quantities of crude oil and petroleum products.

Australia has a *National Plan to Combat Pollution of the Sea by Oil*. The plan '... represents a combined effort by the Commonwealth and the State Governments, with the assistance of the oil industry, to help provide a solution to the threat posed to the coastal environment by oil spills from ships ...' (Department of Transport and Communications 1990).

The National Plan provides a framework for coordinating the activities of the various authorities with responsibility for responding to oil spills in different areas. Under its auspices stockpiles of material and equipment are maintained, training workshops and exercises are conducted and contingency plans coordinated.

As the vast majority of oil spills involve small to medium quantities[1] and are associated with ship operations in ports and oil terminals, the National Plan has been designed to deal with moderate spills in these identified high risk areas. Its stockpiles of equipment are distributed among the main ports, supplementing those of the oil industry's *Marine Oil Spill Action Plan* (MOSAP) (Australian Institute of Petroleum 1989). The National Plan (incorporating MOSAP) is described as being able to cope adequately with spills of up to 1000 tonnes. However, this capability is dependent on the circumstances of the spill, and there are no criteria for the adequacy of response.

The National Plan has not been designed to cope with major spills in open waters away from the identified high risk areas. Events such as the *Exxon Valdez* spill,

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1. In two earlier studies covering the periods 1972–73 to 1978–79 and 1982–83 to 1985–86, out of over 500 spills, the Bureau found one of 800 tonnes, one of 130 tonnes, and no other over 30 tonnes (BTE 1983; Cosgrove 1987).

together with the increased public concern about the environment, have raised questions about how Australia would respond to such incidents.

The oil industry, in particular, has been concerned about the extent of its liability and the adverse publicity from such incidents. The Australian Institute of Petroleum (AIP) has therefore decided to develop a capacity to deal with spills of up to 10 000 tonnes anywhere on the Australian coast (Corinaldi & Wayment 1990). Their proposal involves the establishment of an Oil Spill Response Centre which would not only maintain a centralised stockpile of equipment in constant readiness for immediate dispatch, but also provide training facilities and serve as the command centre for response operations. The centre is to be located in Melbourne and is estimated to cost $10 million initially and $0.75 million per year.

The Commonwealth Government has also been concerned to extend the capability of the National Plan to deal with large spills in remote areas, and consideration is being given to the integration of the additional resources proposed by the AIP into the National Plan (in the same way as the current MOSAP resources are available to the National Plan).

The rationale for the location of the Oil Spill Response Centre in Melbourne is that it will be close to the highest density of shipping traffic (both general shipping and tanker movements) around the Australian coast. It is also within easy reach of the Bass Strait oil fields, and the area contains the greatest concentration of refining capacity (and consequently, handles the greatest volume of oil) in Australia.

This rationale is consistent with the National Plan in focusing on a high risk area, albeit a wider area than formerly considered. However, it is unclear to what extent the Oil Spill Response Centre will contribute to the ability to respond rapidly to events in remote locations, possibly on the other side of the continent. It is true that the AIP proposal explicitly includes a rapid response capability and, it is claimed, equipment could be on site anywhere in Australian (and, indeed, New Zealand and some Pacific Island) waters within 12 hours. However, there appears to have been little detailed logistic planning and, in particular, the difficulties of the 'last leg' of the response to remote locations have not been considered.

AIMS OF THIS REVIEW

This review has two aims:

- to quantify, as far as possible, the risk associated with major at-sea spills in Australian waters; and
- to make a preliminary assessment of the logistics and identify constraints in providing rapid response to remote locations on the Australian coast.

The assessment of risk differs from previous studies of oil spill risk in Australia. Earlier studies (BTE 1983; Cosgrove 1987) dealt with relatively frequent small spills in high risk areas. Whatever the data problems, there was at least a substantial number of events on which to base analysis. The present concern is with very large spills, of which there have been no, or very few instances in Australia. Risk assessments in these circumstances are subject to considerable uncertainties. In addition, there are questions about the appropriate interpretation, for policy purposes, of very low probability estimates for high consequence events. These issues and the risk assessment are presented in chapter 2 and appendixes I, II and III.

Speed is very important for some aspects of oil spill response. The logistic assessment therefore focuses on the availability of vehicles and the location of stockpiles and of suitable airfields and ports, as it is these which determine the ability to arrive rapidly at the spill site with the equipment necessary for an effective response.

Subsequently, logistics of a different kind may be necessary to supply and maintain equipment and personnel in remote areas, possibly for a considerable time. This aspect of the response is not considered in this review. It is less dependent than the initial response time on the prior location of stockpiles, and there is more time to assemble resources and establish the operations. Finally, the extent to which a protracted (clean-up) response is required will be partly determined by the ability to contain or disperse the oil spill in the early stages.

The treatment is highly schematic for three reasons:

- A real response will depend on special features of the location of the spill which it is not feasible to take into account at a strategic level.
- Little planning has yet been done for the response to a major spill in a remote area, in particular for the difficult problem of the 'last leg' of the response. It has therefore been necessary to hypothesise about appropriate arrangements, routes, and vehicles.
- No allowance has been made for administrative or procedural delays. The estimates are based on plausible times for the completion of physical processes such as vehicle positioning, loading and transit.

The logistic assessment is described in chapter 3 and in appendixes IV, V and VI.

This review is not primarily concerned with the effectiveness of operations at the site of the spill. Nevertheless, in the course of the study, the question of effectiveness has inevitably arisen in conversation with practitioners and in various reports. Quite apart from any organisational or logistic problems, there appear to be severe technological limitations on the effectiveness of response to major oil spills in the open sea. This would appear to have some bearing on the balance to be struck between prevention and response.

Although information regarding the risk of an oil spill occurring (larger than a given volume) provides useful background for the decision to invest in response equipment, its practicality is limited since it cannot provide a meaningful expectation of the economic and environmental costs of a spill occurring. This is particularly so in Australia's case, where the probability of a spill occurring may be considered low, but where a spill may occur anywhere along a significantly long coastline with varying degrees of environmentally sensitive regions.

Consequently, the decisions of the oil industry and governments to invest in a response capability will probably be based upon qualitative judgments. Since the *Exxon Valdez* incident it may be argued that the oil industry in general has become more risk-averse and increasingly sensitive to community environmental expectations as well as to the firms' commercial liabilities. Chapter 4 reviews these issues.

Conclusions are presented in chapter 5.

CHAPTER 2 THE RISK OF MAJOR MARINE OIL SPILLS

The analysis in this chapter aims to provide estimates of:

- the overall probability of a major oil spill in Australian coastal waters (outside the identified high risk areas at ports and oil terminals which are the focus of the current National Plan); and
- the distribution of relative risk around the coast.

THE SIZE OF 'MAJOR' OIL SPILLS

This review is concerned with spills in the range 1000 to 10 000 tonnes. The lower limit is set by the generally quoted capacity of the National Plan to deal with spills of up to 1000 tonnes in sheltered waters. The upper limit is determined primarily by the size of compartments in the larger tankers regularly calling at Australian ports.

The upper limit is important in determining the types and quantities of response equipment required but, for the purpose of large spill risk assessment, only the lower limit is significant. Australia has experienced only one spill over 1000 tonnes, that from the *Oceanic Grandeur* which grounded in the Torres Strait in 1970, spilling about 2000 tonnes of crude oil. There is therefore no basis in Australia for distinguishing between spills in the range 1000 to 10 000 tonnes and all spills over 1000 tonnes.

In this chapter, the risk assessment generally refers to spills over 1000 tonnes, though in appendix I, data on spills over 10 000 barrels (1370 tonnes) are also used.

PROBLEMS IN ASSESSING LOW RISK, HIGH CONSEQUENCE EVENTS

Contingency planning for major oil spills can involve the expenditure of many millions of dollars. It would seem relevant to know something about the probability that such events will occur. This risk assessment is offered in the belief that an approximate knowledge of the probabilities involved is important background information. However, it is important to be aware of the technical and policy limitations on the use of this information.

Risk information is generally presented as an event rate, that is, the average number of events to be expected per unit of exposure to some causal factor. For oil spills, exposure variables might be such quantities as shipping traffic, tanker traffic, volume of oil carried, volume of oil produced offshore or numbers of wells drilled. Estimating the event rate is straightforward when a large number of events has been observed, and the estimated rate can be used to forecast expected numbers of occurrences during future exposure. As in all statistical analyses it is necessary to take account of the limits of confidence of the estimates and forecasts.

When only very few (or possibly no) events have been observed the confidence limits on the estimates become very wide. While this presents no new analytical problems, it does make it difficult to use the results for policy or decision making purposes. For example, if only one event has been observed during a certain exposure, the 90 per cent confidence interval for the expected number of events during that exposure is between 0.36 and 4.74 — a ratio of 13.2 between upper and lower limits.

The observation of only one event is the Australian experience. There has been only one tanker spill over 1000 tonnes and the Australian offshore petroleum industry has spilt less than 400 barrels (54.8 tonnes) over 26 years of operation, more than 1000 wells drilled and over 2600 million barrels of oil produced.

While it will be possible to supplement the Australian experience with overseas data, the numbers are still small, and the estimates remain subject to wide confidence limits.

Introducing overseas experience also raises the question whether the underlying causes are the same as in Australia. Ideally, estimates would be based on uniform populations of similar types of spills. As this is not the case then the mathematical model and its estimates need to be heavily qualified.

Since oil spills are due to a wide variety of sometimes poorly understood causes, such simple models can suffer from sampling errors:

- The overall sample of events of all kinds may be too small to permit very much disaggregation. Offshore in the United States over 30 000 wells are drilled each year. This can be compared to Australia in 1990, which was a record year, when 64 offshore wells were drilled.
- The time period of the data sample can also have an important influence on the observed level of risk. It may coincide with an unusually high or low period of accidents, or technology changes may make an older data set no longer relevant.
- Over the years, it would be expected that experience and improvements in technology, procedures and standards would lead to reduced risk, and there is some evidence that this has occurred. This is particularly the case with Australia's offshore petroleum industry, which compared internationally is a relatively young industry. This is clearly not the case in the Gulf of Mexico

where many of the wells were developed before today's more stringent attitudes and regulations.

When robust probability estimates are available, the normal approach is to combine them with some measure of the consequences of the event (costs of various kinds) to produce an 'expected' cost which can be compared with the cost of proposed actions to mitigate the consequences. This approach has not been used in oil spill contingency planning, not only because of difficulties with the risk estimates, but because the nature and impact of the consequences are also very uncertain. Combining low probabilities with high consequences, both subject to great uncertainty, cannot be expected to generate expected values which carry conviction in the policy process.

In addition, even without these uncertainties, there are questions about whether expected values are always a good guide for socially and politically acceptable decisions (Camerer & Kunreuther 1989). In the final analysis, whatever the results of a risk assessment, it would not be politically or socially acceptable to conclude that an oil spill response capability was not justified. The evidence overseas (UK Southampton, US Task Force), is that response capabilities are being proposed and established at considerable expense but their justification on risk assessment or analysis of trade-offs between costs and expected benefits remains uncertain. We will return to this point in chapter 4.

Nevertheless, in spite of these qualifications, it is hard to avoid the belief that some information about the probability of major spills should be available to planners.

SOURCES OF DATA

With only a single Australian spill in the range of interest, it was necessary to turn to overseas data for estimates of the absolute risk. A recent publication (Anderson & LaBelle 1990) brings together data from a variety of sources on US spills from offshore platforms and pipelines and worldwide spills from tankers. Data on appropriate exposure variables were also assembled: US production of crude oil and condensate from the outer continental shelf in relation to platform and pipeline spills; and total international transportation of crude oil in relation to tanker spills.

Data on Australian exposure were obtained from the *Petroleum Gazette* (1989–90) and the *Petroleum Newsletter* (1990).

Further details on these data are provided in appendix I.

Factors relevant to the distribution of relative risk were assumed to be: total shipping traffic; tanker traffic; shipping accidents (groundings and collisions); and coastal transport of crude oil and refined products. Data on shipping and tanker traffic were obtained from AUSREP (the Australian ship reporting system) records; accident data were obtained from the Maritime Operations Division of the Department of Transport and Communications; and information on coastal transport of hydrocarbons was obtained from BTCE (1989).

RESULTS

The analysis leading to the estimates of overall risk of major oil spills in Australian waters is described in appendix I. Table 2.1 reproduces the final result, but the appendix should be read for information on assumptions and qualifications. On balance, it is felt that the overall bias is pessimistic, that is, it has tended to increase the probabilities in table 2.1. Two assumptions are most important.

The first is that the causes of oil spills overseas are the same as those in Australia. With the available data this would be hard to verify or refute. In particular it should be noted that there have been no major spills from Australian offshore platforms or pipelines. This may well indicate that better strategies and conditions apply in the Australian case than in the US experience, from which these probabilities were extrapolated.

The second is that the underlying causes of oil spills have not changed during the 25 years covered by the data. As mentioned earlier, there is some evidence that improvements in technology and procedures have led to reduced risk. This has not been quantified and hence contributes to the pessimistic bias in the results.

TABLE 2.1 PROBABILITY OF ONE OR MORE MAJOR OIL SPILLS IN AUSTRALIAN WATERS OVER VARYING EXPOSURE PERIODS[a]

Type of spill	Exposure period		
	5 years	*10 years*	*20 years*
Tankers (at sea)[b]	0.48	0.73	0.93
International	0.18	0.33	0.55
Coastal	0.23	0.41	0.65
Platforms and pipelines[c]	0.39	0.61	0.83
Platforms	0.26	0.44	0.67
Pipelines	0.17	0.30	0.49

a. A major oil spill for tankers is defined as one greater than 1370 tonnes, while a major oil spill for platforms and pipelines is defined as one greater than 1000 tonnes. This does not allow the figures for tanker spills to be directly comparable to those of platforms and pipelines.

b. Extrapolated from international tanker data.

c. Extrapolated from US offshore production data

Source Appendix I, table I.3 and table I.4.

Appendix II presents information on shipping traffic and petroleum movements around the coast. Generally, the figures support the view that the centre of activity (for all variables) is in the east and south, primarily between Brisbane and the South Australian gulf ports. Tanker traffic and petroleum product movements decrease northwards along the Queensland coast, reflecting the distribution of products from southern refineries. During the approximately nine months covered by the data, 34 tankers over 80 000 dwt used the Inner Route of the Great Barrier Reef (between Cairns and Thursday Island).

Appendix III presents information on shipping accidents (collisions and groundings) for nine sections of the Australian coast from the Torres Strait, southabout to King Sound (Derby). The northern coast was omitted both because there were no recorded accidents and because the shipping traffic information is patchy. The most important point to bear in mind is that, because of the small number of incidents, the qualifications mentioned above in connection with oil spills apply here too. In particular, the confidence intervals on estimates are wide and, except on one section, there is little scope for further disaggregation to investigate causes of accidents.

Despite the uncertainties, two relatively clear conclusions can be reached. The first is that the accident rate in the Torres Strait and Inner Route of the Great Barrier Reef (north of Cairns) appears to be significantly above that on other sections of the coast, possibly by a factor of three to five.

The second conclusion is based on work by Evanson and Potts (1990) who examined the causes of accidents on the Inner Route of the Great Barrier Reef. Their main finding was that the grounding rate for unpiloted vessels was over 30 times that for piloted vessels. Even allowing for statistical uncertainties the result is significant and would appear to support the need for greater use of pilots on this route.

Evanson and Potts also examined collision rates on this route. While the absolute number of events is small, and differing conditions make comparisons with other routes difficult, they concluded that the collision rate on this route may be high by world standards.

CHAPTER 3 THE RESPONSE TO MAJOR MARINE OIL SPILLS

Oil spill response operations are generally carried out over two stages with very different time scales. Depending on the circumstances, the initial response will endeavour to do some or all of the following:

- contain and recover the oil near the spill source;
- disperse the oil;
- protect sensitive or valuable resources.

A rapid response is fundamental for the achievement of success in the initial stage. The result of this initial success can be twofold: it may mitigate the effect of the spill upon the marine environment; it provides visible evidence to the public that something is being done.

However rapid the initial response, it is a fact of spills at sea that, if the weather is onshore, some of the spilled oil is going to come ashore. Clean-up operations are then required on a time scale of weeks or months according to the type and quantity of oil, and the topography and extent of the coastline to be cleaned.

The two different phases of response require different logistic resolution. Whilst sound and proven organisation is a prerequisite to both, the success of the initial rapid phase is fundamentally reliant on the availability of suitable transport vehicles, the location of equipment and proximity of airfields and access ports to the spill location. The second phase in a major incident inevitably involves a longer and more tedious operation requiring continuing coordination of manpower and resources.

This analysis is concerned only with the logistics of the initial response and with the factors which determine the response time.

THE IMPORTANCE OF RAPID RESPONSE

As will be noted in chapter 4, the effectiveness of response to oil spills on the open sea is not expected to be high. Such success as can be expected is likely to be due to prompt action and favourable environmental conditions. Indeed, an important part of the rapid response strategy is precisely to be able to take advantage of any fortunate circumstances which occur in the early stages of the spill — which may not last long. Spills of the order of thousands of tonnes can spread rapidly over areas whose perimeters greatly exceed any likely availability of containment booms. One could be fortunate; wind and tide and the coastal geography might conspire to confine the spill in some way for a limited period and, if the necessary booms, skimmers and recovery vessels could be brought on site in this time, a greater than usual amount of oil might be recovered. But generally, the expectations of containment and recovery on the open sea are low. Historically, the fraction recovered has been of the order of 10 per cent (International Maritime Organisation 1988).

If conditions are suitable and the option is environmentally acceptable, dispersal of the oil can be a more effective course of action. Oil spill dispersants depend for their action on intimate mixing with the oil, and this requires a combination of low oil viscosity and a degree of wave action to encourage mixing. Use of dispersants is therefore limited at the outset, by temperature and the intrinsic properties of the oil which jointly determine its viscosity, or pour point. Assuming the use of dispersants is desirable, they must be applied promptly. The wave action necessary for mixing will, if dispersants are not applied, tend to form a relatively stiff oil/water phase known as a mousse which resists penetration by dispersants. Evaporation works against dispersion by removing the lighter oil fractions, increasing the viscosity of the remainder. Opinion varies, but in most cases it is assumed that dispersants must be applied within, at most, 48 hours of the release of the oil.

Protection of assets would be the next line of defence. Recognising the very limited ability to contain oil on the open sea, and assuming dispersal is either not feasible or not entirely successful, response would focus on protecting the highest priority assets. The technology, involving booms as barriers, is essentially the same as for containment but with the more modest objective of deflecting the oil to less sensitive or more expendable areas. Protection is not subject to an inherent time limit beyond the requirement to get there before the oil. Forecasts of oil movement are clearly relevant, though in all cases it will be important to be on site as soon as possible.

The ability to take advantage of any favourable circumstances has already been mentioned. Chief among these is probably the weather, on which the success of all stages of oil spill response depends very strongly (though in different ways). One of the contributory factors to the severity of the *Exxon Valdez* spill appears to have been the failure to take advantage of the near calm conditions (favouring containment and recovery) which prevailed for most of the first two days after the spill (Cutter Information Corp. 1989).

APPROACHES TO PROVIDING RAPID RESPONSE

The current National Plan provides rapid response by having its stockpiles of equipment close to the high risk areas where most of the spills occur. Relatively modest stockpiles are required to deal with the limited size of the expected spills. Proximity is also the rationale for the location of the AIP stockpile and response centre in the Melbourne area, close to the greatest volumes of petroleum handling and shipping activity.

Extending this approach would suggest the need for additional stockpiles near the principal environmentally sensitive areas. Unfortunately, the very high cost of the equipment necessary to deal with a major spill (and the low probability of such spills), precludes the establishment of fully capable stockpiles near all sensitive areas. Some degree of centralisation is necessary, and it then becomes important to identify the most effective locations (from the point of view of response time) for centralised stockpiles.

LOGISTICS AND RESPONSE TIMES

Appendixes IV and V examine the transport logistics and response times which could be achieved in responding to an oil spill anywhere on the coast of the Australian mainland. Tasmania has not been included because the focus is on the location of stockpiles in the north and west in addition to that proposed by the AIP for Melbourne. Spills in Tasmanian waters would be considered local to the Melbourne stockpile.

The analysis covers the transport requirements for asset protection on the surface at the site of the spill, and application of dispersants from the air by either helicopter or fixed wing aircraft.

In appendix IV the essential steps in the transport tasks are identified and presented on an activity schedule which, with assumptions about the durations of the steps, allows the critical paths to be determined. The steps considered consist of: the location and positioning of vehicles; loading and unloading; and 'line-haul' by the various modes. The appendix deals with the structure of the tasks and the durations of those steps (such as loading and unloading) not expected to be dependent on the location of the spill or the stockpiles.

Appendix V deals with the steps whose durations do depend on the location of the spill and the stockpiles. These are presented both as the actual times for the main steps (air and sea transport times) and as distributions. Summing the times for the steps on the critical paths provides estimates of the overall response times.

Appendix VI examines the impact of logistics on the rate at which dispersants can be can be applied from the air and consequently on the amount of oil which could (in theory) be dispersed in the initial 48 hours during which dispersants are effective. The rate of application per 'effective' aircraft (that is, an aircraft operating continuously) is determined as a function of: distance from base to spill; transit speed; times on task and for turnaround; and the dispersant payload. The (daylight) time available for spraying operations is also considered as a function of response time and the time of day of the spill.

RESULTS

Given the many assumptions and approximations which it has been necessary to make, three qualitative conclusions from this analysis are probably more important than the quantitative results:

(1) The arrangements made for the air transport of heavy equipment, in particular, the availability of the aircraft at short notice, are crucially important. The time taken to position aircraft at an airport near the stockpile can nullify any advantage from having the stockpile close to the area of the spill. Use of both RAAF Hercules and domestic commercial aircraft has been considered. RAAF Hercules aircraft, based at Richmond, could take over nine hours to become available in the north and west. The routine operations of domestic commercial cargo aircraft (from which they would be diverted for oil spill response) are also concentrated in the east and south. It is unlikely that they could be made available in the north or west very much more rapidly than the RAAF Hercules.

(2) Having stockpiles in the north-west of Western Australia (for example Dampier) and Townsville could save up to seven hours in the response time to spills in the north and west (assuming this time is not lost waiting for the aircraft to become available — as in conclusion 1 above). In the immediate vicinity of these ports, of course, air transport might not be required at all. The savings are somewhat less, about three hours, in the average time to respond to a spill anywhere on the Australian coast.

In remote areas, response times may be dominated by long sea passages from the nearest port to the site of the spill.

TABLE 3.1 PROPORTION OF COAST TO WHICH OIL SPILL RESPONSE CAN BE MADE WITHIN VARIOUS RESPONSE TIMES FROM VARIOUS COMBINATIONS OF STOCKPILE LOCATIONS[a]

(per cent)

Location of stockpiles	*Response times*			
	5 hours	*10 hours*	*15 hours*	*20 hours*
Avalon (Melbourne)	5.9	41.8	80.3	92.4
Avalon and Port Hedland	8.9	61.8	86.5	94.1
Avalon, Port Hedland and Townsville	12.8	71.1	89.5	94.4
Avalon, Port Hedland, Townsville and Darwin	14.5	72.7	90.5	94.4

a. Response time for surface access *excluding* positioning time for transport aircraft to stockpile airport.

Source Figure V.6.

(3) Effective dispersal operations may be limited by the availability of suitable helicopters or fixed wing aircraft in the area of the spill. The idealised operations considered in appendix VI lead to a modest rate of dispersant application (in relation to the size of the spill) per 'effective' aircraft. To achieve this rate would require more than one actual aircraft, and correspondingly more if higher rates were desired. These aircraft would have to be equipped with spraying apparatus. Initial studies indicate that the adaptation of existing fixed wing aircraft engaged in the agricultural industry is not a problem. Equipment for use with helicopters would not be limiting as the National Plan has a considerable number of these, although they would have to be assembled from their dispersed locations.

The quantitative results are presented in appendixes IV, V and VI. A summary of the results on response times for surface access is given in table 3.1. Note that these response times *exclude* the transport aircraft positioning times.

CHAPTER 4 THE EFFECTIVENESS OF OIL SPILL RESPONSE OPERATIONS

This review has not been concerned with the effectiveness of the response operations at the site of the spill. However, in addressing the logistics, questions of effectiveness have inevitably arisen. Discussions with oil spill response planners and practitioners and examination of the literature suggest that, even with the most advanced technologies, there are severe limitations on the effectiveness of response to major oil spills on the open sea.

This view is to be contrasted with the proposals, both in Australia and overseas, for the establishment of equipment stockpiles and response centres based on these technologies. It is also relevant to decisions about the appropriate balance between prevention and response.

An early expression of the difficulties appears in the enquiry by the House of Representatives Standing Committee on Environment and Conservation (1978) into the prevention and control of pollution from oil spills. In its report, the Committee expressed concern that:

> Witnesses were unable to tell the committee the size of the spill that the National Plan was designed to cope with.

and that:

> ... the National Plan review chose to maintain a financial basis for equipping the National Plan rather than the size of a likely spill.

The Committee recommended that:

> the National Plan should be equipped to respond to an estimated pollution threat calculated on the basis of the size and volume of shipping using Australian waters.

The National Plan *is* now described as being able to cope with spills of up to 1000 tonnes in sheltered waters. In a similar way, the AIP stockpile and response centre are described as being intended to cope with spills of up to 10 000 tonnes at sea or near coasts facing the open sea. The Oil Spill Service Centre in Southampton (Pyburn 1990) and proposed Petroleum Industry Response Organization centres in the United States (Murray 1989) are intended to deal with spills of up to 30 000 tonnes. It is natural to assume that this usage reflects a known relationship between overall resources and capability, and is based on the known effectiveness of various types of equipment and procedures.

Although the effectiveness of individual types of equipment *is* known (in many cases, in open sea conditions, it is low), the circumstances under which the equipment is used are so varied and unpredictable that no clear relationship between resources and capability can be defined.

One of the sources consulted on this question expressed it in this way (R. Perry, Manager, Oil Spill Services Centre, Southhampton, pers. comm.):

> There are so many uncertainties which relate to sizing equipment capability to the size of a spill. The only certainty is that you must never believe that a stockpile, nominally capable of cleaning up a 30,000 ton spill, can actually do so. The figure is a measure of capacity only, not capability.

The *American Petroleum Institute Task Force Report on Oil Spills* (Murray 1989) warned, in its Executive Summary (p. i):

> ... nothing can be promised to government or the public except a best effort to respond at sea. Further research into recovery technology can certainly help in this regard, but it is not considered likely that we can move to the point of guaranteeing containment and recovery at sea.

Later in the body of the report it was noted (p. 10):

> A realistic appraisal of U.S. and in fact, world wide response to major spills will recognise that no effective containment of such a spill has been accomplished. For such spills that occur near land, unless weather or other conditions of nature are such that oil is carried to sea, it is highly probable that oil will reach the shore. While attempts at containment and at sea recovery are nonetheless desirable, response must also deal on a priority basis with defense of sensitive shore areas and on-shore cleanup capability.

and again (p. 12):

> Statistically the catastrophic spill rarely occurs, is unpredictable in location and response may be considered ineffective even under the best of circumstances.

Clearly there is limited confidence in the existing technology for the containment and recovery of oil at sea.

In view of the technological limitations, it can reasonably be asked why the recommendations of the reports quoted above are for the establishment and upgrading of response centres based on just these technologies.

The American Petroleum Institute Task Force described the rationale for its proposals in the following terms (in a section which includes the earlier quote on response effectiveness) (Murray 1989, p. 12):

> Assessing the cost benefit trade off of developing the capability to respond to a catastrophic spill is especially difficult. Statistically the catastrophic spill rarely occurs, is unpredictable in location and response may be considered ineffective even under the best of circumstances. The financial cost of any realistic plan to optimize

> response to a catastrophic spill will be substantial, but these costs must be weighed against the cost of failing to put such a plan in place. Among those latter costs would be the impact on the environment; the cost to other affected parties; the cost of clean-up; loss of industry reputation and of the reputation of the companies most directly involved; loss of time to conduct normal business; loss of business opportunities and an increased regulatory burden for the industry.

In considering the above quotations it should be noted that, while their context is the overall oil spill response, it is the ineffectiveness of containment and recovery which is emphasised. There is room to suppose that other response measures, such as oil dispersal or the protection of coastal assets, may be more effective. If conditions are right these measures may, indeed, be effective on a small scale, but they provide only a limited solution to the threat posed by a large spill. Dispersants are limited by oil type and weather conditions, can only be used within the first 48 hours, and may themselves pose an environmental threat. The effectiveness of booms, as protective barriers for coastal assets, is limited by wind, waves and current; no boom can effectively contain oil against currents (at right angles to the boom) much above 1 knot (International Tanker Owners Pollution Federation 1987). The scale of the protection problem can be gauged by noting that, if all currently proposed acquisitions go ahead, there would be in Australia less than 20 kilometres of broadly suitable (medium and heavy duty) boom, of which about 7 kilometres would be classified as for heavy duty, offshore. For comparison, oil from a 10 000 tonne spill could threaten some hundreds of kilometres of coast. It is estimated that the 30 000 tonnes spilled from the *Exxon Valdez* contaminated 1800 kilometres of the coast of Alaska (Dicks 1990).

Past oil spill incidents have sometimes resulted in charges of incompetence, poor planning, failure to follow existing plans or regulations, and personal and institutional failures of various kinds. Many of these charges may have been substantiated. What is not known is whether, without these failings, the final outcomes, in terms of oil recovered or reaching the shore, would have been very different. The inference from the above is that it might not.

The point is not that a response capability is not required. The current National Plan effectively deals with the more routine small spills in sheltered waters. As the techniques and equipment proposed for dealing with major at-sea spills are basically extensions of those currently in use, some enhancement of the current capability is appropriate in order to be able to take advantage of any favourable circumstances which occur. But this modest goal should not be confused with an ability to prevent oil pollution following a major spill with any degree of assurance.

Given the uncertainties and the difficulties of conducting cost–benefit analyses referred to above, the appropriate degree of enhancement of the current capability is a matter for judgment. A factor influencing this judgment will be the degree to which resources devoted to prevention may be more effective in reducing pollution.

PREVENTION

Prevention is, and will remain the first line of defence against oil spills. The virtual absence of large spills in Australian waters is a testament to the effectiveness of the preventative measures taken by industry and government. However, as prevention can never be perfect, there is a need for contingency response plans such as those considered in this report.

Ideally, decisions about prevention and response and the balance between them would not be taken separately. Both contribute to the same overall objective — minimising the expected amount of oil pollution. At any stage, the next increment in resources should be allocated to the measure which will provide the greatest contribution to the overall objective. In practice, rigorous analysis along these lines is probably not possible, but the doubts which have been expressed about response effectiveness at least raise the question of what could be achieved by way of prevention with equivalent resources.

It is beyond the scope of this report to investigate this question. However, a number of actual and potential steps in the direction of prevention should be noted.

Compulsory pilotage will shortly be introduced for ships using the Inner Route of the Great Barrier Reef. The intention is that all ships of 70 metres in length and over and all loaded oil tankers, chemical tankers and gas carriers irrespective of length will be required to carry a pilot whilst navigating in the Inner Route between the latitude of Cape York and latitude 16 degrees 40 minutes south and also in the Hydrographers Passage. These routes lie within the Great Barrier Reef Marine Park.

Legislation has been passed in the United States which in effect introduces mandatory provisions of double hull construction for new oil tankers and a retrofit scheme for existing vessels. With few exceptions, all tankers operating in US waters will need double hulls by the year 2010. There is considerable controversy both in the United States and internationally about the merits of this legislation.

Other measures, such as radar surveillance of hazardous areas and sophisticated ship position reporting systems could be considered and are in use in some busy sea lanes overseas. Generally they have not been thought to be economically justifiable for Australia's low ship traffic densities.

CHAPTER 5 CONCLUSIONS

Extrapolating from international tanker oil spill data and anticipated Australian exposure, the probability of one or more major oil spills (over 1370 tonnes) occurring in Australian waters, from tankers, could be as much as 48 per cent in the next five years and 93 per cent in the next twenty years.

For platforms and pipelines the probability estimates were based upon US data. If the same determinants apply to the present Australian situtation the probability of one or more major oil spills (greater than 1000 tonnes) occurring could be as much as 39 per cent in the next five years and 83 per cent in the next twenty years. Considering the nature of the qualifications required for such an analysis, there is reason to believe that these figures are likely to be pessimistic.

Shipping and tanker traffic and movements of crude oil and petroleum products suggest that the highest risk areas would be in the Bass Strait and more generally in the south and east between Brisbane and the South Australian gulf ports.

Shipping accident rates per unit of shipping traffic are highest on the Inner Route of the Great Barrier Reef where there is strong evidence for the effectiveness of pilots in preventing groundings.

The main limitation on rapid response is the availability of suitable transport aircraft and the time required for them to be positioned to an airport near the stockpile of response equipment. Little is gained by having stockpiles close to high risk or sensitive areas if the aircraft to transport the equipment have to come from the other side of the continent.

The availability of sufficient numbers of suitable aircraft (helicopters or fixed wing) and spraying equipment may be a limitation on the rate at which dispersants can be applied.

Finally, although an estimation of the probability of an oil spill occurring provides important background to oil spill response and prevention policy, in the Australian context such information is limited as it cannot provide a meaningful expectation of the economic and environmental costs should a major oil spill occur.

APPENDIX I OIL SPILL RISK

The commonest assumption used in oil spill risk analysis is that oil spills occur randomly according to what is described as a Poisson process (Ross 1985). An exposure variable is defined and the probability, P(n), that n spills will occur during an exposure t is given by

$$P(n) = \frac{(kt)^n\, e^{-kt}}{n!} \tag{1}$$

The parameter k, the spill rate, is the expected number of spills per unit of exposure. Typical exposure variables are volumes of oil shipped or piped or numbers of wells drilled, and the analyses seek to estimate spill rates from observations of spill occurrences and cumulative exposure. If the pattern of spills supports the Poisson model, the estimated spill rates can then be used to determine probabilities of future spills under varying exposure assumptions.

This procedure is straightforward when substantial numbers of events have been observed. It is more difficult when the focus is on very rare events, none, or few, of which have yet been observed. The estimates of spill rates then have very wide confidence limits and are difficult to apply to the assessment of future risk. This is the situation with major marine oil spills in Australian waters.

Australia has experienced only one such large spill (over 1000 tonnes), that from the *Oceanic Grandeur* which grounded in the Torres Strait in 1970, spilling about 2000 tonnes of crude oil. On the basis of this single observation of a tanker spill and of zero observations of spills from oil platforms and pipelines, the earlier Bureau work on oil spill risk during the period 1970–79 (BTE 1983) estimated upper confidence limits for spill rates due to various causes, and these results can be updated to reflect the spill free period since that time (see table I.1).

It is difficult to use such upper confidence limits directly to provide generally intelligible statements about the level of risk. Probability statements are difficult enough for the non-specialist to grasp at the best of times. Statements about the *probability* that an *expected* number of spills will be less than some value, or about the *percentage confidence* that the *probability* of one or more spills in a give time will be less than some other value, can only lead to confusion.

TABLE I.1 UPPER CONFIDENCE LIMITS ON OIL SPILL RATES FROM VARIOUS CAUSES[a]

Type of spill	Cumulative exposure from 1970 to 1978	Cumulative exposure from 1970 to 1989	Exposure variable units	Number of spills	Upper confidence limit on spill rate[b] 90 per cent	Upper confidence limit on spill rate[b] 95 per cent
Tankers at sea	403	750[c]	Gigalitres shipped near coast	1	0.0052	0.0063
Undersea pipeline	170	388[d]	Gigalitres piped under sea	0	0.0059	0.0077
Drilling rig blow-out	381	827[e]	Offshore wells drilled to final depth	0	0.0028	0.0036
Offshore platform	170	415[f]	Gigalitres produced offshore	0	0.0056	0.0072

a. Update of estimates from BTE (1983).

b. Number of spills per unit of exposure variable.

c. 403 plus total imports and export (feedstock and products) 1979–89 (*Petroleum Gazette*, various editions) plus estimate of domestic shipments (feedstock and products) 1979–89 (BTCE 1989).

d. 170 plus 73 per cent of total domestic production 1979–89 (*Petroleum Gazette*, various editions).

e. 381 plus offshore wells drilled to final depth 1979–87 (*Petroleum Newsletter* 1990).

f. 170 plus 82 per cent of total domestic production 1979–89 (*Petroleum Gazette*, various editions).

Smith et al. (1982) applied an alternative approach. If spills *are* occurring according to an underlying Poisson process given by equation 1, and if m spills are observed during an exposure s, then the probability that n spills will be observed during a subsequent exposure t is given by

$$\mathrm{P}(n) = \frac{(n+m-1)!\, t^n\, s^m}{n!\,(m-1)!\,(t+s)^{(n+m)}} \qquad (2)$$

This works so long as at least one event has been observed (that is, so long as $m > 0$). The probability of one or more spills occurring anywhere is

$$\mathrm{P}(n \geq 1) = 1 - \mathrm{P}(n=0)$$

$$= 1 - \frac{s^m}{(t+s)^m} \qquad (3)$$

Applying it to the Australian experience (one tanker spill during the shipment of 750 gigalitres over 20 years) leads to the following probabilities for one or more

TABLE I.2 CRUDE OIL SPILL RATES FOR SPILLS OVER 10 000 BARRELS (1370 TONNES)
(per unit of oil handled)

Spill source	*Number of spills*[a]	*Spill rate per billion barrels*[b]	*Spill rate per gigalitre*
Platforms (US OCS)	3 of 11	0.24	0.0015
Pipelines (US OCS)	3 of 8	0.17	0.0011
Tankers at sea worldwide	59	0.55	0.0035

a. There is evidence that the US spill rate from platforms and pipelines is declining. The estimates give the more recent, lower rates based on the smaller figure. The larger figure includes spills at the earlier, higher rate.

b. Anderson and LaBelle calculated the spill rates for spills of 10 000 barrels and greater by applying the percentage of historical spills equal to or greater than 10 000 barrels against the 1000 barrels or greater spill rate.

OCS Outer continental shelf

Source Anderson & LaBelle (1990).

tanker spills over the next 5, 10 and 20 years (assuming average shipments continue at 37.5 gigalitres per year): 0.20, 0.33 and 0.50. The procedure cannot be applied to establish probabilities of spills from platforms or pipelines, for which we have no Australian observations. Also, it is wasteful of information in that it neglects oil spill experience from the rest of the world. Certainly there may be special features in the Australian circumstances; Australia's good record for platforms and pipelines may reflect better preventive strategies or more favourable conditions. However, these differences are likely to be less troublesome than the statistical uncertainties resulting from dealing with very small samples.

Anderson and LaBelle (1990) give estimates of crude oil spill rates from platforms and pipelines on the US outer continental shelf and from tankers worldwide. Their results for spills of over 10 000 barrels (1370 tonnes) are given in table I.2.

The spill rates in table I.2 are consistent with the upper confidence limits in table I.1. Note that Anderson and LaBelle do not distinguish drilling rig blow-outs from other platform spills; both are associated with platforms and use offshore production as the exposure variable.

RISK OF OIL SPILLS FROM TANKERS AT SEA

Because the spill rate for tankers in table I.2 is based on a sufficiently large sample, it can be substituted directly in equation 1 to provide intelligible risk estimates of one or more spills occurring anywhere, P($n \geq 1$, anywhere). With respect to equation 3, equation 1 can be simplified to

$$P(n \geq 1, \text{anywhere}) = 1 - e^{-(kt)} \qquad (1a)$$

Certain qualifications should be made when applying this method to the Australian experience.

Firstly, due to the data limitations discussed previously, Anderson and LaBelle report only the *international* component of all worldwide movements of crude oil and product by tankers.

But Australia is unique in that it has a significantly large domestic component — approximately 40 per cent of all tanker movements, by volume. Excluding the domestic component would seriously understate the probability of a spill occurring.

This understatement may be overcome if it is assumed that since the international component of the total world crude oil and product task is very high, the spill rate provided by Anderson and LaBelle may be considered as a close proxy to the spill rate with respect to an exposure variable of any movement of crude oil and product by tankers. This accepted, the international spill rate may be applied to the Australian coastal tanker component.

Secondly, with respect to the international component of Australia's total exposure, it should be noted that not all the spills will occur within Australian waters. If spills occurred uniformly along shipping routes, only a small proportion can be expected to occur in Australian waters. It is assumed here that spills were more likely to occur near voyage ends, in which case up to half the spills associated with the international component of the total Australian exposures would occur in Australian waters.[1]

Table I.3 shows the resulting probabilities for the occurrence of one or more major spills from tankers in Australian waters in the next 5, 10 or 20 years. There are further qualifications that should be noted:

- It is assumed that the circumstances leading to future oil spills in Australian waters are the same as those acting worldwide over the period covered by the data. There are two reasons for believing that this assumption may be pessimistic: Australian practices may be safer than the overseas norm; and accumulated experience, improved technology and stricter standards would

1. For spills associated with the international component of Australia's total exposure, equation 1 provides the probability of one or more occurring anywhere, P($n \geq 1$, anywhere). The probability of one or more of these spills occurring in Australian waters is given by

$$1 - \sqrt{P(n = 0, \text{anywhere})}$$

TABLE I.3 PROBABILITY OF ONE OR MORE MAJOR OIL SPILLS IN AUSTRALIAN WATERS FROM TANKERS OVER VARYING EXPOSURE PERIODS

		Cumulative exposure (gigalitres)			*Probability of one or more spills during future period*[d]		
Component	*Spill rate*	*5 years*	*10 years*	*20 years*	*5 years*	*10 years*	*20 years*
International[a]	0.0035	115	230	460	0.18	0.33	0.55
Domestic[b]	0.0035	75	150	300	0.23	0.41	0.65
Total[c]	0.0035	na	na	na	0.48	0.73	0.93

a. Assuming international crude oil and product shipments by tankers of 23 gigalitres per year.

b. Assuming domestic crude oil and product shipments by tankers of 15 gigalitres per year.

c. Assuming that spills occurring as the result of international or domestic shipments are independent events, then the probability that one or more spills will occur in Australian waters is

$$1 - \mathrm{P}(n = 0, \text{international}) \times \mathrm{P}(n = 0, \text{domestic})$$

d. Spills over 1370 tonnes.

na Not applicable

Source BTCE estimates.

be expected to reduce the risk of future spills. It is difficult to quantify either effect, and they have not been taken into account in the estimates.

- The 59 spills on which the estimates are based are those of over 10 000 barrels, corresponding to 1370 tonnes.
- The exposure variable is not related to the length of coast that tankers travel adjacent to. Therefore the probability of a spill occurring from tankers would be the same even if Australia had the same length of coastline as Tasmania. In this respect the estimates are conservative.
- Finally, the estimated volumes of exposure variable are based on calculations provided in table I.1. It should be noted that if present total volumes are maintained, but the international component increases at the expense of domestic shipments, the actual probability of a spill occurring, according to the methodology adopted, should decrease.

RISK OF OIL SPILLS FROM OFFSHORE PLATFORMS AND PIPELINES

The spill rate estimates in table I.2 for spills of over 10 000 barrels (1370 tonnes) from platforms and pipelines were, in fact, based on spills of over 1000 barrels (137 tonnes) and scaled in proportion to the presence of the larger spills in the overall population. In addition, because of the evidence for declining spill rates, each estimate was based on only the three most recent spills and is therefore subject to wide confidence limits and the problems of interpretation mentioned

TABLE I.4 PROBABILITY OF ONE OR MORE MAJOR OIL SPILLS IN AUSTRALIAN WATERS FROM PLATFORMS AND PIPELINES OVER VARYING EXPOSURE PERIODS

Type of spill	*Number of spills*	*Cumulative exposure (gigalitres)*	*Probability of one or more spills during future period*[a]		
			5 years	*10 years*	*20 years*
Platforms[b]	5	1607	0.26	0.44	0.67
Pipelines[b]	3	1580	0.17	0.30	0.49
Total[c]	-	-	0.39	0.61	0.83

a. Assuming for pipeline and platform spills, offshore oil production of 20 gigalitres per year, which loosely reflects the average over the last 20 years.

b. Spills over 1000 tonnes.

c. Spills due to platforms or pipelines, assuming independence, based on the combination of separate probabilities from each cause

$$= 1 - P(\text{no platform spills}) \times P(\text{no pipeline spills})$$

Source BTCE estimates.

above. However, Anderson and LaBelle provide details of all 11 platform and eight pipeline spills used in their analysis, as well as the exposure variable (offshore production from the US outer continental shelf). For the current purposes, it seems preferable to use these data directly.

Spills of over 1000 tonnes were selected from this sample (five platform and three pipeline). The Australian experience of platform and pipeline spills (that is, no spills and platform and pipeline exposure of 415 gigalitres and 388 gigalitres respectively, as detailed in table I.1) was combined with the US data. The events and exposure of this combined experience were inserted in equation 3 to provide the probability estimates in table I.4. The following qualifications should be noted:

- It is assumed that Australian offshore exploration and production practices are similar to those in the United States. Possible differences are discussed in chapter 2.
- The estimates are based on Bass Strait oil being piped and Timor Sea oil being shipped. No allowance has been made for growth in the latter component.
- All the US data were used; no account was taken of the evidence that spill rates from platforms and pipelines have been declining. The estimates are therefore pessimistic.

APPENDIX II SHIPPING TRAFFIC PATTERNS AND OIL SPILL RISK

Appendix I provided estimates of the overall risk of oil spills from tankers in Australian waters. The location of possible spills will depend on the distribution of shipping traffic, movements of crude oil and petroleum products near the coast, and the location of navigational hazards. Relevant information is presented in this appendix.

SHIPPING TRAFFIC DENSITY NEAR THE AUSTRALIAN COAST

Primarily for the purposes of sea safety and search and rescue, the Australian ship reporting system AUSREP records the routes of ships reporting their transit through waters monitored by Australia.[1] While the system keeps track of the ship's actual position during the transit, a record of the proposed route, in the form of a sequence of latitude–longitude pairs, is created when the ship first reports. Where the route is close to the coast, the latitude–longitude pairs are selected from a limited number of precisely specified 'waypoints' which have been defined around the Australian coast. The limited number (82) of these waypoints makes this data set more amenable to analysis, and the fact that the actual routes may not pass exactly through the waypoints is not important from the point of view of aggregate traffic.

Data covering all reported voyages from 28 October 1989 to 4 August 1990 (77 per cent of a year) were obtained from AUSREP. In this context, a voyage is defined as: a passage between two Australian ports; a passage in either direction between an Australian port and the boundary of monitored waters; or a passage between two points on the boundary (ship in transit not calling at an Australian port). For each voyage the following information was given: ship call sign, name, flag, tonnage, tonnage units (usually deadweight tonnes, a few gross registered tonnes), length, vessel type, origin, destination, date of first report, and the sequence of latitude–longitude pairs (waypoints near the coast). Table II.1 lists the waypoints by number, name and position.

1. About one-ninth of the world's oceans: east of 75°E; west of 163°E; and south of a more complicated boundary separating Australia from Indonesia and Papua New Guinea.

TABLE II.1 AUSREP WAYPOINTS USED IN THE DEFINITION OF SHIPPING ROUTES NEAR THE AUSTRALIAN COAST

No.	*Name*	*Lat. (S)*	*Long. (E)*	*No.*	*Name*	*Lat. (S)*	*Long. (E)*
1	Booby I.	10°38'	141°54'	42	Gabo I.	38°10'	149°52'
2	Pow Channel	10°30'	142°32'	43	Wilsons Promontory	39°12'	146°25'
3	Turtle Head	10°52'	142°50'	44	Port Philip/Westernport	39°05'	145°10'
4	Shelburne Bay	11°38'	142°55'	45	Cape Otway	39°00'	143°30'
5	Cape Grenfell	11°57'	143°18'	46	Cape Northumberland	38°13'	140°25'
6	Temple Bay	12°15'	143°12'	47	Point d'Entrecasteaux	35°24'	116°31'
7	Eel Reef	12°32'	143°24'	48	Cape Leeuwin	34°25'	114°45'
8	Cape Weymouth	12°36'	143°30'	49	Fremantle	32°00'	115°00'
9	Cape Direction	12°53'	143°35'	50	Geraldton	29°00'	113°24'
10	Claremont I.	13°51'	143°41'	51	Cape Inscription	25°30'	112°35'
11	Princess Charlotte Bay	14°05'	143°50'	52	Carnarvon	24°10'	113°00'
12	Cape Melville	14°08'	144°35'	53	North West Cape	21°45'	113°40'
13	Barrow Point	14°21'	144°40'	54	Dampier	20°15'	116°53'
14	Cape Flattery	14°52'	145°23'	55	Port Hedland	19°38'	118°20'
15	Cooktown	15°33'	145°23'	56	Broome	18°05'	122°00'
16	Port Douglas	16°21'	145°35'	57	Lacepede I.	16°45'	122°00'
17	Cairns	16°41'	145°47'	58	Yampicockatoo	16°00'	122°55'
18	Cape Grafton	16°50'	146°00'	59	Holothuria	12°50'	126°30'
19	Franklin I.	17°13'	146°08'	60	Bathurst I.	11°42'	129°45'
20	Mourilyan	17°37'	146°12'	61	Melville I.	11°02'	130°24'
21	Brook I.	18°10'	146°20'	62	Cape Don	10°55'	131°40'
22	Great Palm I.	18°45'	146°45'	63	New Year I.	10°40'	133°05'
23	Townsville	18°58'	147°04'	64	Cape Wessel	10°43'	136°50'
24	Bowen	19°45'	148°22'	65	Bramble Cay	09°10'	144°00'
25	Hook I.	20°00'	149°00'	66	Darwin West	12°05'	130°30'
26	Mackay/Hay Point	20°46'	149°45'	67	Cape Hotham	12°00'	131°35'
27	Port Clinton	22°15'	151°14'	68	Stretton Strait	11°46'	135°56'
28	Rockhampton	22°30'	151°30'	69	Miller I.	11°43'	136°42'
29	Gladstone	23°06'	152°09'	70	Cape Arnhem	12°21'	137°00'
30	Bundaberg	24°00'	153°05'	71	St Vincents Gulf ports	35°23'	137°41'
31	Sandy Cape	24°50'	154°00'	72	Spencers Gulf ports	35°10'	136°15'
32	Cape Moreton	26°52'	153°54'	73	N. Tasmanian ports	40°20'	146°23'
33	Ballina	29°00'	153°47'	74	S. Tasmania	40°54'	148°52'
34	Clarence R.	30°20'	153°24'	75	S. Tasmania/Hobart	43°25'	148°08'
35	Smokey Cape	30°55'	153°14'	76	S. Tasmania/Hobart	43°27'	147°35'
36	Port Macquarie	31°27'	153°05'	77	S. Tasmania/Hobart	43°46'	146°01'
37	Sugarloaf Point	32°39'	152°30'	78	King I. South	40°20'	144°20'
38	Newcastle	33°03'	152°10'	79	Frederick Reef	21°05'	154°20'
39	Sydney/Botany Bay	33°55'	151°30'	80	Imperieuse Reef	17°31'	118°57'
40	Port Kembla	34°32'	151°15'	81	S. Kangaroo I.	36°00'	136°00'
41	Eden	37°00'	150°20'	82	Saumarez Reef	21°56'	153°35'

AUSREP Australian ship reporting system.

Note 1 to 64 clockwise round mainland from Torres Strait; 65 north-east of Torres Strait; 66 to 70 north coast and islands of the Northern Territory; 71 to 72 and 81 South Australian gulf ports; 73 to 78 clockwise round Tasmania; 79 to 81 offshore reefs.

These data are potentially very valuable and could provide a great deal of information about shipping movements in Australian waters. There are, however, a number of issues such as coverage and unidentified ships which it has not been possible to resolve for this review. The information in figures II.1 to II.6 should

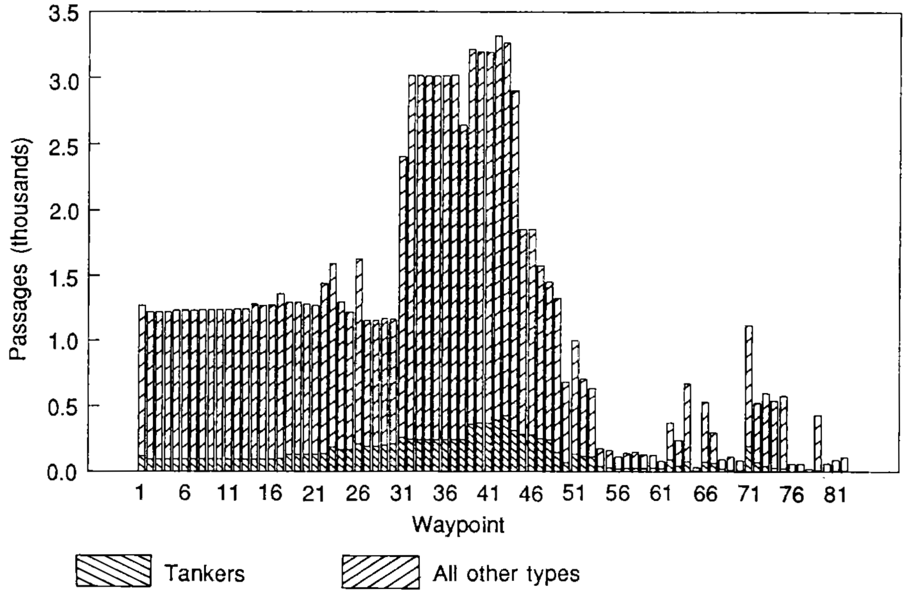

Figure II.1 **Shipping traffic through waypoints, 28 October 1989 to 4 August 1990. See table II.1 for details of waypoints**

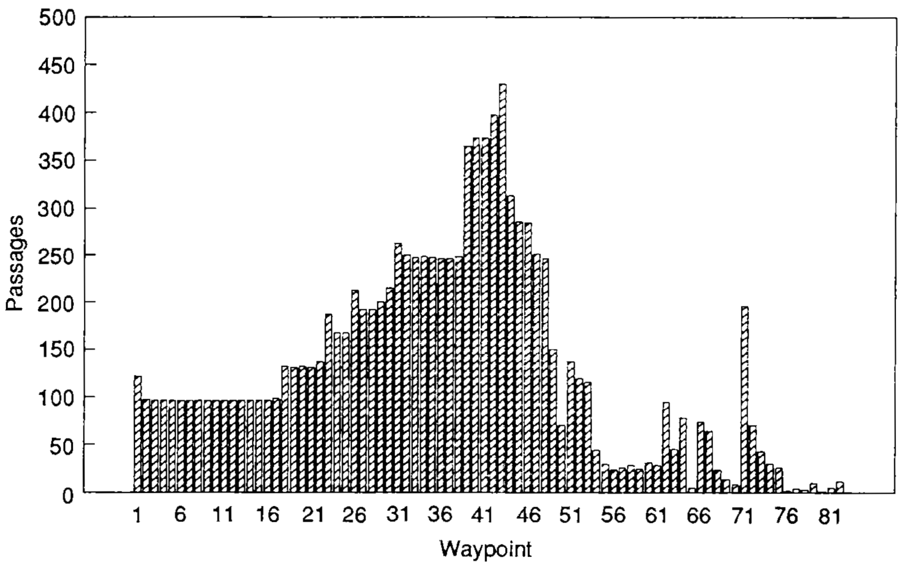

Figure II.2 **Tanker traffic through waypoints, 28 October 1989 to 4 August 1990. See table II.1 for details of waypoints**

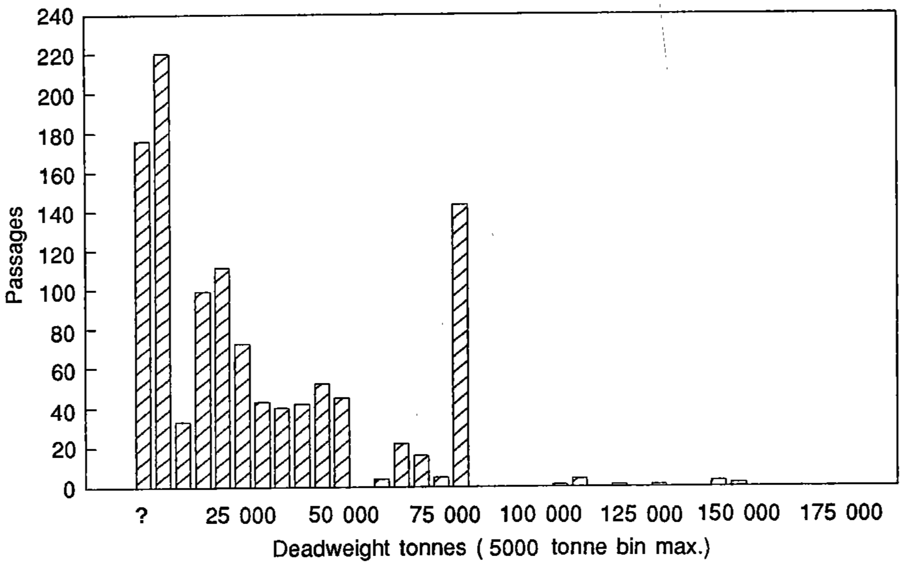

Figure II.3 **Deadweight tonne distribution of non-tankers at Cape Direction (waypoint 9) on the Inner Route of the Great Barrier Reef; 1135 passages in the period from 28 October 1989 to 4 August 1990**

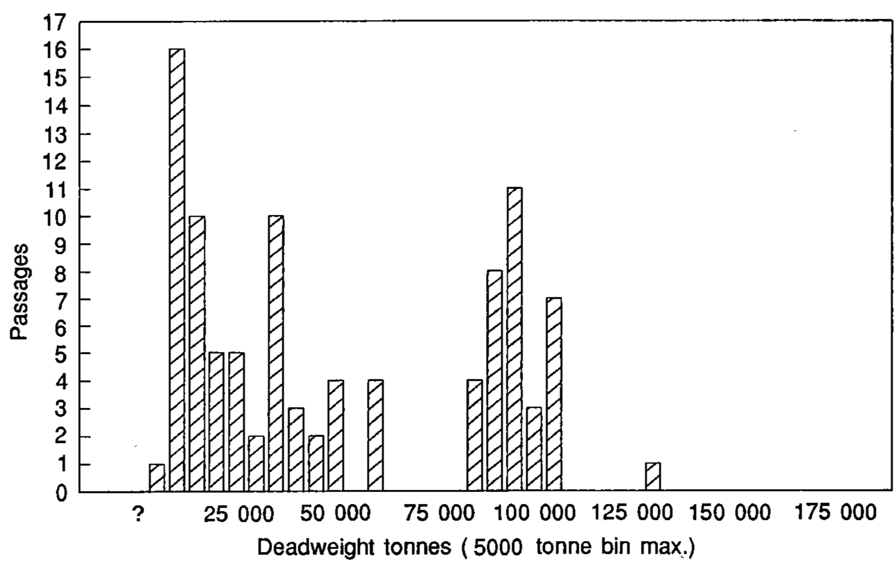

Figure II.4 **Deadweight tonne distribution of tankers at Cape Direction (waypoint 9) on the Inner Route of the Great Barrier Reef; 96 passages in the period from 28 October 1989 to 4 August 1990**

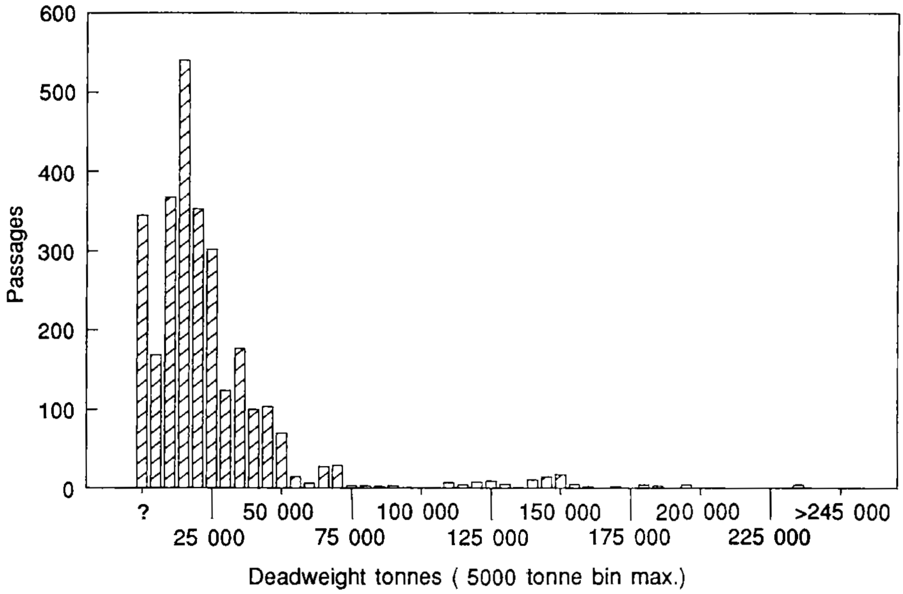

Figure II.5 **Deadweight tonne distribution of non-tankers at Wilsons Promontory (waypoint 43) in Bass Strait; 2836 passages between 28 October 1989 and 4 August 1990**

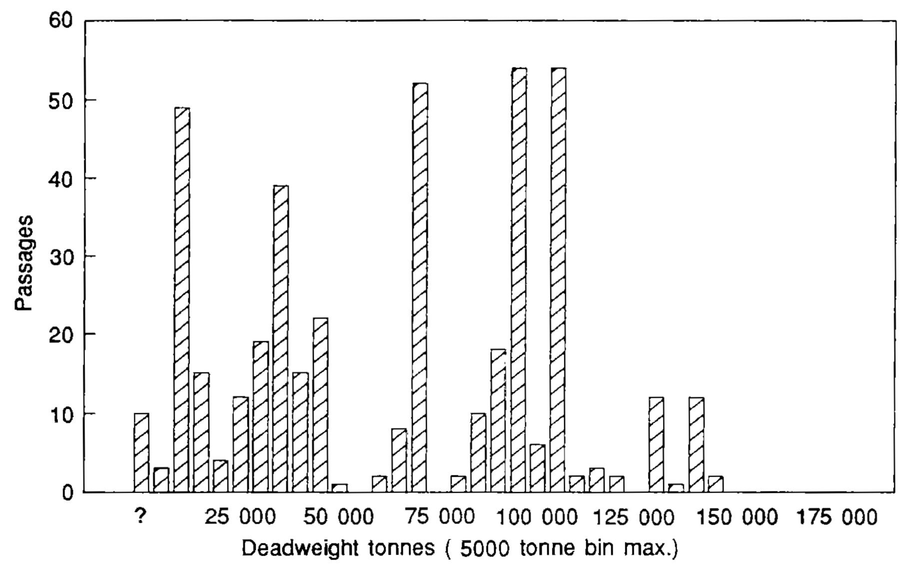

Figure II.6 **Deadweight tonne distribution of tankers at Wilsons Promontory (waypoint 43) in Bass Strait; 429 passages between 28 October 1989 and 4 August 1990**

therefore be treated as only approximate. Traffic volumes may be multiplied by 1.3 to obtain values on an annual basis.

Figure II.1 shows total traffic through the waypoints. The constant level of about 1200 passages during the period corresponds to the Queensland coast between Booby Island (waypoint 1) in the Torres Strait and Bundaberg (30). The peaks at 17 (Cairns), 23 (Townsville) and 26 (Mackay/Hay Point) represent vessels using passages through the Great Barrier Reef. The broad peak of about 3000 passages extends from 32 (Cape Moreton/Brisbane) to 44 (Port Philip/Westernport). Traffic near the coast then falls off steadily around to North West Cape (53) as routes to and from the Atlantic, Suez, South Asia and East Asia branch off successively. Traffic is sparse on the North West Shelf. Note that the sequence of waypoints is not strictly consecutive; 71 and 72 (St Vincents and Spencers Gulf ports), for instance, would more naturally fit between 46 and 47; see table II.1.

Figure II.1 includes tanker traffic. Tankers average about 12 per cent of total traffic over the whole range, and between 8 and 12 per cent on the busy section between Brisbane and Melbourne. Tanker traffic is shown separately in figure II.2. The traffic rises in steps along the Queensland coast from just under 100 passages on the Inner Route north of Cairns (17), 130 between Cairns and Townsville (23), 170 between Townsville and Mackay/Hay Point (26), and 200 between there and Bundaberg (30). These steps presumably represent the distribution of products from southern refineries to the Queensland ports. The plateau at about 250 passages extends from Cape Moreton (32) outside Brisbane to Newcastle (38). The heaviest tanker traffic extends from Sydney (39) to the maximum of 430 passages at Wilsons Promontory (43). The traffic then falls off round the coast in a way which reflects the total traffic pattern. Recall that 71 (St Vincents Gulf ports) would fit more naturally between 46 and 47.

Distributions of vessel size can be provided for the traffic through any of the waypoints. Figures II.3 to II.6 show the distributions separately for non-tankers and tankers at waypoints 9 (Cape Direction on the Inner Route of the Great Barrier Reef) and 43 (Wilsons Promontory). The distributions use a bin size of 5000 deadweight tonnes (dwt). In the figures, the bins are labelled by their upper bounds, that is, the bin 25 000 counts the passages of vessels between 20 000 and 25 000 dwt. The leftmost bin, labelled ?, counts passages where the vessel size was not given. The count in '?' for non-tankers is proportionately greater because passages where the vessel type was not given were treated as non-tankers. Some of these, perhaps 10 per cent, may have been tankers.

In figure II.3, the peak of 140 at 75 000 to 80 000 dwt is due to the bauxite traffic between Weipa and Gladstone.

Of most concern, from the point of view of major oil spills, are the 34 passages (figure II.4) of vessels over 80 000 dwt along the navigationally difficult Inner Route of the Great Barrier Reef.

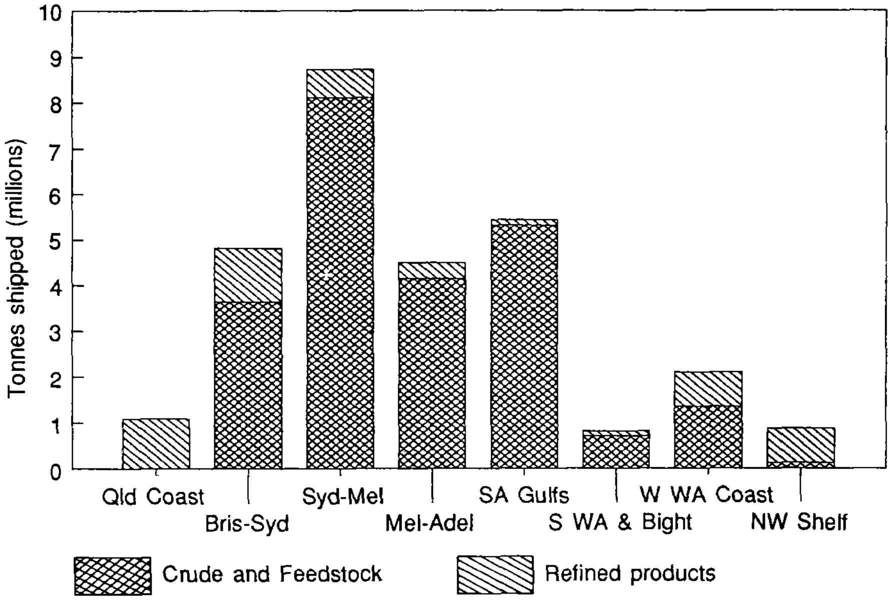

Figure II.7 **Shipments of petroleum (crude oil and refined products) near sections of the east, south and west Australian coast, 1986-87**

The distribution of non-tankers at Wilsons Promontory (figure II.5) peaks at 10 000 to 15 000 dwt and falls to low levels by 75 000 dwt, though there is a long tail out to 200 000 dwt.

Tankers at Wilsons Promontory (figure II.6) are more uniformly distributed to 105 000 dwt with smaller numbers out to 150 000 dwt.

PETROLEUM SHIPMENTS AROUND THE AUSTRALIAN COAST

Figure II.7 presents information derived from BTCE (1989). The east, south and west coasts of the continent from approximately Cairns to Broome are divided into the indicated sections. The bars give the quantities of feedstock (including crude oil) and refined products passing (in both directions) near each coastal section.

(Note that a label such as Syd–Mel refers to a stretch of coast past which petroleum is shipped; it does not imply that the corresponding quantity of petroleum is shipped from one city to the other.)

This figure is broadly consistent with the information on tanker traffic in figure II.2: refined products along the Queensland coast; peak traffic between Sydney and Melbourne; substantial traffic between Brisbane and the South Australian gulf ports; and much less in the west.

APPENDIX III SHIPPING ACCIDENTS NEAR THE AUSTRALIAN COAST

Records of shipping accidents in Australian waters are kept by the Maritime Operations Division of the Commonwealth Department of Transport and Communications. The records are kept primarily as a contingency in case of subsequent litigation, rather than as a basis for statistical analysis. It is likely, however, that most incidents involving substantial loss or damage (loosely defined) would be included in the Maritime Operations Division records.

The Maritime Operations Division provided information on 23 incidents which occurred during the period 1981–88. The information included: ship name, gross registered tonnage, and flag; the type, date and location of the incident; whether a pilot was on board; and a brief description of the damage. Table III.1 summarises the information about the type, date and location of incidents. In the table, the Australian coast has been divided into nine sections along which the coastal traffic is approximately uniform. Except for the first three, the sections correspond to those used for figure II.7. Groundings, collisions and other incidents are shown for each year and each coastal section. Incidents near Sydney have been included in the Sydney–Melbourne section, and those near Melbourne in the Melbourne–Adelaide section. The table omits the northern coast from King Sound (Derby) to the Torres Strait, both because no incidents were recorded in this section and because the shipping traffic information is patchy.

In figure III.1, the accidents on each section (for the whole period) are related to coastal traffic in an attempt to derive traffic based accident rates. It must be emphasised that the resulting accident rates reflect the special features of each section of coast, in particular, their different lengths, navigational hazards and types of shipping; they are not applicable in other contexts.

The upper graph (a) in the figure shows numbers of accidents on each section, taken from table III.1. With the exception of the first section, the numbers are low — which will lead to large statistical uncertainties in the estimated rates.

Graph (b) shows the annual coastal traffic for the sections. The values are derived from figure II.1 and are subject to the uncertainties about those data mentioned in appendix II. The numbers of passages through the waypoints on

TABLE III.1 SHIPPING ACCIDENTS AROUND THE AUSTRALIAN COAST 1981 TO 1988

Section of coast	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*Total all types*
Torres Strait and Inner Route of the Great Barrier Reef south to Cairns				C	CCG	GG	GGG		9
Remainder of Great Barrier Reef Marine Park					GG		G		3
Bundaberg to Sydney	G	C							2
Sydney to Melbourne	O				G	O	C		4
Melbourne to Adelaide				CO					2
South Australian gulf ports									0
South WA Coast (from Fremantle) and Bight				G					1
West WA Coast (Fremantle to North West Cape)		C						G	2
North West Shelf (North West Cape to Yampi Sound)				O					1
Total all types	2	2	0	5	6	3	5	1	24

C Collision
G Grounding
O Other

Source Information provided by the Maritime Operations Division of the Department of Transport and Communications

each section were averaged and multiplied by 1.3 (to convert to annual values). It was assumed that traffic has not changed substantially since 1981.

In graph (c), the accident numbers from (a) are divided by the accumulated traffic exposure over the period (annual traffic from (b) multiplied by the 7.3 years for which accident data were provided) to provide a crude estimate of the accident rate for each section. The notable feature is the (relatively) high accident rate on the Torres Strait and Inner Route, and the North West Shelf sections. The former is high because of the relatively large number of accidents on this section; the latter, despite the single accident, because of the low traffic.

The significance of these rates is put in perspective by the confidence intervals shown in graph (d). Little significance can be attached to the high rate on the North West Shelf because of the very wide confidence interval (a ratio of 7.3 between the upper and lower 80 per cent confidence limits) associated with the single accident. Much the same is true for all sections except the first (Torres Strait and Inner Route).

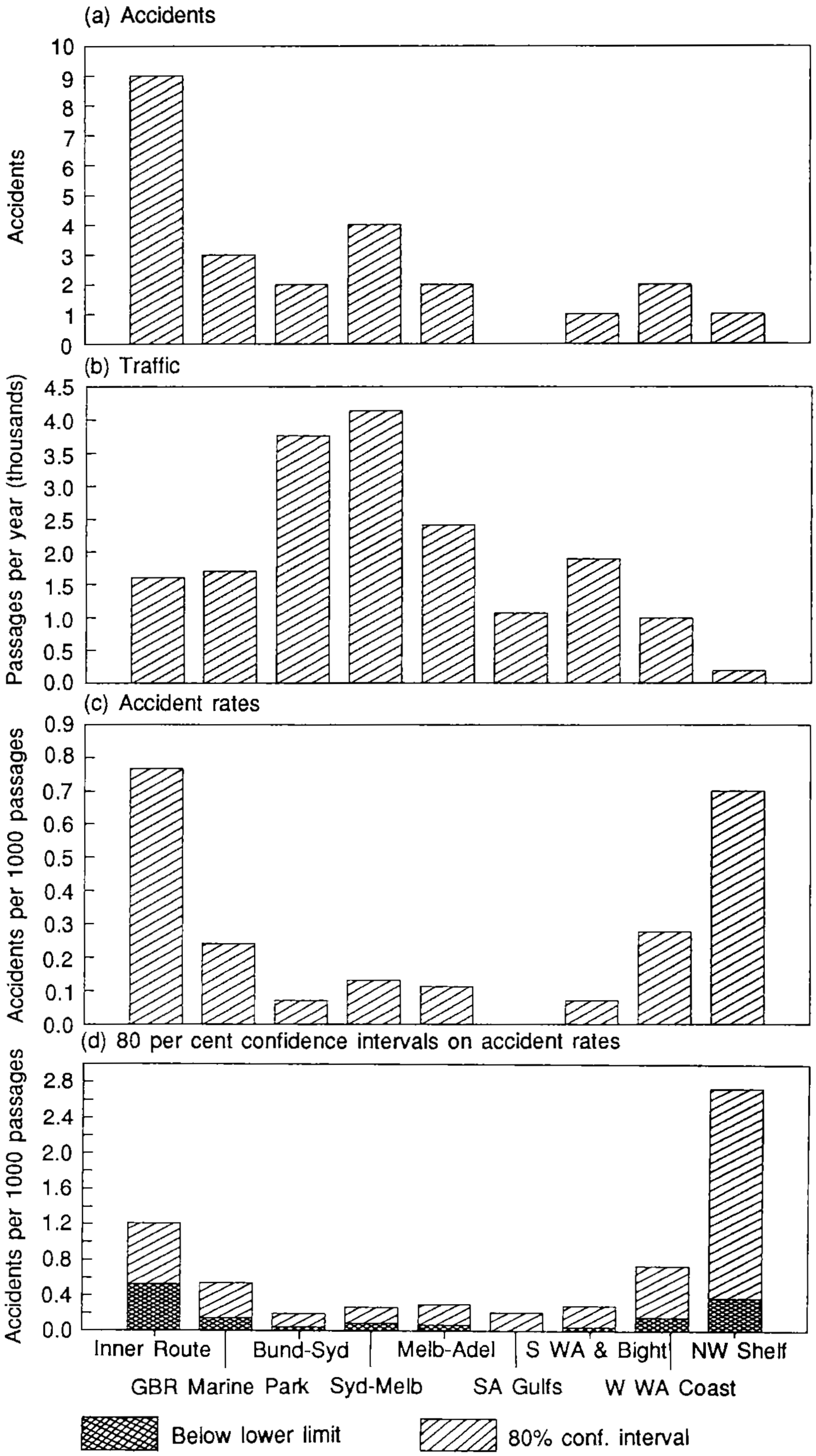

Figure III.1 **Shipping accidents, traffic and accident rates on the Australian coast 1981-88**

TABLE III.2 ACCIDENT RATES ON THE TORRES STRAIT AND INNER ROUTE OF THE GREAT BARRIER REEF: SIX YEARS TO AUGUST 1990
(accident rate per thousand passages[a])

Type of accident	*Number of accidents*	*Central estimate*	*80% confidence interval*	
			Lower limit	*Upper limit*
Collisions				
Piloted	2	0.25	0.14	0.66
Unpiloted	2	1.11	0.61	2.96
Total	4	0.40	0.25	0.81
Groundings				
Piloted	1	0.12	0.07	0.48
Unpiloted	7	3.89	2.59	6.54
Total	8	0.81	0.55	1.31
Total	12	1.21	0.87	1.80

a. Assuming annual traffic for six years of 1650 passages per year, of which 1350 are piloted and 300 unpiloted.

Source Evanson & Potts (1990); BTCE calculations.

In the case of the Torres Strait and Inner Route section, while the 80 per cent confidence interval is still wide (a ratio of 2.3 between the upper and lower limits), it does seem that the accident rate is substantially above that on the other sections, and may be worth further investigation.

Evanson and Potts (1990) derived accident rates for a total of 12 incidents on this section for the six years to August 1990. Their data and findings are summarised (with modifications) in table III.2.

Evanson and Potts provided a caution regarding the reliability of the estimated rates in view of the small numbers of incidents. They did not, however, give the confidence intervals shown in table III.2 and illustrated in figure III.2. They also noted that the incidents did not occur uniformly along the route, but were concentrated in four locations.

These accidents rates were compared among themselves, to bring out the effect of piloting, as well as with worldwide and specific overseas rates in an attempt to compare the Inner Route situation with other comparable locations.

PILOTAGE

The grounding rate for unpiloted vessels appears to be over 30 times greater than for piloted vessels. Even taking account of the uncertainties due to the small

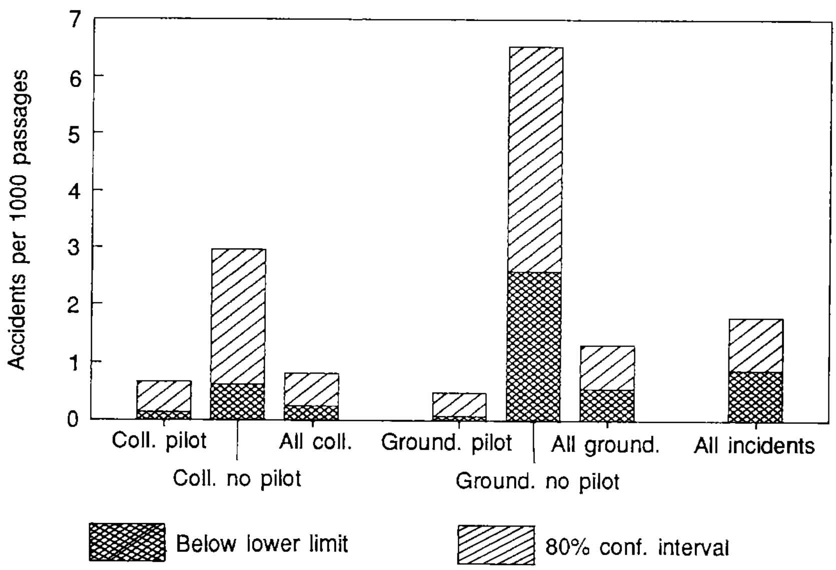

Figure III.2 **Shipping accidents rates (80 per cent confidence intervals) in Torres Strait and the Great Barrier Reef Inner Route north of Cairns 1985-90; collisions and groundings, with and without pilots and all accidents**

numbers (figure III.2), pilots clearly provide a very significant reduction in the grounding rate.

The collision rate for unpiloted vessels is about 4.5 times greater than for piloted vessels. In this case, the significance of the finding is less clear as the confidence intervals for the estimates (figure III.2) are not well separated. It is also unclear to what extent the pilots' specifically local knowledge will contribute to collision avoidance.

COMPARISON WITH OTHER LOCATIONS

A rigorous comparison is extremely difficult because of the many local factors affecting the rates. Nevertheless, the evidence, such as it is, suggests that the Great Barrier Reef Inner Route may have a relatively high risk of collision. For example, although the absolute numbers are small, the rate is 25 times that in the much busier Dover Strait. Possible reasons for this are less disciplined navigation and watchkeeping by fishing vessels on the Great Barrier Reef Inner Route (all four collisions were with fishing vessels) and reduced visibility for vessels rounding islands and headlands.

Grounding rates appeared to be within the range found for a number of (very loosely) comparable restricted waterways. The most that can be said is that no differences were found sufficiently great (such as the factor of 25 in collision rates) to dominate the other uncertainties in the comparison.

APPENDIX IV DETERMINANTS OF OIL SPILL RESPONSE TIMES

Two components of oil spill response are critically time dependent: the application of dispersants and the protection of assets. From the point of view of response, the basic task is to transport substantial quantities of specialised equipment and materials from a stockpile to the site of the spill. In this appendix, the steps in these transport tasks are identified and rough estimates of their likely durations are given. Appendix V gives a more detailed analysis of the steps whose durations are particularly dependent on the locations of oil spills and equipment stockpiles. Combining the estimates of the durations of the steps on the critical paths gives estimates of the overall response times.

The treatment is highly schematic for three reasons:

- A real response will depend on special features of the location of the spill which it is not feasible to take into account at a strategic level.
- Little planning has yet been done for the response to a major spill in a remote area, in particular for the difficult problem of the 'last leg' of the response. It has therefore been necessary to hypothesise about appropriate arrangements, routes, and vehicles.
- No allowance has been made for administrative or procedural delays. The durations are intended to be plausible indicative times for the completion of the physical processes (generally loading times and transit times).

THE TRANSPORT TASKS

The equipment and materials required at the spill site are assumed to be stored at a single central stockpile. There may, of course, be more than one stockpile, but this will not be considered at this stage. One of the purposes of this analysis is to determine the ability of stockpiles in different locations to provide rapid response to spills along different sections of coast. Unduly slow response from the single stockpile to particular sections of coast may be an indication of the need for an additional stockpile to close the gap.

This analysis is not concerned with the details of the equipment to be carried except to note that it requires heavy lift transport aircraft and mechanical loading equipment. For asset protection the main requirement is for booms. Medium duty boom, suitable for initial response, weighs 7.5 kilograms per metre and is stored in 300-metre lengths weighing 2.25 tonnes. Heavy duty, inflatable, offshore boom is stored on reels in 200-metre lengths. The reels weigh 3.6 tonnes and measure 2.2 x 2.0 x 1.8 metres. The power pack for inflation weighs 650 kilograms.

Dispersant application requires spraying equipment and dispersants. This analysis focuses on aerial spraying by plane or helicopter. The spraying equipment for these aircraft is not particularly heavy, but the exercise requires dispersant to be applied at an oil:dispersant ratio of 20:1 — 50 tonnes of dispersant per 1000 tonnes of oil.

These figures provide an indication of the scale of the transport task. The load for an initial response involving 1000 metres of heavy and 1500 metres of medium duty boom (a very modest response to a large spill) would be about 30 tonnes. Dispersant operations would require certainly tens and possibly hundreds of tonnes of dispersant to have a significant impact.

Three transport tasks are considered:

- booms to the site of the spill; and
- aerial spraying of dispersant, either
  - by plane from an airfield to which supplies can be brought by heavy transport aircraft; or
  - helicopter from a point on the coast closer to the spill, but to which supplies must be brought by road.

The rationale for these aircraft operations is that the rate at which dispersant can be applied is strongly dependent on the distance over which it must operate (between its refuelling and reloading base and the site of the spill). The two operations take advantage of the different strengths of fixed wing aircraft (greater speed and payload) and helicopters (ability to operate from unprepared sites close to the spill). The details are discussed in appendix VI.

All three tasks require the same initial transport stages: road from stockpile to the nearest suitable airport (the 'stockpile airport' or simply the 'airport'); air from the stockpile airport to an airfield in the spill area (the 'spill airfield' or simply the 'airfield' — any landing ground with road access able to accommodate the transport aircraft).

If the spill airfield is sufficiently close to the spill site to serve as a base for aerial spraying by plane (it is unlikely to be sufficiently close for helicopter operations), this may complete the initial heavy transport task.

Spraying operations by helicopter from a base on the coast close to the spill require, in addition, road transport from the spill airfield to the coast base.

Providing booms on the surface at the spill site requires road transport from the spill airfield to a port (the 'spill port' or simply the 'port' — a location with minimal

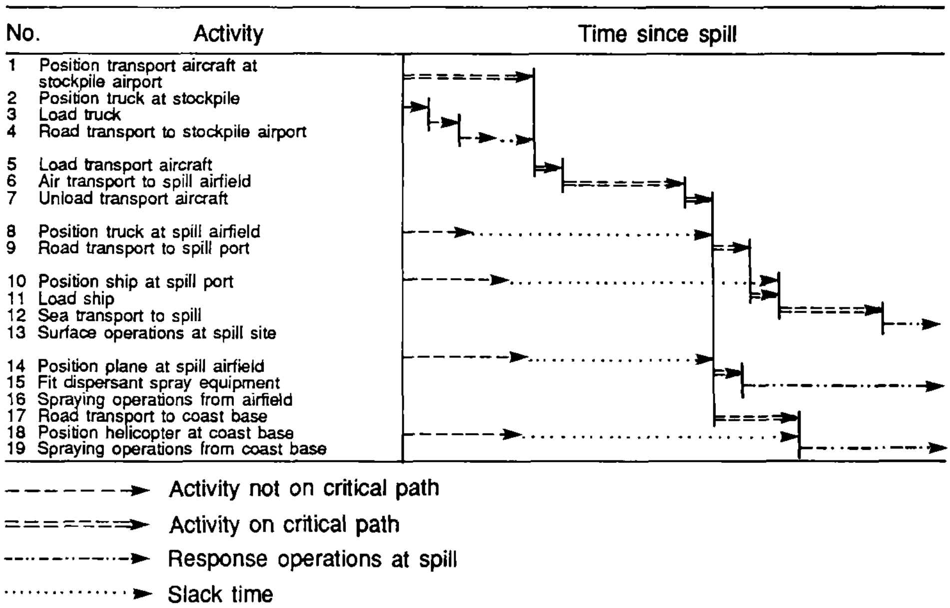

Figure IV.1 Activity schedule and critical paths for oil spill response

port facilities at which heavy equipment can be loaded onto a vessel) and, finally, a sea passage to the spill site.

Figure IV.1 shows the timing of these transport stages, and their dependence on earlier stages and other activities such as loading and unloading and the process of locating and positioning vehicles at the places where they will be needed.

Critical paths for each of the three transport tasks are indicated though, of course, these will depend on the activity times. An overview and estimates of the duration of some of the activities follow. Activities are numbered as in figure IV.1.

Activity 1. Position transport aircraft at stockpile airport

Two arrangements for air transport have been envisaged: the use of RAAF Hercules or domestic commercial aircraft. In both cases the same issue arises: on notification of a spill, aircraft must be located, diverted from current tasks, made ready and flown to the airport where the equipment from the stockpile is to be loaded. The availability of suitable transport aircraft is considered in appendix V.

Activities 2 to 4. Road transport to the stockpile airport

In view of the time to obtain a transport aircraft, these steps are unlikely to be on the critical path. As all stockpiles are located in urban areas, it is assumed that a truck could be on site within half an hour. If equipment were stored on pallets ready for transport it could be loaded within half an hour. Distance to the airfield would vary, but one hour travel time would probably cover most cases.

Equipment should be available at the airfield for loading onto the transport aircraft within two hours.

Activities 5 to 7. Air transport to the spill airfield

Hercules aircraft can be loaded very rapidly from trucks backed directly up to the ramp and equipped to accept their specialised roller pallets. Similar arrangements, also involving specialised equipment, exist for commercial aircraft. However, it seems prudent to assume that loading would be by conventional fork-lift truck and take about an hour.

The flight time to the spill airfield is estimated as distance divided by airspeed. This flight time has been seen as one of the determining factors in the location of stockpiles; it is considered in detail in appendix V.

Unloading at the destination airfield would take about an hour using fork-lift trucks which, in remote areas, might have to be brought in by the trucks coming to receive the load.

Activities 8 and 9. Road transport to spill port

Arranging for a truck to meet the transport aircraft should not be on the critical path.

Road transport of the equipment to port facilities is on the critical path but, because the airfield is usually chosen for proximity to port facilities, the average road travel time is only about half an hour. In some areas, with few airfields able to accommodate transport aircraft, longer road journeys are required with travel times up to four hours. These road journey times are considered in more detail in appendix V.

Activities 10 to 13. Sea transport to the spill site

Ensuring that suitable vessels are available to provide access to the spill and from which surface operations can be conducted may be a limiting factor in remote areas. If suitable vessels are available locally there will probably be plenty of preparation time and positioning the vessel should not be on the critical path. If such vessels are not available locally this could be the source of considerable delay; indeed, information about the availability of suitable vessels will determine the choice of port and airfield. In this analysis it is assumed not to be limiting.

Loading the vessel from the truck is on the critical path and assumed to take about one hour. Minimal port facilities, in the form of alongside road access to the vessel, are required and would be a factor in the selection of the port.

The time for the coastal passage to the site of the spill is determined mainly by the density of port facilities (and availability of suitable vessels) along the coast. In remote areas it makes the single largest contribution to the response time. Its variation around the coast is considered in appendix V.

Following arrival at the spill site it is assumed that adequately effective surface response operations can be conducted. Clearly, this depends on the ability to resupply the operation and to support the personnel and equipment in the field. This ability is not considered in this analysis.

Activities 14 to 16. Dispersant application from spill airfield

It is assumed that fixed wing aircraft suitable for spraying operations over the sea will have been identified previously. These must be located, diverted from current tasks, and flown to the airfield to meet the transport aircraft bringing spraying equipment and dispersant from the stockpile. In most cases, making the spraying aircraft available should not be on the critical path.

Fitting the dispersant spray system would take about one hour, after which spraying operations can begin. The effectiveness of these operations in terms of the rate at which dispersant can be applied is considered in appendix VI.

Activities 17 to 19. Dispersant application from coastal base

If spraying operations were conducted by helicopter from a coastal base, spraying equipment and dispersant would be brought by road from the nearest airfield. The road transport time required is estimated in appendix V.

These operations are assumed to make use of previously identified, locally based helicopters. These would have to be located, diverted from current tasks, and flown to the coastal base for spraying operations. This is assumed not to be on the critical path.

Fitting the underslung spray system used by helicopters is on the critical path but is not a lengthy process; spraying operations can then begin. Their effectiveness in terms of the rate of applying dispersant is considered in appendix VI.

APPENDIX V DURATIONS OF SELECTED RESPONSE ACTIVITIES

In appendix IV the main response activities were identified and approximate durations estimated for the less geographically dependent of them. In this appendix, the durations are estimated for those which will be critically dependent on the locations of stockpiles, airfields, ports — and the spill itself.

Five activities are considered (numbers refer to table IV.1):

- positioning the transport aircraft (1);
- air transport to the spill airfield (6);
- road transport to spill port (9);
- sea transport to the spill site (12); and
- road transport to coast base (17).

The second, third and fourth of these are interdependent and will be considered together in the context of surface access to the spill site, airfield and port being chosen together to minimise total response time. For reasons of clarity, air transport times are considered after the discussion of road and sea transport times.

POSITIONING THE TRANSPORT AIRCRAFT (ACTIVITY 1)

Two arrangements have been envisaged: the use of RAAF Hercules or domestic commercial aircraft. In both cases the same issue arises; on notification of a spill, aircraft must be located, diverted from current tasks, made ready and flown to the airport where the equipment from the stockpile will be loaded.

The RAAF has 12 Hercules aircraft based at Richmond. At all times, one is available for search and rescue work on one hour's notice (that is, airborne within one hour) during working hours and three hours' notice out of hours. Unless it were already engaged, this aircraft could be available for oil spill response. Depending on where they were and what they were doing, two or three additional aircraft could become available within six to eight hours and, in principle, seven or eight within 24 hours.

Initial inquiries suggest that there may be serious limitations on the use of domestic commercial aircraft for oil spill response (J. Halloran, TNT Air Carriers, 1990 pers. comm.). It appears that there may be as few as six dedicated commercial cargo aircraft in Australia:

- one 707 belonging to TNT and operated by Ansett; maximum load 41 tonnes (significantly less on a trans-Australia flight); currently operates mainly on a shuttle service between Melbourne and Perth;
- one 727 belonging to Ansett; maximum load 18 tonnes; operates mainly on the east coast between Brisbane and Tasmania;
- two BAE 146 QT; operate in the east and south-east between Cairns and Adelaide; and
- two DC-9-30 belonging to IPEC, operate between Brisbane and Tasmania.

While these aircraft can lift substantial loads, they are designed to carry air freight containers and generally require specialised loading equipment available only at major airports. Access doors are also restricted and none could pass the heavy duty offshore boom storage reels whose dimensions are 2.2 x 2.0 x 1.8 metres.

The availability of these aircraft at short notice would presumably be the subject of prior negotiation. A limiting factor from the point of view of making unscheduled calls on aircraft would be the availability of crews. RAAF crews could not be used as pilots require clearance for the exact type of aircraft to be flown.

In view of these uncertainties, the availability of RAAF Hercules aircraft is taken as indicative for this exercise: three hours plus the flying time from Richmond to the stockpile airport. Table V.1 shows the flying times from Richmond to potential stockpile sites.

TABLE V.1 FLYING TIMES OF RAAF HERCULES AIRCRAFT FROM RICHMOND TO POTENTIAL STOCKPILE SITES

Potential stockpile site	*Air distance[a] from Richmond (kilometres)*	*Flying time[b] from Richmond (hours)*
Thursday Island	2 698	5.40
Townsville	1 643	3.29
Brisbane	722	1.45
Melbourne (Avalon)	752	1.51
Perth	3 250	6.50
Port Hedland	3 493	6.99
Darwin	3 100	6.20

a. Great circle distance.

b. Distance divided by speed (270 nautical miles per hour = 500 kilometres per hour).

Source BTCE estimates.

Adding three hours (notification time) to the times in table V.1 gives positioning times of the order of ten hours in the north and west (Perth to Darwin) and progressively shorter times in the east. The possibility of additional aircraft becoming available within the six to eight hours from the time of the spill has been mentioned and, if these were engaged in the stockpile area, they could conceivably become available more rapidly. Clearly, however, this could not be relied upon.

The fact that commercial aircraft operations are mainly in the east and south suggests that they would not be able to respond more rapidly in the north-west (even assuming the other restriction could be resolved).

RESPONSE TIME FOR SURFACE ACCESS TO THE SPILL SITE (ACTIVITIES 6, 9 AND 12)

In order to estimate response time as a function of location, representative points at which oil spills might occur were chosen at 50-kilometre intervals around the entire Australian coast, a total of 304 points. For each point, an access airfield and port were identified through which response equipment would pass en route to a spill.

The representative points were marked out on the 1:1 000 000 maps of the *Reader's Digest Atlas of Australia* (1977) and the ports and airfields were chosen after reference to these maps and to road routes in the *Reader's Digest Motoring Guide to Australia* (1982). The airfields were selected from those shown in the Department of Transport and Communications *Annual Report* (1989).

In principle, the airfield and port for access to each point were selected to minimise overall response time taking into account the location of the stockpile. In practice, the speed differences between the transport modes mean that the overriding consideration is to minimise, first, the distance by sea from port to spill and, second, the distance by road from airfield to port.

Figure V.1 shows the surface transport times to each of the 304 representative points around the Australian coast, assuming road and sea speeds of 60 kilometres per hour and 12 knots (19.8 kilometres per hour) respectively.

ROAD TRANSPORT FROM AIRFIELD TO PORT (ACTIVITY 9)

The road contribution (airfield to port) is small except between Sydney and Melbourne (Avalon), near the South Australian Gulfs and on the coast of Western Australia between Cape Leeuwin and Geraldton. Figure V.2 shows the distribution of these road transport times. The mean time is about 30 minutes and, in almost 90 per cent of the cases the time is less than 1 hour reflecting the fact that the airfields were chosen for proximity to the port. However, in a small number of cases road distances of up to 250 kilometres are involved.

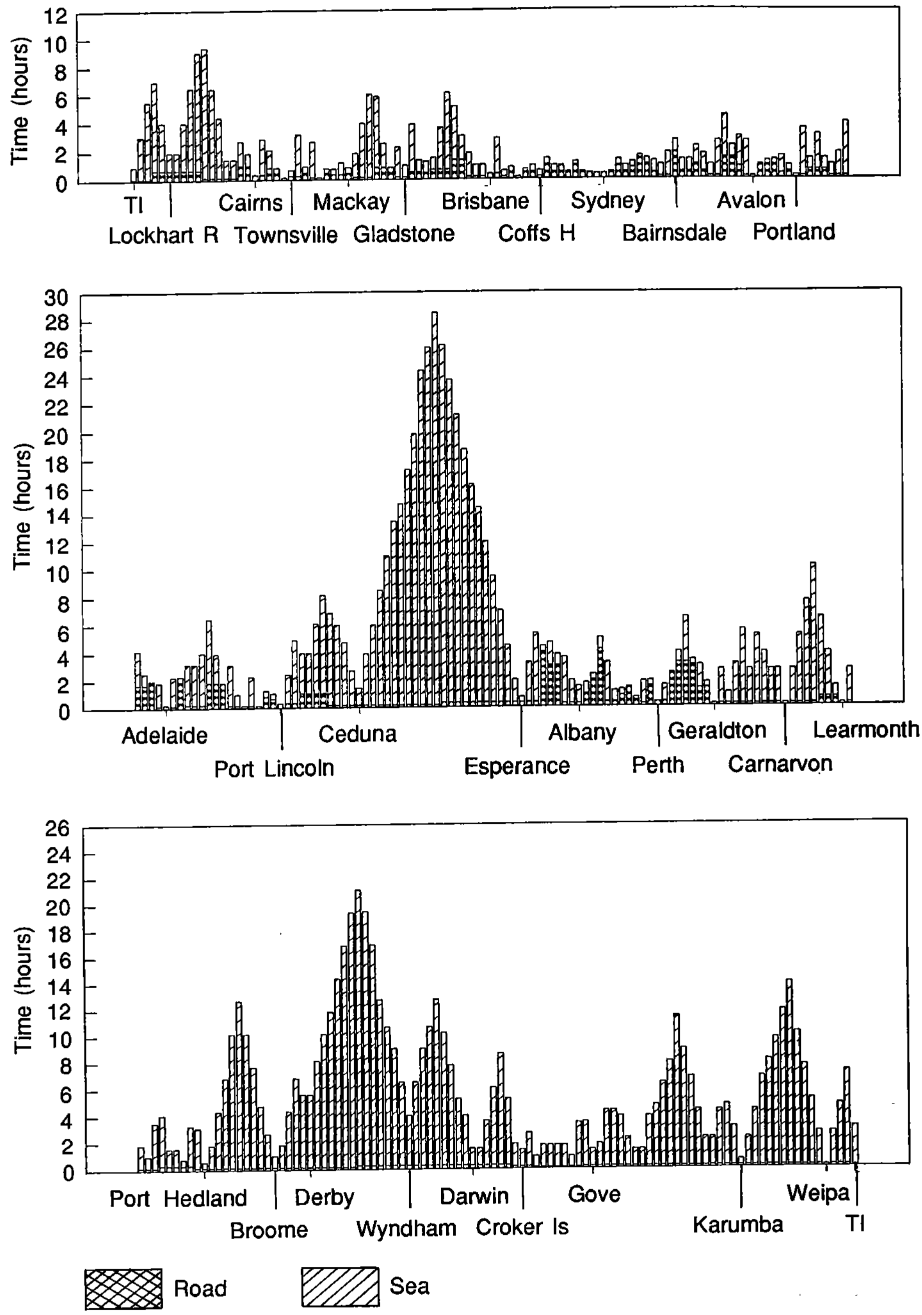

Figure V.1 **Road transport and sea passage times for access to oil spill sites at 50-kilometre intervals around the Australian coast**

SEA TRANSPORT FROM PORT TO SPILL (ACTIVITY 12)

In figure V.1, the characteristic pattern for the sea passage times to a sequence of representative points between two access ports is a triangle which peaks at the midpoint and falls to zero at each of the ports. The most striking case is in the Great Australian Bight where it is assumed that there are no port facilities between Ceduna and Esperance. The sea passage time to a point midway between these ports is about 28 hours. Other notable peaks occur along the Kimberley coast between Broome/Derby and Wyndham (21 hours) and in the Gulf of Carpentaria between Karumba and Weipa (14 hours).

Figure V.3 shows the distribution of sea passage times for the whole coast. For 67 per cent of the coast the time is less than four hours (which is also the mean time), and for 10 per cent of the coast the time is greater than ten hours.

AIR TRANSPORT FROM THE STOCKPILE AIRPORT (ACTIVITY 6)

The air transport times from stockpiles located at Melbourne (Avalon), Port Hedland and Townsville are shown in figure V.4. The step between Ceduna and Esperance reflects the absence of port facilities along this coast and corresponds to the maximum sea passage times shown in figure V.1. The maximum air transport time is about seven hours from each stockpile and corresponds to crossing the continent. One of the main arguments against a single centralised stockpile is that it necessarily involves air transport times of this order when responding to events on the other side of the continent. By having subsidiary stockpiles the response time is reduced to that from the nearest stockpile. The effective air transport time is then the minimum envelope of the three (in this case) curves plotted in figure V.4.

The contribution of subsidiary stockpiles to reducing the air transport time is shown in another way in figure V.5. The figure shows the distributions of air transport times for various combinations of stockpile locations. The rightmost curve is that for a single stockpile at Melbourne using the airport at Avalon (A). The air transport time, in responding to a spill anywhere on the coast, would be under seven hours — as can also be seen from figure V.4. Half the coast (50 per cent) would have an air transport time of less than five hours.

The effect of a second stockpile at Port Hedland, in addition to that at Melbourne (Avalon) is shown by the second curve from the right (A + PH). The air transport time to a spill anywhere on the coast is reduced to less than 5.5 hours but, more significantly, half the coast would have an air transport time of less than 2.5 hours.

A third stockpile, at Townsville, reduces the maximum air transport time to less than 3.5 hours as shown by the third curve from the right in figure V.5 (A + PH + T). Almost half the coast is within 1.5 hours air transport time. This stockpile, of course, covers the important Great Barrier Reef section.

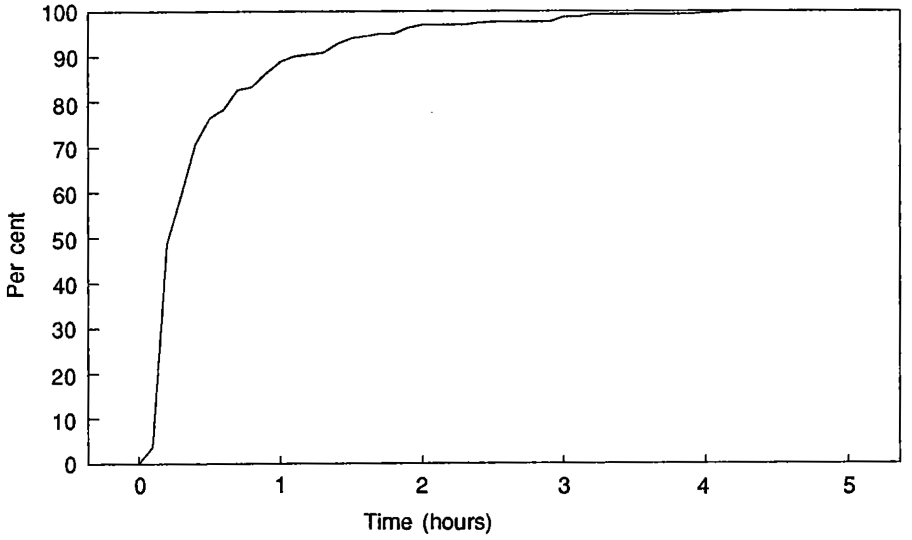

Figure V.2 **Cumulative distribution of road transport times between airfield and port for oil spill response**

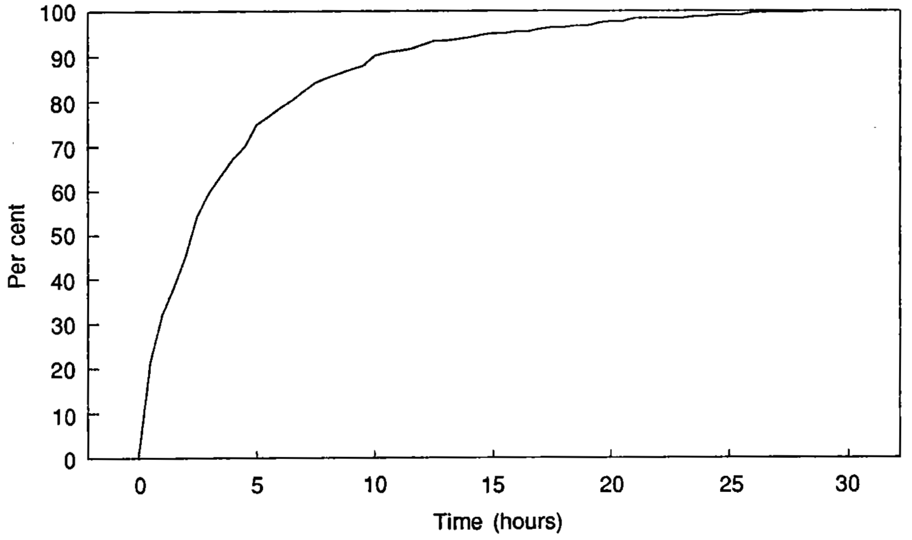

Figure V.3 **Cumulative distribution of sea passage times from port to oil spill site**

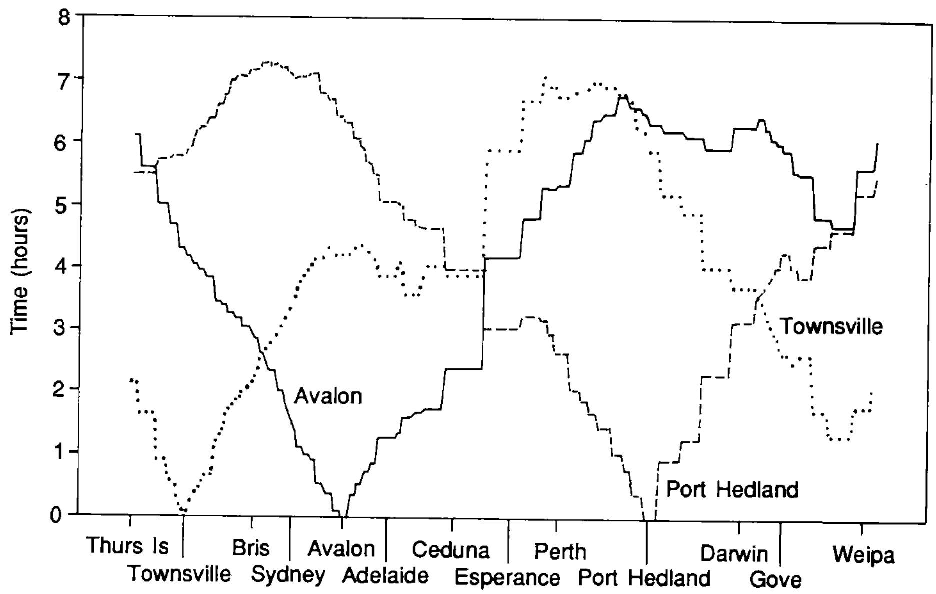

Figure V.4 **Air transport times for oil spill response from stockpiles at Melbourne (Avalon), Port Hedland and Townsville**

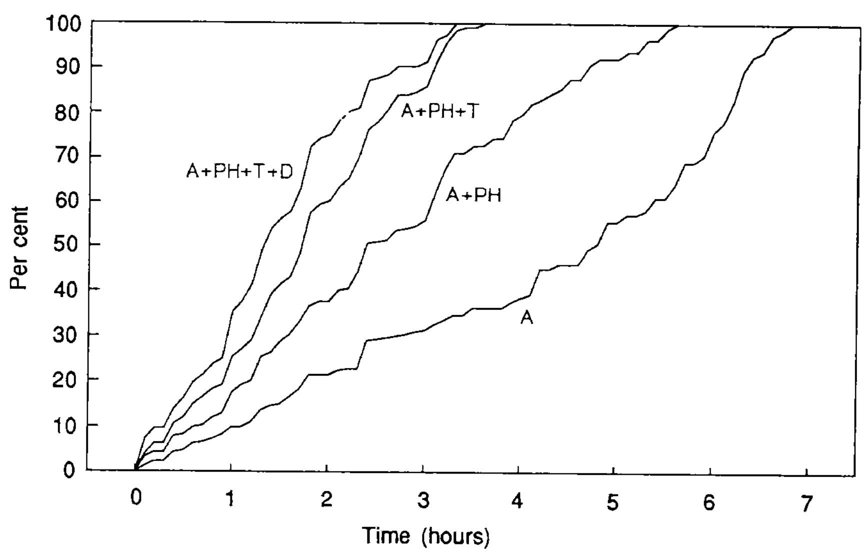

Figure V.5 **Cumulative distribution of air transport times for various combinations of stockpile locations: Melbourne (Avalon) (A), Port Hedland (PH), Townsville (T) and Darwin (D)**

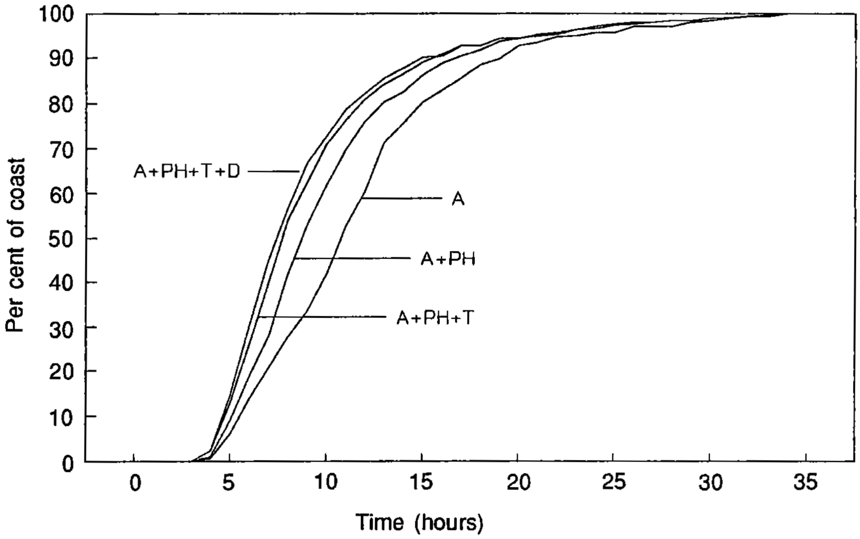

Figure V.6 **Cumulative distribution of percentage of coast accessible in a given response time from combinations of stockpile locations: Melbourne (Avalon) (A), Port Hedland (PH), Townsville (T) and Darwin (D)**

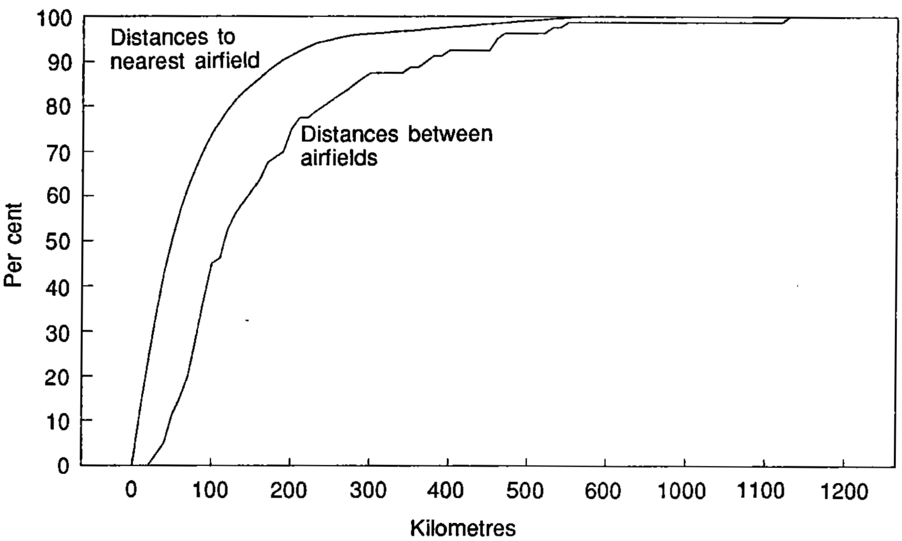

Figure V.7 **Cumulative distributions of distances between airfields and straight-line distance to nearest airfield for oil spill response**

Finally, the leftmost curve in figure V.5 (A + PH + T + D) shows the effect of a fourth stockpile at Darwin. Little further reduction in air transport time is gained.

STOCKPILE LOCATION AND SURFACE RESPONSE TIME

Figure V.6 (analogous to figure V.5) shows the impact of stockpile location on overall surface response time, including all activities on the critical path (table IV.1) *except* activity 1, positioning the transport aircraft at the stockpile airport.

Each of the three loading activities is assumed to take one hour (hence all distributions start at three hours). Air transport times are as given in figure V.4, and road and sea transport times as in figure V.1. The four distributions correspond to those in figure V.5, that is, from the right: (A) stockpile in Melbourne (Avalon) alone; (A + PH) Avalon and Port Hedland; (A + PH + T) Avalon, Port Hedland and Townsville; and (A + PH + T + D) Avalon, Port Hedland, Townsville and Darwin.

From Avalon alone, 50 per cent of the coast can be covered in under 11 hours; this falls to about eight hours with additional stockpiles at Port Hedland and Townsville. Little is gained from a fourth stockpile at Darwin.

The most remote 10 per cent of the coast cannot be reached in under 15 hours, reflecting the dominance of the surface and particularly the sea transport times in these areas.

It must be emphasised that this assessment does *not* include the initial positioning time for the transport aircraft.

ROAD TRANSPORT TO A COASTAL BASE (ACTIVITY 17)

The airfields used in this analysis were selected because they were close to the ports which provide surface access to the spill. No separate identification of airfields for aerial spraying operations has been made. To the extent that there are suitable airfields in addition to those already selected, the estimates in this section will be pessimistic. This bias is countered to some extent by the optimistic assumption that suitable roads exist and that the distance by road to the nearest airfield is close to the straight-line distance.

With these assumptions, the maximum overland distance to be travelled will be somewhat over half the distance between the two airfields on either side (along the coast) of the spill. Assuming that oil spills might occur anywhere along the coast, the actual distance to be travelled would vary from some small value (if the spill occurred near an airfield) to this maximum. Figure V.7 shows the distribution of distances between adjacent airfields and also the distribution of the distance to the nearest airfield from a randomly located spill.[1]

The mean distance between airfields is 170 kilometres, and 75 per cent of these distances are less than 200 kilometres. The mean (straight-line) distance from a coastal base near the spill (from which dispersant spraying by helicopter could be conducted) to the nearest airfield is about 80 kilometres, and this distance is less than 100 kilometres over almost 75 per cent of the coast.

Making some allowance for the existence and directness of roads, an average road transport time from airfield to coastal base of about two hours seems appropriate.

1. This distribution is based on the following assumptions: suitable roads exist; road distances are close to the straight-line distances; and the coast runs close to the line between adjacent airfields.

APPENDIX VI THE APPLICATION OF DISPERSANTS FROM THE AIR

Dispersant application is the most time sensitive part of oil spill response. Estimates vary, depending primarily on oil viscosity, temperature and wave action, but in most cases it is assumed that dispersants must be applied within 48 hours of the release of the oil. While oil may certainly be released progressively, for the purpose of this analysis it is assumed that dispersants must be applied within 48 hours of the start of the spill.

This appendix is concerned with the logistics of applying dispersants from the air. Dispersants may also, of course, be applied from the surface but, in view of the limited time available and the distances involved, air may be the only possibility. In any case, the logistics of applying dispersants from the surface will not be very different from those of other surface response operations, and these are dealt with in appendixes IV and V.

The object of the analysis is to relate the scale of the task (dispersing some thousands of tonnes of oil on the sea off a remote section of the coast) to resources and operational constraints. The operations considered are highly idealised and the focus is on the purely physical constraints of a trouble-free operation; questions of maintenance, downtime, fatigue and so on have been ignored. The resulting estimates are therefore optimistic.

RATE OF APPLICATION OF DISPERSANTS BY AIRCRAFT

The basic operation consists of an aircraft (helicopter or fixed wing) fitted with dispersant spraying equipment operating from some suitable airfield as near as possible to the oil spill. The aircraft shuttles between the airfield, where it reloads and refuels, and the spill, on which the dispersant is sprayed. The critical parameters which govern the effectiveness of the operation are:

- the distance of the spill from the airfield;
- the aircraft transit speed;
- the time on task at the spill — searching for and evaluating the oil, and spraying the dispersant;
- the turnaround time at the airfield — taxiing, refuelling and loading dispersant; and

TABLE VI.1 OIL DISPERSANT APPLICATION BY DIFFERENT AIRCRAFT AT VARYING DISTANCES

	Helicopter	*Fixed wing*
Transit speed (km/hr)	185	300
Time on task (minutes)	15	15
Turnaround time (minutes)	10	15
Dispersant load (tonnes)	0.9	2.0
Dispersant applied in 12 hours (tonnes) for distance to spill:		
10 km	19.8	42.0
30 km	14.4	34.0
50 km	10.8	28.0
100 km	7.2	20.0

Source BTCE estimates.

- the dispersant load — determined either by the capacity of the spraying equipment or the aircraft load limit.

These parameters determine the rate at which dispersant can be applied by a single 'effective' aircraft. Note that more than one actual aircraft would be required to ensure that one 'effective' aircraft was always available.

Table VI.1 gives estimates of the quantity of dispersant which may be applied by a single 'effective' aircraft in a 12-hour daylight period. Two different aircraft types are considered, a helicopter carrying an underslung spray system of the type widely available in National Plan stockpiles, and a fixed wing aircraft carrying one of the systems being purchased for the Australian Institute of Petroleum stockpile in Melbourne. With the assumed parameters, the helicopter applies between a third and a half of the quantity applied by the aeroplane, and the effectiveness of the aeroplane at 100 kilometres is the same as that of the helicopter at 10 kilometres.

For both types of aircraft, the quantities applied are modest. Assuming an oil to dispersant ratio of 20:1, the aeroplane operating over only 10 kilometres is able to disperse only about 800 tonnes in 12 hours — possibly up to 1600 tonnes in the total of 24 hours of daylight available during the 48 hours after the spill. This is a small but significant proportion of the total under consideration (10 000 tonnes) and might be adequate if the focus were limited to the most threatening small fractions of the spill. However, this is the most favourable ideal case. Clearly a considerable number of aircraft (not forgetting back-ups in order to make up the number of effective aircraft) and sets of spraying equipment would be needed to disperse any substantial proportion of the spill.

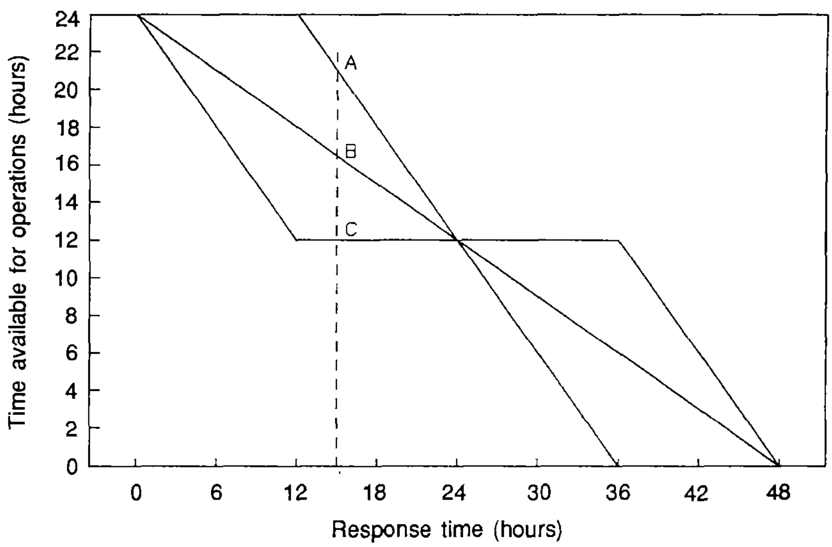

Figure VI.1 Dependence of time available for operations on response time and time of day of spill - see text

TIME AVAILABLE FOR AIR SPRAYING OPERATIONS

Seasonal variations aside, during the 48 hours after the spill, there will be 24 hours of daylight (in two or three periods) during which dispersants can be sprayed from the air. Depending on the time of day of the spill and the response time (the time taken to set up the air spraying operation as discussed in appendixes IV and V), some of this time may be lost. Figure VI.1 shows how the time available for operations varies with these two factors. For example, the dotted line corresponds to a response time of 15 hours. Assuming 12 hours of daylight from 6 a.m. to 6 p.m., the best time for the spill to occur would be between 3 p.m. and 6 p.m. as this would allow the whole of the subsequent night (when spraying is not possible) to be used for setting up, and only 3 hours of daylight spraying time would be lost. The remaining 21 hours would be available for operations (A). On the other hand, if the spill occurred between 3 a.m. and 6 a.m. the whole of the first 12 hours of daylight would be lost, leaving only 12 hours for operations (C). Assuming spills could occur with equal probability at any time of day, the best estimate for the time available for operations is the average of 16.5 hours on the central diagonal (B).

The figure shows that, on average, half the response time will be lost from the maximum operational time of 24 hours. Estimates of the response time are discussed in appendixes IV and V.

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Abbreviations

AGPS	Australian Government Publishing Service
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics

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ABBREVIATIONS

1972–73	Australian fiscal year 1 July to 30 June
AIP	Australian Institute of Petroleum
AUSREP	Australian ship reporting system
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
dwt	Deadweight tonne
MOSAP	Marine Oil Spills Action Plan
OCS	US outer continental shelf
RAAF	Royal Australian Air Force
UK	United Kingdom
US	United States