Preliminary interpretation of report by Technica Ltd on "Risk assessment of ammonia import facility, Kwinana"

Environmental Protection Authority
Perth, Western Australia
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PRELIMINARY INTERPRETATION OF REPORT BY TECHNICA LTD ON

"RISK ASSESSMENT OF AMMONIA IMPORT FACILITY, KWINANA"

MAKING A SUBMISSION

The Environmental Protection Authority invites people and organisations to make comments on this Bulletin.

The purpose of this Bulletin is to provide an initial Environmental Protection Authority response to the Technica report on the "Risk Assessment of Ammonia Import Facility, Kwinana". The Authority's response is based on its proposed criteria for the assessment of acceptability of risk levels imposed on the public by development of hazardous industry. Therefore this Bulletin should be read in conjunction with "Review of the guidelines for risk assessment in Western Australia". Also of relevance to this matter is the update of the Kwinana Cumulative Risk Model which has been carried out for the Department of State Development. This is used as the Base Case to which the ammonia shipments are added. This update is to be published in the very near future. However, access to the Kwinana Cumulative Risk Model is not a necessary prerequisite to comment on this report.

Due to concerns about risk levels in the vicinity of the ammonia importing facility, the Environmental Protection Authority commissioned Technica Ltd, Consulting Scientists and Engineers, to carry out a study into the importation of ammonia through the Bulk Cargo Jetty by Kwinana Nitrogen Company.

The purpose of the report was to analyse the risks to the public in the Kwinana area, with and without the ammonia import facility. The Authority was then to assess the risk levels against the draft revised guidelines and criteria to answer the question "Is public safety adequately protected?"

This Bulletin gives some background to the project and events which surrounded two shipments of ammonia in 1989. There is a preliminary interpretation of the report based on proposed acceptable risk criteria. Finally there is a statement of suggested actions and their priority based on the implications for exposure of the public to unacceptable risk levels.

Comments are being sought on this report from the public, industry and Government agencies, to assist the Authority in preparing a final report with recommendations to Government for an action programme.

The closing date for comments is 26 April 1991.

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
1 Mount Street
PERTH WA 6000

Attention: Dr B Kennedy

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Appendix

1. Introduction

The purpose of this Bulletin is to provide an initial Environmental Protection Authority response to the Technica report on the "Risk Assessment of Ammonia Import Facility, Kwinana". A copy of the Technica report is attached as Appendix 1.

The Authority's response is based on its present position on the matter of appropriate criteria for the assessment of acceptability of risk levels imposed on the public by development of hazardous industry. Therefore this Bulletin should be read in conjunction with "Review of the guidelines for risk assessment in Western Australia". The Summary from that review is attached as Appendix 2 to enable easy reference. Also of relevance to this matter is the update of the Kwinana Cumulative Risk Model which has been carried out for the Department of State Development. This is used as the Base Case to which the ammonia shipments are added. This update is to be published in the very near future, but the main results are included in Appendix 1 of this document.

Due to an apparent land use conflict in the vicinity of the ammonia importing facility, the Environmental Protection Authority commissioned Technica Ltd, Consulting Scientists and Engineers, to carry out two studies. The first was a review of risk criteria used around the world, and this report has been made publicly available as part of the "Review of the guidelines for risk assessment in Western Australia" at present in progress.

The second report was into the importation of ammonia through the Bulk Cargo Jetty by Kwinana Nitrogen Company. This report was paid for by the Authority (75%) and Kwinana Nitrogen Company (25%). Two shipments in late 1989 were the cause of concern, particularly over the requirement by the Environmental Protection Authority that a public exclusion zone be put in place over the area of Kwinana Beach. This requirement was motivated by concern at the perceived high level of risk during the operation, and a belief that emergency response capabilities were inadequate to deal with evacuation of members of the public in the unlikely event of a major incident.

The purpose of the second report was to analyse the cumulative risks to the public in the Kwinana area, with and without the ammonia import facility. The report is presented in full as Appendix 1 to this document. The Authority was then to assess the risk levels against the draft revised guidelines and criteria to answer the question "Is public safety adequately protected?"

Since the public input period for the review of guidelines has not yet been completed, and since the matter of ammonia importation was one of the significant triggers for the review, the Authority believes it appropriate to release the second report immediately. This will allow those with an interest in the matter to have an actual example of the application of the proposed guidelines, thereby improving the level of understanding and input to the debate on both matters.

In their report on ammonia importation, the criteria used by Technica to provide the basis for their findings and recommendations, differ from those presently favoured by the Authority for application in Western Australia. Therefore it is essential that the Authority provides a preliminary interpretation of the Technica report based on the Authority's favoured position.

This Bulletin gives some background to the project and events which surrounded two shipments of ammonia in 1989. There is a preliminary interpretation of the report based on the proposed acceptable risk criteria. Finally there is a statement of suggested actions and their priority based on the implications for exposure of the public to unacceptable risk levels.

2. Background

In August 1988, CSBP and Norsk Hydro received conditional environmental approval from the Minister for the Environment for the development of an Ammonia/Urea Plant at Kwinana. The project involved, in part, the manufacture of ammonia and its export onto the world market.

Due to changes in the economics for ammonia, the Ammonia/Urea project has been delayed. Kwinana Nitrogen Company, part-owned by CSBP, therefore applied to the Environmental Protection Authority to activate those parts of the proposal related to ammonia storage and shipping, and to use

these facilities to import rather than export ammonia. The Authority agreed that this could proceed on the basis of the conditions set for the Ammonia/Urea Plant.

This importation was commenced in late 1989, with two shipments of 6000 tonnes being received. These shipments were a cause of concern, particularly over the requirement by the Environmental Protection Authority that a public exclusion zone be put in place over the area of Kwinana Beach. This requirement was motivated by concern at the perceived high level of risk during the operation, and a belief that emergency response capabilities were inadequate to deal with evacuation of members of the public in the unlikely event of a major incident. It should be noted that had the Kwinana Integrated Emergency Management System been in place to cater for such incidents, then the need for public exclusion would have been considerably reduced.

To provide some commonality of understanding on the issues involved, and the means of assessing the importance of these issues, the Authority engaged Technica Limited of London to provide an input into the review of risk guidelines in Western Australia, and to analyse and make recommendations on the risk implications of hazardous industry. The analysis was to concentrate on ammonia importation and the impact on the Wells Park area, and it is this work which is discussed in this Bulletin.

In this Bulletin the term Kwinana Beach denotes the previous residential area bordered by Cockburn Sound (west), the railway (east), CSBP (north) and CBH (south). Wells Park is the recreation area bordered by Kwinana Beach Road and between Wells Road and John Street, and Cockburn Sound.

3. Interpretation of the Technica Report

3.1 Accuracy of the analysis

The ammonia import operation is amongst the most extensively analysed of all hazardous industries in Western Australia. The present Technica report is the fourth risk analysis carried out by different consultants. Although the details within each analysis vary, the overall conclusions in terms of safety are similar. The operation, when combined with the existing risk levels from other industry, would preclude the development of residential areas close to the industrial sites. The existing closest residential areas such as Rockingham, Leda, Calista and Medina meet the present acceptable risk criterion. However, all studies identified possible emission events which could impact on residential areas, and which result in high risk levels in the immediate surrounding area including the area of public access at Wells Park.

Section 3 of the Technica report contains the analysis of the importation facility. The accuracy of this section has been reviewed by the proponent, Kwinana Nitrogen Company, and they consider that this part of the work is technically correct.

Since the Authority's judgement on acceptability of risk is based on cumulative risk levels from all industries in the Kwinana Industrial Area, the Kwinana Cumulative Risk Model is the main decision-making tool. The main output from this model is presented in the Technica report in the form of contours of individual risk. As noted in the report this cumulative model has recently been updated to include "as-built" data for plants and to use the latest version of the SAFETI computer model. This work was carried out for the Department of State Development. A copy of cumulative risk contours is included in the Technica report (Appendix 1), with the full report expected to be available in the very near future.

3.2 Environmental Protection Authority comments

3.2.1 Introduction to report

The Authority believes that the work by Technica, on the Base Case and the review of ammonia importation, is sufficient to form an adequate basis for decision-making.

In regard to the comments made in Section 1.2 of the attached report on the previous studies on the ammonia terminal and the updated Base Case, the Authority agrees that the terminal satisfies the existing criterion for cumulative risk in residential areas.

The comments made at the end of Section 1.2 about the influence of management on failure frequencies and types are regarded by the Authority as self-evident. This is the basis for the Authority's recommendation on "life-of-plant" risk management programmes for hazardous industries which it assesses. These generally are given the title of Total Hazard Control Programmes.

3.2.2 Base Case cumulative risk

As noted above the Authority regards the Base Case, detailed in Section 2 of the Technica report, as a sufficient basis for decision-making. There is some conservatism in the choice of failure frequencies, and the risks are interpreted for residential areas on the basis of 100% occupancy.

Assessment of the acceptability of the individual risk levels is provided in Section 3.3 below.

Since the concept of societal risk is relatively new to Western Australia, it is appropriate that some comments be made on this section. Firstly, it should be noted that the terms "infrequent" and "more frequent" are relative when allied to the number of people who could be involved in an incident. The actual frequencies are low, with the frequency for one death being once in 40,000 years. Although the Authority does not favour the setting of criteria for societal risk at this time, the curve shown in Figure 2.2 generally would represent moderate risk of a low number of deaths to very low risk of a high number of deaths.

The Authority sees no cause for immediate action to reduce these societal risk levels. It shows the value of buffer zones around hazardous industry, from the viewpoint of both industry and residences.

Because the risk criteria presently favoured by the Authority are somewhat different to those used by Technica in Section 2.4 of their report, the results are reassessed below.

It should be noted that in assessing the acceptability of the risk levels shown in Figure 2.1, Technica have applied a "presence factor" for land uses other than residential uses. The factors are 10% for recreational users and 25% for other workers. These are then applied to give the values in Table 2.1 of the Technica report.

In the approach used by the New South Wales Department of Planning, and favoured by the Authority, the presence factor is applied for various land uses, in conjunction with other factors such as vulnerability of the population concerned. These are used to derive "acceptable risk" criteria for a variety of land uses. The Authority's proposed criteria are shown in Table 1 below. These values can then be used to evaluate acceptability directly from the contour maps without the need for further calculations.

Table 1. Suggested individual risk criteria for different categories of the public
(Taken from "Review of the Guidelines for Risk Assessment in Western Australia")

Land Use	Suggested Criterion (risk of death per million people per year)
Sensitive uses including hospitals, schools, child-care facilities, old age housing	0.5
Residential including hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Workers on other industrial sites	50

3.3 Compliance with proposed criteria

3.3.1 Base Case

The Base Case is assessed below for the land uses listed in Table 1.

Sensitive uses - None known.

Residential - The only residential area exposed to non-negligible risks is the northern part of Rockingham near the CBH Facility. The risk levels are below one-in-a-million deaths per year, and are therefore acceptable. But residential developments in the form of new subdivisions or increased residential densities should be avoided.
However it is understood that the owner/operators of the Bottle Shop opposite Wells Park reside on the premises. Risk levels in this area are 10-in-a-million deaths per year. The Authority believes that this inappropriate land use should be terminated as soon as possible.

Commercial - As indicated above, risk levels at the Bottle Shop are 10-in-a-million compared with the suggested criterion of 5-in-a-million for commercial areas. This is unacceptable. The Authority believes that this inappropriate land use should be terminated as soon as possible.

Recreation - Risk levels in the Wells Park recreation area vary from about 30-in-a-million close to the Bulk Cargo Jetty to 7-in-a-million near the boat ramp. Technica's assessment puts this in the zone of action to make the risks as low as reasonably practicable (ALARP). At this time the Authority does not fully accept the concept of ALARP because it would seem to allow for exceedences above "acceptable risk" criteria. For the Base Case, risk levels over approximately two thirds of the Wells Park Beach south of the bulk cargo jetty to the wreck exceed the Authority's suggested criterion of 10-in-a-million deaths per year. Therefore a land use conflict exists and action should be taken.

It should be noted that some action has been taken already to manage the risk levels from surrounding industry, and this has been incorporated in the analysis of the Base Case. Also, the Authority considers that a safety margin should be applied to new developments in areas affected by industrial risks, to protect the integrity of any buffer zone.

Therefore the Authority believes that there should be no further development or intensification of recreation land uses at Wells Park. There should be a programme developed for provision of similar facilities at a more suitable location over a period of time, to reduce the number of people exposed to risk. Given the existing level of risk, this should be of low to moderate priority. An exception to this is the urgent need to avoid use of the area for activities, such as concerts, involving large numbers of people, even for short periods of time. The reasons for this are:

- the impact of any incident;
- the possibility of panic should a minor incident occur; and
- the difficulty of maintaining security at neighbouring industries and therefore preventing incidents through vandalism.

Industrial - At this stage, the level of detail is inadequate to identify any areas where workers offsite could be exposed to risk levels above 50-in-a-million. Also, these populations are not included in the societal risk analysis so any comment on this aspect would be inappropriate.

On the matter of the societal risk information presented in the report, the Authority notes the comments that "there are very few offsite populations within the range of the majority of accidents modelled. This is to be expected in the Kwinana area, given the relatively large separation distances .....". The Authority believes that this is an important feature of the Kwinana Industrial Area which should be strenuously protected against conflicting land uses.

The term "potential loss of life" (Section 2.4.2) has not been used in any previous study to which the Authority has access. The Authority does not have any background information on which to base judgements on the values contained in the report.

3.3.2 Import Case

The following conclusions can be drawn from Figure 4.1 of the Technica report, which gives the cumulative individual risk levels including the Import Case.

Residential - The inclusion of the ammonia facility moves the one-in-ten-million contour several hundred metres to the south to cover more of the residential area of Rockingham north of Victoria Road. While not resulting in a situation of unacceptable risk, it does reinforce the comments on the Base Case that intensification of residential uses in this area would be inappropriate. Potential to develop hazardous industries which would increase risk levels in this area is also limited.

Commercial - No additional commercial premises are subjected to risk above 5-in-a-million with the inclusion of the ammonia import facility in the analysis.

Recreation - With the influence of the ammonia case, the level of risk over almost the whole of the Wells Park recreation area exceeds the suggested criterion of 10-in-a-million. While not changing the conclusion above for the Base Case, the Authority believes that there is a corresponding increase in the urgency of action to rectify this conflict.

A particular concern, because of the direction of increase in risk, is the small recreation hall to the south of the Kwinana Beach area. This is owned by Rockingham City Council and leased to the Naval Association, who sub-lease it to a variety of community groups as a meeting hall. It is understood that this is in use almost every night, and is the only hall suitable for small groups in the Rockingham area. The Authority believes that the hall should be relocated to another, more suitable, site. Although not urgent at this stage, this should be progressed as part of an overall plan to reduce land use conflicts due to risk levels.

Industrial - No change.

While not commenting on the acceptability of the societal risk curve, the Authority notes that the increases reflect the extension of the individual risk contours to the south. This reinforces the need to ensure that any future expansion of industrial activity which increases risk levels in Rockingham north of Victoria Road is carefully analysed and assessed.

3.3.3 Additional controls on unloading

Section 4.4 of the Technica report analyses the main contributors to the increase in risk. Section 6.1 makes recommendations as to possible further improvements of the emergency shutdown system, to reduce the duration of major releases. While accepting that there may be practical limitations to the installation of these additional controls, the Authority believes that the proponent should fully investigate their options in this regard.

The Authority accepts the desirability of applying all cost-effective measures to reduce risk. However, the Authority also recognises that, even with such measures for the ammonia import, many of the land use conflicts would remain due to the Base Case. The Authority believes that it will remain necessary to reduce exposure of the public to the overall risks in the area.

3.3.4 Exclusion zone at Wells Park

The imposition of an exclusion zone during the two ammonia shipments in 1989 caused considerable adverse community reaction. While recognising the social impact of such restrictions on access to

public areas, the Authority considers that the latest study, coupled with the lack of an integrated emergency response system, provides support for such action.

In the light of the detailed information now available the Authority believes that there should be some changes in the extent of controls on access. Firstly there should be no public access to the area adjacent to the Bulk Cargo Jetty at any time. It is suggested that the appropriate cutoff should be at the southern boundary of the Fremantle Port Authority land. This achieves the minimum exposure of the public to the high risk levels which exist in the area at all times. It also gives a better level of security for the wharf area, including the pipelines for hazardous materials which traverse the area.

Secondly, the public should be excluded from the Wells Park recreation area, including the car park, during the ammonia unloading operations. The public road could remain open, but parking should not be permitted. There should be an investigation of the need for further periods of closure during the movement of other hazardous materials, since it is understood that these operations were not part of the Base Case.

Thirdly, the Authority is in complete agreement with the statement by Technica that "future developments which might significantly increase the length of time spent by individuals in this area should be avoided". In particular, the present focus on Wells Park as a recreation area is inappropriate and should be redirected. Further funding by Government is inappropriate and also should be redirected. The community aspects of such redirection should be an integral part of the strategy to handle this issue.

4. Draft programme of action

The Authority believes that the exposure to risk for members of the public should be kept as low as reasonably practicable (ALARP). Given all the information provided in the Technica report and the previous risk analyses, the Authority believes that the following programme of action is appropriate to reduce the land use conflicts and public risk exposure in the Kwinana Beach area:

- The residential use of the Bottle Shop premises should be stopped immediately.
- The Bottle Shop and associated ice works should be removed as soon as possible.
- Public access to the beach area immediately south of the Bulk Cargo Jetty should be permanently closed off as soon as possible.
- The public should be excluded from the Wells Park recreation area during the ammonia unloading operations. The public road could remain open, but stopping should not be permitted.
- The proponent should report, as soon as possible, on the feasibility of implementing the suggested additional controls.
- There should be no use of the Wells Park area for activities, such as concerts, involving large numbers of people, even for short periods of time.
- The existing buffer zone of the Kwinana Industrial Area should be protected against conflicting land uses by the development of appropriate planning policies.
- There should be no further development or intensification of recreation land uses at Wells Park. There should be a programme developed for provision of similar facilities at a more suitable location over a period of time, to reduce the number of people exposed to risk.
- The Kwinana Beach recreation hall should be relocated.
- There should be an investigation of the need for further periods of closure of Wells Park during the movement of other hazardous materials over the Bulk Cargo Jetty.

- The present focus for the upkeep and improvement of the Wells Park recreation area should be redirected to more suitable locations.

- Residential developments in the Rockingham area north of Victoria Road in the form of new subdivisions or increased residential densities should be avoided.

Appendix 1

Copy of Technica Report

Technica

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RISK ASSESSMENT OF AMMONIA IMPORT FACILITY, KWINANA

FOR

ENVIRONMENTAL PROTECTION AUTHORITY, WESTERN AUSTRALIA

REPORT 2

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Technica
C2192/AHJ

February 1991

RISK ASSESSMENT OF AMMONIA IMPORT FACILITY, KWINANA
FOR
ENVIRONMENTAL PROTECTION AUTHORITY, WESTERN AUSTRALIA
REPORT 2

CONTENTS PAGE

SUMMARY

This report describes the results of an assessment of the cumulative risk levels in the Kwinana area arising from industrial activities. The report presents the second and final phase of a study for the WA Environmental Protection Authority conducted by Technica. The first phase is a discussion of public risk acceptability criteria for the Kwinana area. The criteria developed in the first phase are used in this report.

Two cases of industrial activity are analysed in this study: the "Base Case" which consists of existing industries, and the "Import Case" which consists of the Base Case plus the ammonia bulk import and storage facility at Kwinana. Approximately 150,000 tonnes per year of refrigerated ammonia will be brought by gas carrier to the Kwinana Bulk Cargo Jetty. A mobile loading arm is installed on each visit to an existing fixed pipeline from the jetty to the plant storage area onshore. This currently consists of one 10,000 tonne tank, and a further 30,000 tonne tank is under construction to provide capacity for the imported ammonia.

The Base Case cumulative risks to the public (individual and societal) are well below the upper limit of tolerable risks for total industry in the area. The individual risks are negligible (below 10^{-7}/year) for the majority of the Kwinana area population. The individual risk levels over the Kwinana Beach area (to the south of the Bulk Cargo Jetty) are also below the tolerable limit, but in the "ALARP" region (between 10^{-5}/year and 10^{-7}/year). The risks over Barter Road Beach area are lower than on Kwinana Beach due to the greater distance between Barter Road beach and the main industrial sites. The risks to typical recreational users of this area vary from below the negligible limit of 10^{-7}/year, up to a maximum of about three times this value. The individual risks are therefore more significant over Kwinana Beach than Barter Road Beach.

In the Import Case, the overall risks in the area remain well below the individual and societal risk upper limits of tolerability. The overall societal risks are increased more significantly than the overall individual risks; however, the societal risks due to the import facility alone are well below the upper limit for single existing plants. The import facility causes an increase in risks over the Kwinana Beach area but it remains in the "ALARP" region. The risks over Barter Road Beach area are not significantly affected by the import facility.

Since the import facility can be considered to fall in the "ALARP" region of societal risk, the scope for remedial measures should be investigated, in order to ensure that all reasonable measures have been taken to minimise the risks. The main causes of risk from the import facility are the loading arm and pipeline. A number of possible risk-reducing measures for these are suggested.

Regarding the Kwinana Beach area, the import facility increases individual risks but does not make a substantial difference to the risk assessment of this area: the risk levels remain within the "ALARP" region. The close proximity of the beach area to the main industrial areas means that there is little margin between existing risk levels and upper limits of tolerability. Developments or activities leading to individuals spending more time, or large numbers present at any one time, in this area may therefore lead to intolerable risks to the public. Similarly, new industrial developments close to the beach area may also cause intolerable risks in this area.

It is understood that the EPA is likely to adopt risk criteria similar to the New South Wales approach. This differs slightly from the criteria developed in the first report, in that although the range of acceptable individual risks remains betwen 10^{-5}/year and 10^{-7}/year, proposals exposing individuals to risk levels above the midpoint value of 10^{-6}/year would be deemed to need further work with the aim of reducing risks to below 10^{-6}/year. Thus, a target level of 10^{-6}/year is likely, with risk levels exceeding this being judged more stringently than under the "ALARP" approach.

Using this approach, the base case cumulative individual risk levels remain below the target value of 10^{-6}/year for residential areas, but the Kwinana Beach area is exposed to risk levels which border on the central target value for the criterion for 'active open spaces'. They would therefore fall under 'ALARP' considerations. This remains the case with the import facility incorporated into the cumulative risk model.

There are a number of alternatives open for consideration under this principle because of the diversity of risk reducing measures available, and the current stage of the update of the KCRA Base Case model (soon to be released to the public).

1. INTRODUCTION

1.1 Background

The Environmental Protection Authority of Western Australia has asked Technica Ltd to assess the risks to the public of ammonia import activities at Kwinana. Bulk importing of ammonia by ship has not occurred routinely in the past. However, in order to satisfy an increasing demand for ammonia in the Kwinana industrial area, CSBP are intending to operate an import and storage terminal to handle up to nine bulk shipments, or 150,000 tonnes, of ammonia annually.

One shipment of ammonia has already been received. Currently the imported ammonia is unloaded at the Kwinana Bulk Cargo Jetty (BCJ) and transferred via a fixed pipeline to a 10,000 tonne storage tank on the Kwinana Nitrogen Company (KNC) site. A further 30,000 tonne storage tank and associated equipment is being constructed to meet the increased volume of imported ammonia.

Safety studies of the loading facility, existing pipework and storage tank have already been conducted by Industrial Risk Management (IRM) Pty. Ltd. (Ref. 1) and Det Norske Veritas (Ref. 2). These have concluded that the existing ammonia import facility satisfies WA legislation controlling the risks to the public from industrial activities.

Technica has conducted a risk analysis study of the entire Kwinana Industrial Area (Ref. 3). This produced the Kwinana Cumulative Risk Model, which has been updated in subsequent studies by Technica to reflect further industrial developments in the area. The 30,000 tonne storage tank was incorporated into the model (Ref. 4) but this was at a stage where the actual site and pipe route had not been finalised, and no design details were available.

1.2 Objectives

This report is the second Technica report to the EPA: the first was a discussion document on the subject of risk criteria (Ref. 5). This report presents an analysis of the cumulative risks to the public in the Kwinana area, with and without the ammonia import facility.

The specific objectives of this report are outlined below.

1. Present the cumulative risk levels (individual and societal) for the "Base Case" situation, i.e. for all existing industries, including the KNC storage tank, but excluding the ammonia import facility (loading arm, pipeline and 30,000 tonne tank).

2. Assess whether the risk levels in the Base Case are acceptable according to the criteria developed in conjunction with the EPA; areas of specific concern are the Kwinana Beach area and Barter Road Beach, which are recreational areas near the BCJ.

3. Analyse the risks due to the import facility on the basis of 9 shipments per year, and calculate the new cumulative risk levels with the ammonia import facility included. This is referred to as the "Import Case".

4. Assess whether the risk levels in the Import Case are acceptable, with particular regard to the beach areas near the BCJ.

The analysis of the import facility takes into account information obtained from the earlier studies by IRM and DnV; however, information provided directly by CSBP is incorporated and the analysis is conducted independent of previous approaches. The risks of fatality to members of the public only are calculated; onsite (i.e. hazardous industry) workers are not included.

The present study covers the shipping and unloading activities, pipeline, 30,000 tonne storage tank and associated equipment. The study does not include an analysis of the destinations of the imported ammonia or changes to other plant in the Kwinana area which might arise as ammonia importing increases. The analysis uses generic failure rate data (escribed in Appendix I), which has been derived from world-average experience. The management systems applied to the import facility can have a significant effect on failure rates; however an assessment of this is outside the scope of this study. It is assumed that a high level of management procedures (training, reporting, etc), typical of hazardous installation operation, is applied to the facility.

2. BASE CASE CUMULATIVE RISKS

2.1 Base Case Plants and Activities

The base case is defined as the set of hazardous industries and activities contributing to the Kwinana cumulative risk levels, without the proposed ammonia import operation. The base case consists of the following contributors:

- WMC nickel refinery
- SECWA pipeline
- WANG pipeline
- KNC plant (including 10kte tank and transfer pipe to WMC)
- CSBP fertiliser plant
- BP refinery
- Kleenheat LPG depot
- Wesfarmers LPG plant
- CSBP sodium cyanide plant
- Nufarm plant
- CSBP chlor-alkali plant
- ICI zirconia plant
- CIG plant

These facilities were modelled using SAFETI in the original Kwinana study (Ref. 3). All of the modelling has been subsequently upgraded to the latest version of SAFETI (3.1). Some facilities have been fully remodelled to reflect the current conditions on those facilities (Ref. 7). Note that hazardous materials transport in the Kwinana area is not included in the risk results shown in this study, in accordance with previous risk assessment studies.

2.2 Individual Risks

The total individual risks due to the facilities listed above, are shown in Figure 2.1. Individual risk is a geographical distribution of the risk of death caused by the hazardous facilities or operations under consideration. The risks shown in Figure 2.1 apply to an individual who is outdoors for 100% of the time.

The individual risks are shown in contours from 10^{-4}/year to 10^{-7}/year. Directly over most sites the risk level may be higher than 10^{-4}/year because of minor hazardous incidents which could cause fatalities onsite and occur relatively frequently. These are not covered fully by the cases modelled, since the study is concerned only with risk to members of the public beyond the boundaries of the industry sites. Also, the risk contours extend beyond the 10^{-7}/year contour but these are not shown, since a risk below 10^{-7}/year is considered negligible.

The individual risk levels in the base case are assessed in Section 2.4.

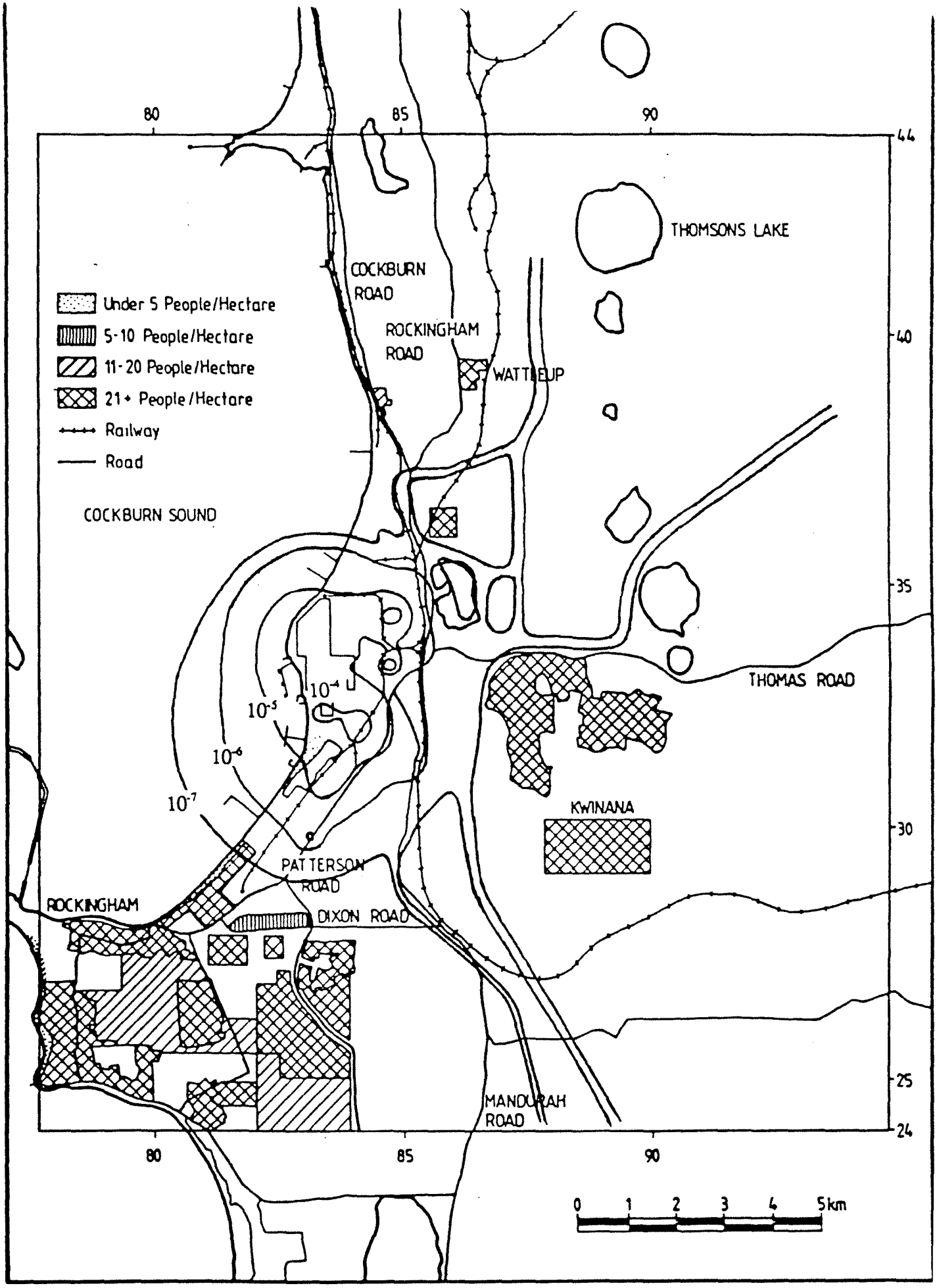


FIGURE 2.1 : CUMULATIVE INDIVIDUAL RISK LEVELS - BASE CASE

2.3 Societal Risks

The total societal risk curve associated with the above facilities is shown in Figure 2.2. Societal, or group risk, shows the magnitudes and frequencies of the entire range of accidents that can occur as a result of the facilities modelled. The cumulative frequency of events causing N or more fatalities is plotted against N, where N can vary from 1 to the maximum number of fatalities in any single event. Thus, the societal risk curve shows the distribution between generally infrequent accidents causing many fatalities and more frequent accidents causing few fatalities.

Since societal risk is not concerned with the risks to any particular individual or at any particular location, the frequencies are calculated taking into account the fraction of the population outdoors. An average value of 0.2 is applied uniformly to all populations. There is no presence factor (i.e. fraction of time spent by individuals at any location) applied in societal risk, since the population is averaged over the year, and the presence factor of any individual is not relevant to societal risk. The limitation of using annual average populations is that there can be significant seasonal or daily fluctuations in the total population, for example in a recreational area. However, societal risk is usually insensitive to this because no single population cluster dominates the risks calculated. Also, populations substantially larger than the average would generally occur only for a small fraction of the time, so that larger accidents have lower frequencies.

The societal risks in the base case are assessed in Section 2.4.

2.4 Assessment of Risk Levels

2.4.1 *Individual Risks*

The cumulative individual risk levels for the Base Case (Figure 2.1) show that the main residential areas (Kwinana, Rockingham) are exposed mostly to a negligible level of individual risk from the operations modelled. Only the northern tip of Rockingham is within the 10^{-7}/year contour, i.e. exposed to a non-negligible risk. However, this is some distance from the point at which individual risk becomes intolerable (at 10^{-5}/year).

The Kwinana Beach area (to the south of the BCJ) is exposed to individual risks from about 3 x 10^{-5}/year adjacent to the jetty root to about 7 x 10^{-6}/year near Wells Park and down to about 10^{-6}/year near the grain handling jetty. These values are for an individual present 100% of the time, and should be multiplied by the appropriate presence factors for actual occupying populations. These are 10% for recreational users and 25% for workers on the beach; note that these "offsite" workers (e.g. retailers) are included as members of the public. The corrected individual risks are shown in Table 2.1 below.

FIGURE 2.2: CUMULATIVE SOCIETAL RISK CURVE - BASE CASE

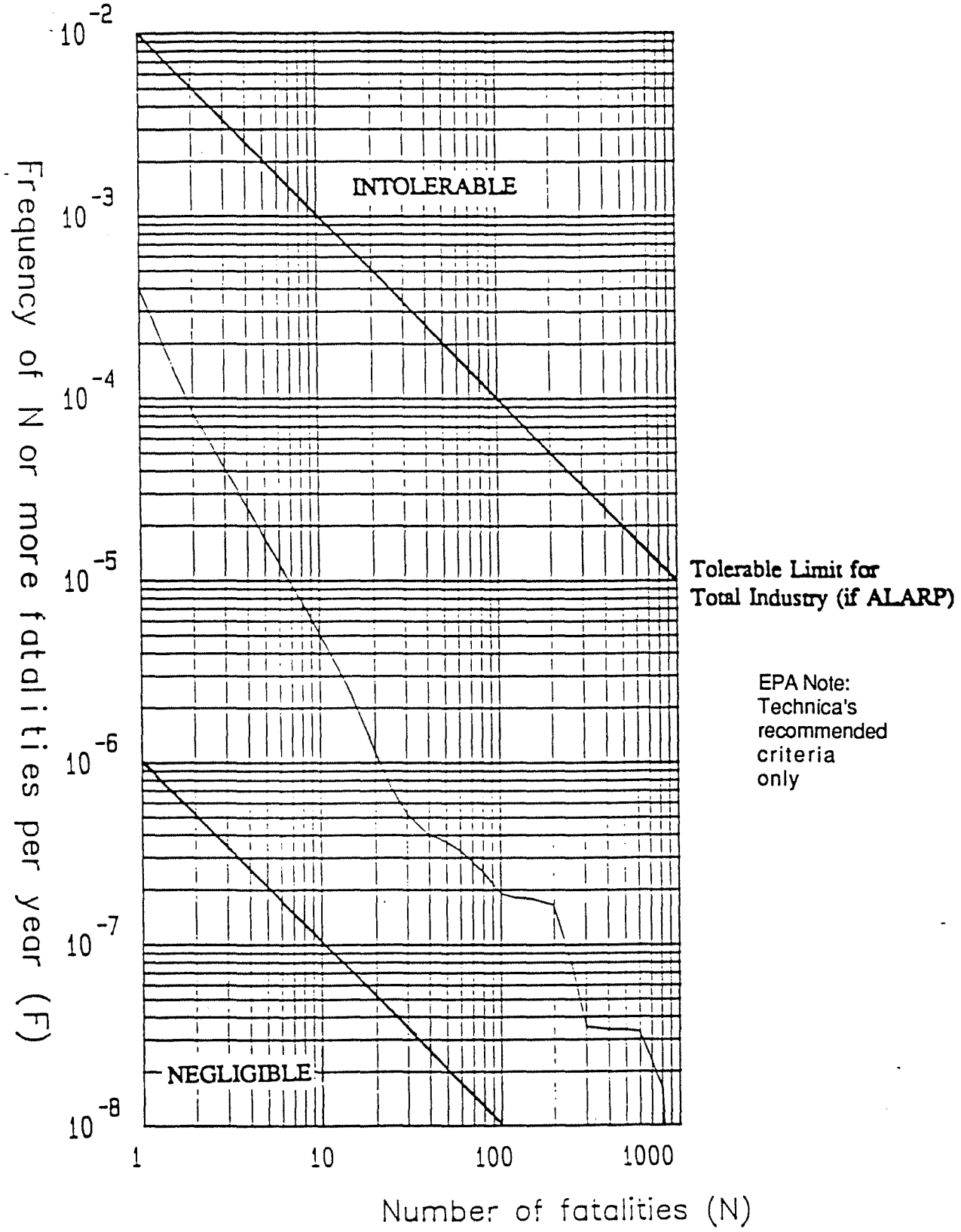


TABLE 2.1: BASE CASE INDIVIDUAL RISKS (/YEAR) IN KWINANA BEACH AREA

BEACH LOCATION	POPULATION TYPE	
	RECREATIONAL	WORKER
Near BCJ	3×10^{-6}	7.5×10^{-6}
Near Wells Park	7×10^{-7}	1.8×10^{-6}

The tolerable limit of public individual risk for the total Kwinana facilities is 10^{-5}/year and individual risk becomes negligible below 10^{-7}/year. Hence, the range of individual risks in the beach area falls in the tolerable but non-negligible (i.e. ALARP) region.

Risk levels on Barter Road Beach are lower than on the Kwinana Beach area; they vary roughly from 3×10^{-6}/year near the LPG jetty root down to below 10^{-7}/year further north. Risks to people in this area with a presence factor around 10% would therefore fall mainly in the negligible region.

2.4.2 *Societal Risks*

The base case societal risk curve (Figure 2.2) is well within the tolerable limit for total industry in the area. The closest approach of the curve to the tolerable limit occurs in the low fatality region (less than 4 fatalities); this is a reflection of the fact that there are very few offsite populations within the range of the majority of accidents modelled. This is to be expected in the Kwinana area, given the relatively large separation distances between industrial areas and the nearest large population centres.

The Potential loss of life (PLL) is a commonly used single value for expressing societal risk: it is the frequency of a fatal accident multiplied by the number of fatalities in that accident, summed over all accidents modelled. It is therefore the average number of fatalities per year. The PLL for the Base Case is 7.04×10^{-4} fatalities per year among members of the public.

2.4.3 *Major Contributions to Risk*

The main causes of the base case individual and societal risks were discussed in the original Kwinana Cumulative Risk Analysis (Ref 3). The large industrial plants in the Kwinana area account for the majority of the risks to the public. Since there are large distances between most populations and these plants, major releases of toxic materials (such as hydrogen fluoride, sulphur trioxide and ammonia) are the greatest risk contributors. Flammable and small releases (such as process and piping leaks) contribute little to the overall public risk levels.

3. ANALYSIS OF AMMONIA IMPORT FACILITY

3.1 Description of Facilities

The import facility consists of the following items:

a) mobile loading arm trolley
b) temporary spool piece from trolley to fixed pipeline
c) fixed pipeline with chill down line
d) 30,000 tonne refrigerated tank with associated liquefaction units and transfer pumps

These items and the ships typically used for ammonia import are discussed briefly below. Some of the information has been obtained from previous studies (Refs. 1 and 2); detailed data such as PIDs and ESD information were supplied by CSBP.

a) Mobile loading arm trolley: this is a self-contained unit already in use for LPG transfer at another jetty nearby. The trolley has a 250mm articulated liquid loading arm, fitted with ranging sensors and an emergency quick-release (or dry-break) coupling. There is a similarly equipped vapour return arm from the surge and drain tank on the trolley. Both liquid and vapour lines have shutdown valves on the trolley. These may be activated by ESD push-buttons on the trolley, at the jetty root and transfer house and the control room at KNC. Shutdown is automatically initiated by high pipe flow differential or high tank pressure/level detectors, or by arm ranging to 95% of the arm envelope. Shutdown of these valves is delayed by 30 seconds to allow the shore operators to request the ship crew to stop the ship's pumps. The emergency couplings isolate the arm automatically upon ranging to 100% of the arm envelope. The jetty is continuously manned during the unloading operation; also the jetty operators, ship's crew and control rooms are in radio communication. The unloading rate is 700 tonnes/hour.

b) Temporary spool piece: this is a 300mm insulated pipe installed once the trolley is in place, each time an unloading operation is to occur. The spool piece connects to the fixed pipeline on the jetty. Its length is approximately 20m, and it is assumed that it consists of a single pipe section. An ESD valve is located on the fixed pipeline at the junction with the spool piece .

c) Fixed pipeline: this is a 300mm insulated pipe of length approximately 1.5km and liquid hold up of 70 tonnes. There is a 50mm chill line fitted above the main pipeline, used to pump liquid ammonia from the tank to the loading arm and pipeline, thus cooling it in preparation for the unloading operation. Both pipes are installed on a pipe rack along the jetty, and then laid in a concrete lined culvert from the jetty root to the plant boundary. There are ESD valves for both lines at the jetty root, which are initiated by the same causes as the trolley valves. There are further ESD valves on the liquid pipeline where it joins the tank and on the chill line pump discharge.

The pipeline can be pigged from the jetty end to the tank end, which will be done when the ship's tanks need to be vented to the onshore flare for use by another cargo. The pigging operation can also be used to clear ammonia from the pipeline prior to maintenance operations.

The pipeline is patrolled during unloading operations. The differential flow indicators between the ship's tank and the onshore tank initiate ESD of the system at a differential of $80m^3$/hour.

d) Storage tank: this is a fully-refrigerated single-walled steel tank with a full-height concrete secondary containment (bund) wall. The tank is fitted with ROVs on the two main liquid inlet/outlet connections at the bottom of the tank, between the tank and the bund wall. ESD of the inlet pipe during unloading or the chill line pumps during chilling are caused by high pressure or high liquid level in the tank. There are two transfer pumps (one on standby) located in a drained containment pit. There are provisions for large export pumps to be installed in the future. NH_3 detectors are located inside the bund wall and around the transfer pumps.

There are 3 reliquefaction units for maintaining the liquid temperature at -33°C. It is assumed that under normal conditions one unit will be functioning; up to 3 may function during chilling, unloading and post-unloading warm up of the pipeline.

e) Ships: the type used for ammonia trade is assumed to be a fully-refrigerated ammonia carrier built to the IMO International Gas Carrier Code. The ship ESD system consists of a number of push-buttons and fusible plugs around the ship, which all cause the tank manifold valves to close, and shutdown of the ship's pumps. The ship relies on radio communication to be notified of an ESD onshore.

The following precautions are taken when an unloading operation is to take place:

- ship movements to/from the BCJ are halted during unloading.
- non-essential personnel/operations are restricted on the jetty.
- electrical equipment not approved for hazardous areas is shutdown.

In addition, adverse weather conditions or other major factors which may affect the operation would lead to a postponement of the unloading. Fremantle Port Authority control all shipping within Cockburn Sound using radar surveillance. The BCJ is within a restricted shipping area which allows only authorised vessels to enter the area.

3.2 Accidental Release Cases

Ammonia is both toxic and flammable. However, it has a narrow flammability range in air and a very high ignition energy. Also, the consequences arising from an ignited release would be expected to be less than those from an identical unignited release. Thus, only non-ignited incidents are assumed to occur. This simplification leads to a very slight overestimate of risks.

A number of release cases covering large and small failures of equipment, are modelled for each of the four main areas of the import facility:

- 30000te tank and associated equipment
- import pipeline including temporary spool piece
- loading arm trolley
- ship while approaching or berthed at the BCJ.

The full set of release cases modelled are listed in Table 3.1 below. The frequencies of the cases are shown to give an indication of their importance. Detailed descriptions of the release cases and their conditions (such as durations, flowrates etc) are given in Appendix II. The main points are summarised below.

- Tank cases: failure of the tank inner wall will give a liquid pool contained in the concrete bund. This is based on the assumption that the bund is designed to withstand the load imposed by the inner wall collapsing and releasing its contents. A major collapse of the inner wall will give a pool evaporating from the total area within the bund (T1); leaks will not cause roof collapse and will give a pool evaporating in the annulus only (T3 and T4). The worst-case scenario of the bund collapsing (T2) leads to a much larger pool and thus larger cloud; however this has an extremely low frequency. The reliquefaction units contain small volumes of pressurised ammonia liquid; these cases are modelled although their consequences are expected to be small. Releases from the transfer pumps have been considered, however because of the containment pit their consequences are negligible and are not modelled.

- Pipe cases: large (full-bore) and small leaks from the pipeline are modelled. These include releases from the spool piece and its associated flanges. These are considered particularly prone to failure due to the relatively high frequency of fitting operations. Since there are shutdown valves along the pipe and on the ship manifold, each case is subdivided between short duration (ESD successful) and long duration (ESD failed) leaks. Because of their lower frequency and the low probability of ESD failure, large long duration leaks have a negligible frequency. ESD is assumed to be initiated usually by the flow differential indicator; the short duration leaks therefore last for about 1 - 2 minutes. The fixed pipe cases on the jetty (P3, P4) and on land (P5, P6) are distinguished since in the former case the ammonia would fall on water and in the latter case would form a pool in the culvert, giving different behaviour.

- Loading Arm cases: releases due to either disconnection or rupture are considered. Large (full-bore) and small leaks, with rapid or delayed ESD, are modelled. An event-tree approach has been developed for estimating the frequencies of each of these cases. ESD can be delayed significantly if the ship operators become incapacitated by the release, since there is no automatic mechanism for shutting the ship's manifold valve, or direct link between the shore and ship ESD systems.

- Ship cases: releases from the ship's tanks while approaching the BCJ and while berthed are modelled. Since releases while approaching have a very low frequency, these are allocated to the berth location, making the analysis slightly conservative.

TABLE 3.1: AMMONIA FACILITY RELEASE CASES

IDENTIFICATION CODE	DESCRIPTION	FREQUENCY (per year)
T1	Catastrophic failure of tank wall, contained in bund	1×10^{-5}
T2	Catastrophic tank failure not contained in bund	2.5×10^{-8}
T3 and T4	Large or small leaks from tank wall into bund	1.2×10^{-4}
T5	Large leak in reliquefaction unit	2.6×10^{-5}
T6	Small leak in reliquefaction unit	1.7×10^{-4}
P1	Full-bore rupture of spool piece	2×10^{-6}
P2	Small leak from spool piece or flanges	1.9×10^{-4}
P3	Full-bore rupture of fixed pipe to jetty root station	1.7×10^{-6}/10m
P4	Leak in fixed pipe to jetty root station	5.3×10^{-6}/10m
P5	Full-bore rupture of fixed pipe between root station and tank	1.7×10^{-6}/10m
P6	Leak in fixed pipe between root station and tank	5.3×10^{-6}/10m
L1	Full-bore rupture of loading arm or ranging disconnection with failure of emergency coupling, rapid ESD	7.9×10^{-5}
L2	As for L1, but ESD delayed due to incapacitated operator	3×10^{-5}
L3	Leak in loading arm, rapid ESD	4.1×10^{-4}
L4	Leak in loading arm, delayed ESD	9.5×10^{-5}
S1	Large leak in ship tank while approaching jetty or berthed	2×10^{-6}
S2	Catastrophic failure of ship tank while approaching jetty or berthed	2.2×10^{-7}

3.3 SAFETI Risk Analysis

The release cases identified in section 3.2 have been modelled using SAFETI. This is the software package used in the original Kwinana Cumulative Risk Analysis and subsequent studies; the package is described in the original study report (Ref. 3). The latest version of SAFETI (3.1) has been used in this study.

The modelling of ammonia risk is simplified considerably by neglecting the possibility of ignition. The modelling then consists of release behaviour, dispersion and toxic impact modelling. The details of the release modelling are contained in Appendix II. The major aspects of this and the other modelling areas are discussed briefly below.

The majority of release cases defined involve refrigerated releases of ammonia. These lead to pools of liquid evaporating into the atmosphere. This may be modelled as a standard refrigerated liquid release. However, in the case of spills into the storage tank annulus, the ammonia would be released to the atmosphere at the top of the tank. This is therefore modelled as an elevated vapour release. Refrigerated spills onto water also require different modelling. Some of the ammonia is dissolved and the ammonia entering the cloud behaves as a dense gas due to the formation of a water-ammonia "fog". Modelling of this is therefore more complex: in this study the ammonia cloud is forced to be initially dense by specifying the ammonia as two-phase. This reflects observations from both experiments and actual accident cases.

The toxic impact of ammonia is modelled using a Probit equation (DCMR/Technica, 1984). This allows the probability of death to be calculated at different locations, given the concentration and duration of the exposure. The risks are calculated down to a probability of death of 10^{-3}.

The accidental release case identification is to the same level of accuracy as the previous cases modelled; however the equipment data and other information made available for this study is more detailed than in some of the previous analyses. Also the latest version of SAFETI incorporates some modelling improvements which may enhance the analysis.

4. IMPORT CASE CUMULATIVE RISKS

The import case consists of all the base case industries (listed in Section 2.1) plus the ammonia import facility, consisting of the 30000te tank, pipeline, loading arm and ships. The cumulative individual and societal risks for the import case, based on 9 shipments per year, are shown below.

4.1 Individual Risks

The cumulative individual risks for the import case are shown in Figure 4.1. The individual risks for the import facility alone are shown in Figure 4.2 on a smaller scale map, for greater resolution of risks on the beach area. The risks apply to an individual outdoors for 100% of the time, as discussed in Section 2.2. The risks are discussed in Section 4.3.

4.2 Societal Risk

The total societal risk curve for the import case is shown in Figure 4.3 below. The base case societal risk curve is drawn on this diagram to show the increase in societal risk caused by the import facility. The societal risk curve due to the import facility alone is shown in Figure 4.4. This is shown to enable comparison of the societal risk due to the facility with the risk criterion for single existing plants. The societal risks of both the import case (i.e. the total for the area) and the import facility alone, are discussed in Section 4.3.

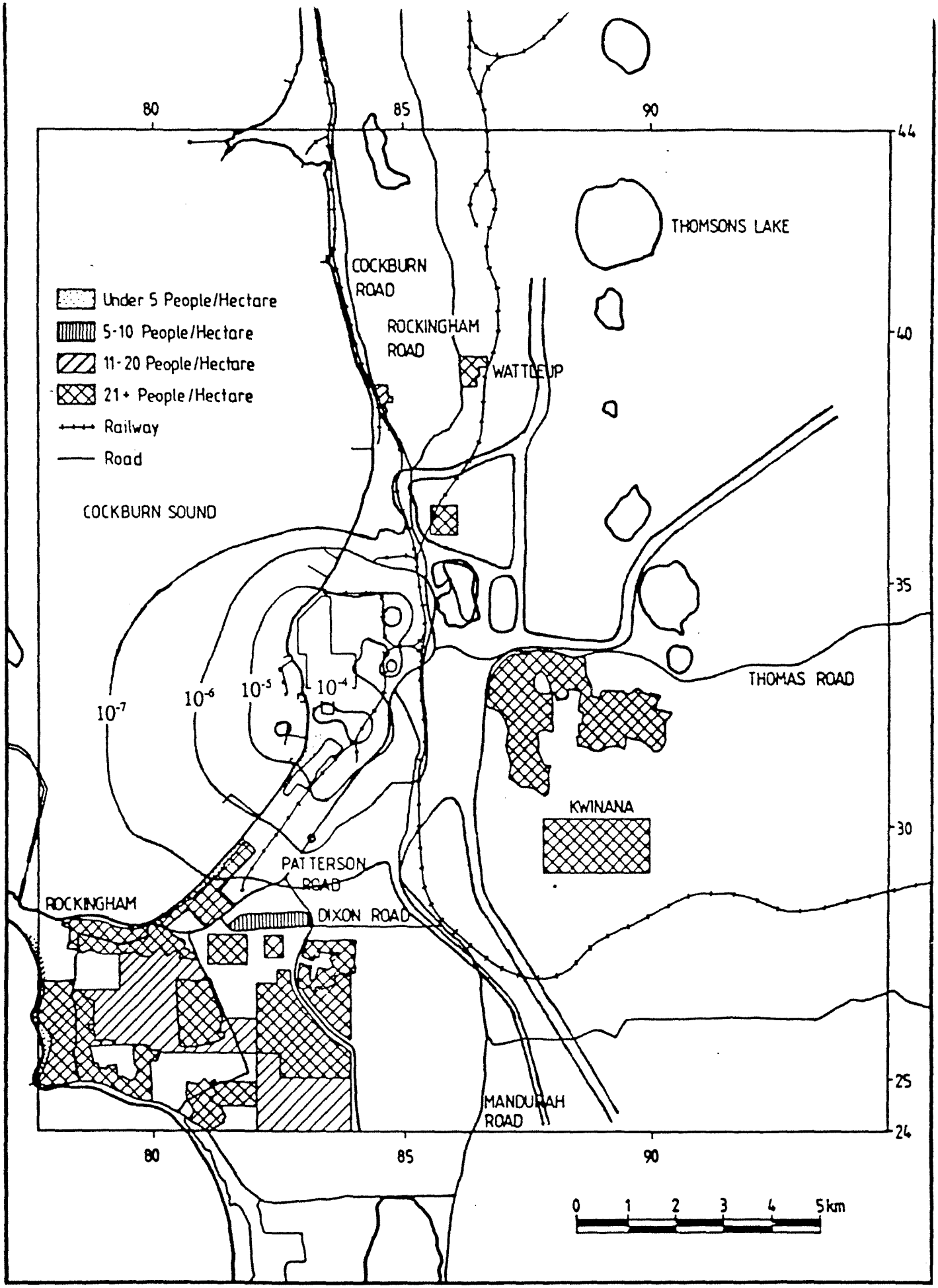


FIGURE 4.1 : CUMULATIVE INDIVIDUAL RISK LEVELS - IMPORT CASE

FIGURE 4.2: INDIVIDUAL RISK LEVELS FOR IMPORT FACILITY ALONE

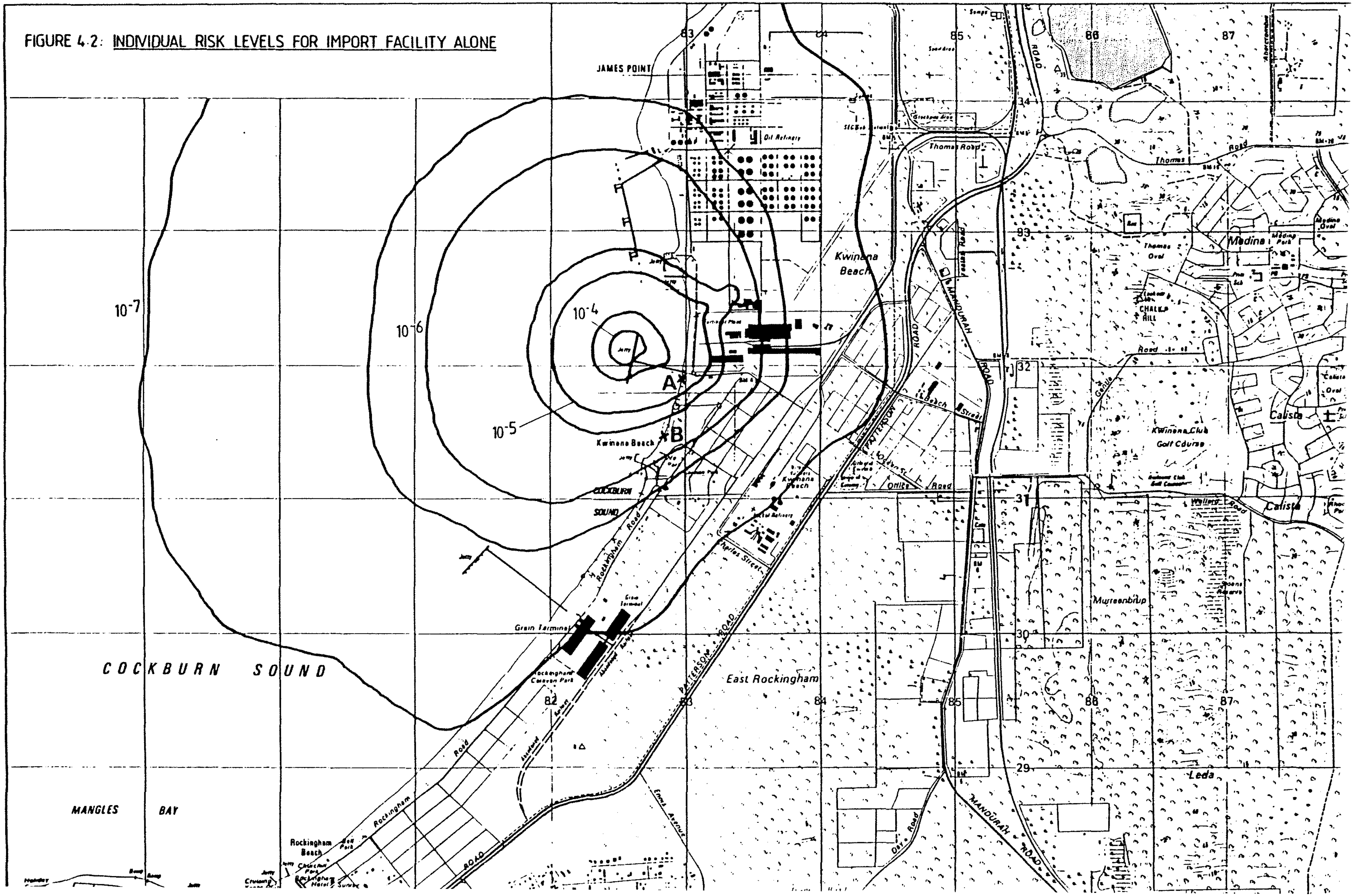


FIGURE 4.3: CUMULATIVE SOCIETAL RISK CURVE - IMPORT CASE

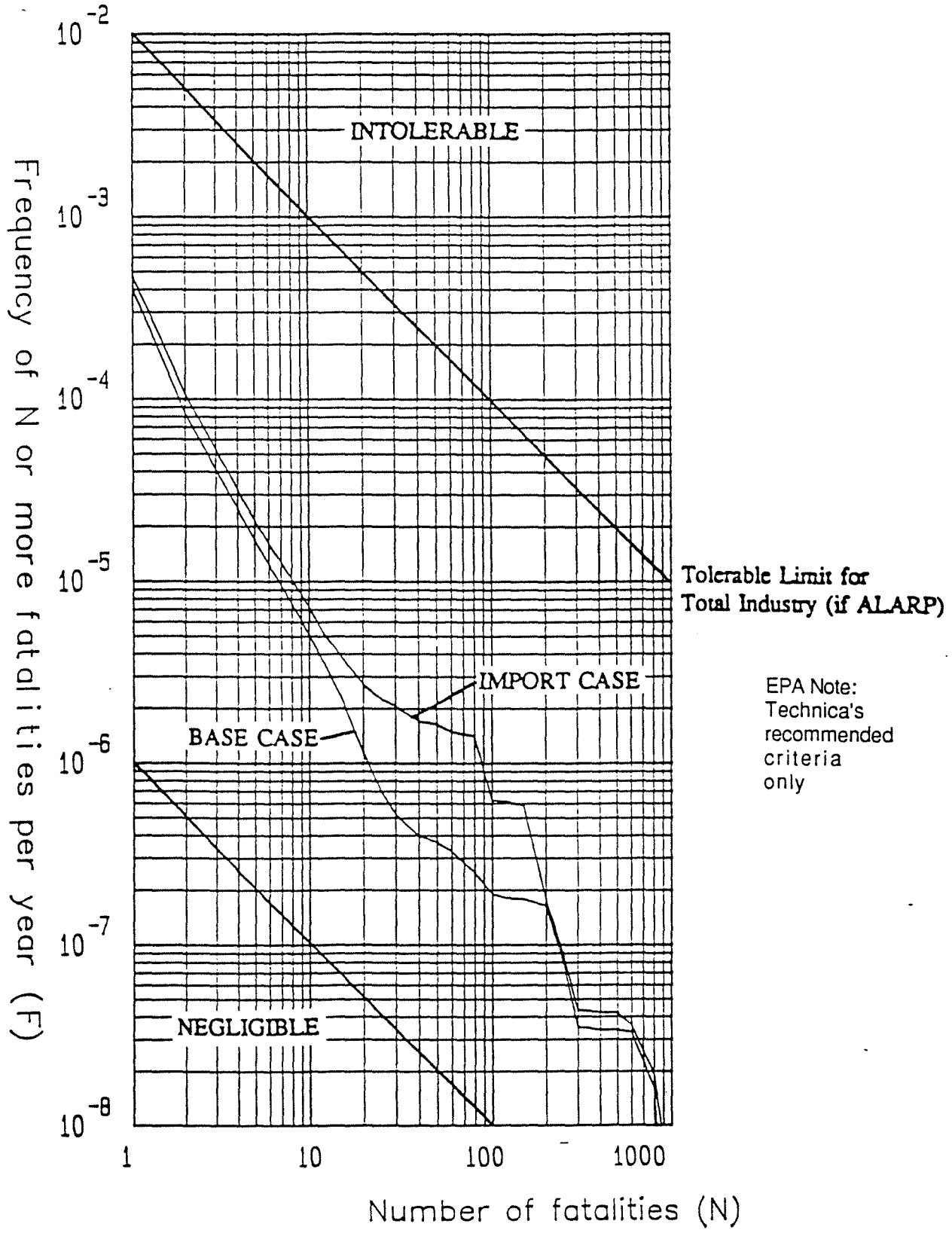
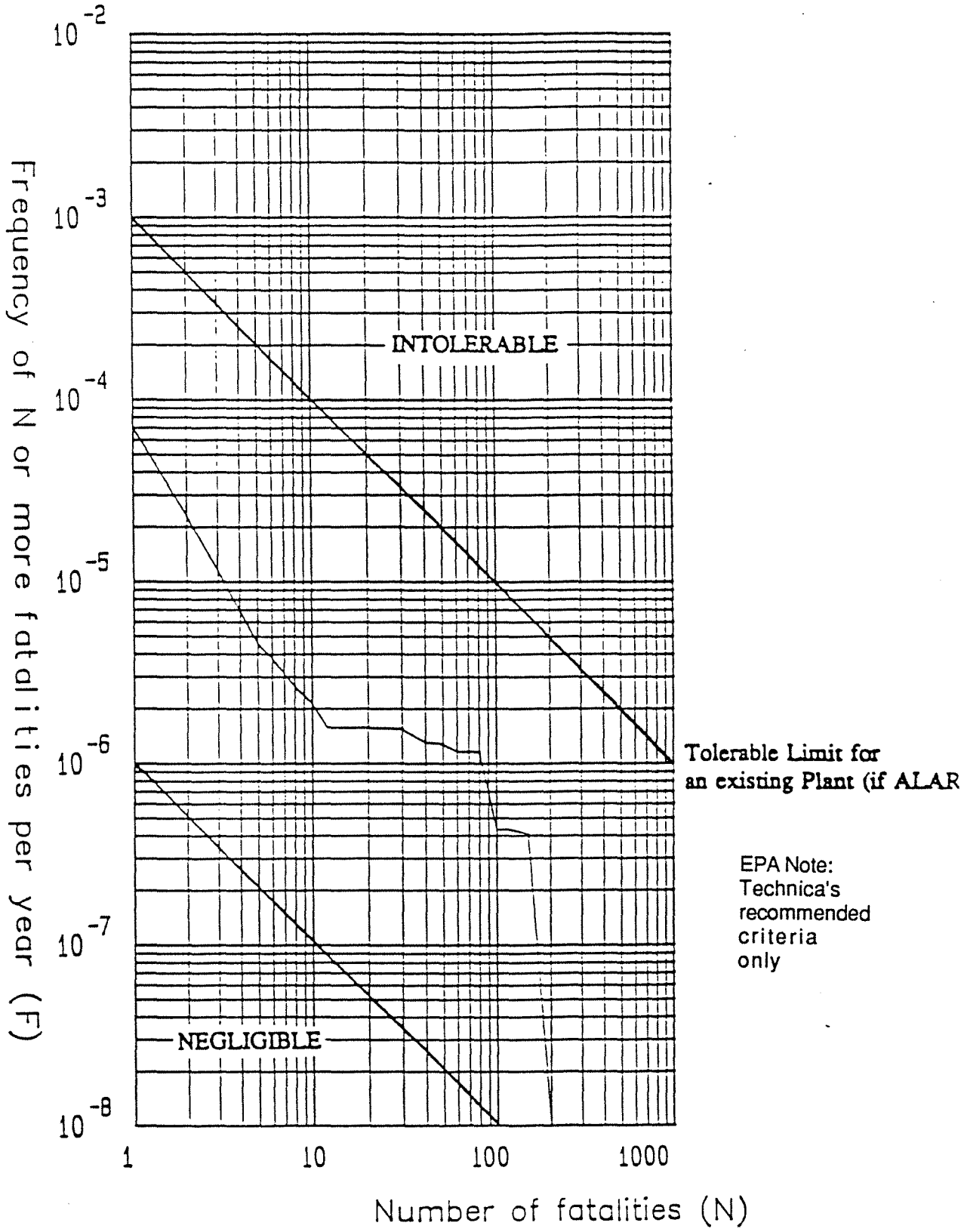


FIGURE 4.4: SOCIETAL RISK CURVE FOR IMPORT FACILITY ALONE



4.3 Assessment of Risk Levels

4.3.1 *Individual Risks*

Comparing Figures 2.1 and 4.1, the import case can be seen to cause an expansion of the risk levels towards the west and south. There is an extra 10^{-4}/year contour at the jetty head, reflecting the peak risk due to the ammonia import activities. The 10^{-5}/year to 10^{-7}/year contours are shifted further south and west, the effect being largest for the 10^{-7}/year level. This is borne out by the individual risk contours for the import facility alone (Figure 4.2).

A larger part of the north of Rockingham falls within the 10^{-7}/year contour; however, the 10^{-6}/year contour is only slightly closer to Rockingham. The rest of the area where individual risk has increased over the base case, is largely offshore and therefore not of great importance.

The Kwinana Beach area is exposed to cumulative individual risks between 5 x 10^{-5}/year near the BCJ root and about 9 x 10^{-6}/year near Wells Park; applying the relevant presence factors for occupying populations (as in Section 2.4.1), the actual individual risks shown in Table 4.1 are obtained. The two locations at which the risk levels are given are shown on Figure 4.2 as A and B.

TABLE 4.1: IMPORT CASE INDIVIDUAL RISKS (/YEAR) IN KWINANA BEACH AREA

BEACH LOCATION	POPULATION TYPE	
	RECREATIONAL	WORKER
Near BCJ (A)	5×10^{-6}	1.3×10^{-5}
Near Wells Park (B)	9×10^{-7}	2.3×10^{-6}

Comparing Tables 2.1 and 4.1, the import facility would cause an increase in individual risk over the entire Kwinana Beach area, the greatest increase occurring close to the BCJ where the risk is almost doubled. Further away along the beach, the increase becomes more modest.

The actual cumulative risks to individuals on the beach remain below the upper limit of 10^{-5}/year, except for any offsite workers close to the BCJ. Their risks very slightly exceed this criterion; however, this is not particularly significant since recreational facilities with workers are not likely to be situated at location A.

The import facility has a negligible effect on cumulative risks over Barter Road Beach.

4.3.2 Societal Risks

The effect of the import facility on the societal risk curve is shown in Figure 4.3; the facility has little effect on the high fatality range (>200) or the low fatality range (<10), but the frequency of accidents causing between 20 and 130 are increased significantly. The total societal risk curve, however, remains well below the tolerable limit for total industry but above the negligible region (i.e. in the ALARP region). The import facility, therefore, takes up only a small fraction of the area's remaining capacity to accept industrial risk, leaving a substantial capacity for further industrial development.

The societal risk curve for the import facility alone (Figure 4.4) is well below the tolerable limit for a single existing plant; thus, at a level of nine shipments per year, the import facility does not exceed the criterion for risk generated by single facilities.

The potential loss of life (PLL) for total industry in the import case is 9.81×10^{-4} fatalities/year among members of the public; hence the import facility causes a 40% increase in the PLL over the base case value of 7.04×10^{-4} fatalities/year.

4.4 Discussion of Risk Contributors

In order to demonstrate the main contributors to individual and societal risk from the import facility, breakdowns of the individual risks (at location B on Kwinana Beach, near Wells Park) and the societal risks (in terms of PLL) have been determined. These are useful for identifying the risk-reducing measures which would have the greatest effect. Note that the individual risk levels shown in the breakdowns are for an individual continuously present outdoors, i.e. without a presence factor.

The individual and societal risks have been broken down at two levels of detail: the first shows the risk contributions from the four main "areas" of the facility (tank, pipe, loading arm and ship) and the second shows the contributions from the most important release cases.

4.4.1 *Risks by Facility Area*

The individual and societal risk contributions from the four facility areas are shown in Table 4.3, ranked in descending order.

TABLE 4.3: RISK CONTRIBUTIONS BY IMPORT FACILITY AREAS

AREA	INDIVIDUAL RISK (/YEAR) (AT LOCATION B)
PIPE	1.01×10^{-6}
ARM	6.46×10^{-7}
SHIP	3.19×10^{-8}
TANK	4.31×10^{-10}
TOTAL	1.68×10^{-6}
AREA	**SOCIETAL RISK (FATALITIES/YEAR)**
ARM	1.74×10^{-4}
PIPE	8.74×10^{-5}
SHIP	1.51×10^{-5}
TANK	5.30×10^{-8}
TOTAL	2.77×10^{-4}

The main areas of interest, in terms of both individual and societal risks, are the pipe and loading arm. The ship and tank contribute very little to the total risks in both cases.

The pipe contributes a greater proportion of the individual risk than the arm, partly because the pipe passes closer to the point at which the individual risk is measured. The loading arm causes greater societal risk than the pipe, because large releases arising from the loading arm can affect a significant number of people at a relatively high frequency. This type of accident is the main cause of the increase in the societal risk curve between 20 and 130 fatalities.

4.4.2 *Risks by Release Cases*

The top 5 release cases contributing to individual and societal risk, are shown in Table 4.4 below. The totals shown are the sums of these contributions to the two types of risk, expressed as a percentage of the total for the import facility. This demonstrates that the remaining release cases contribute a negligible fraction of the total risk.

The pipe cases denoted by a W (e.g. P4-W) represent the cases where ESD is successful. The cases where ESD is unsuccessful cause a negligible risk in comparison, indicating that there is little scope for improving the pipe ESD arrangements.

TABLE 4.4: RISK CONTRIBUTIONS BY IMPORT FACILITY RELEASE CASES

RELEASE CASE	INDIVIDUAL RISK (/YEAR) (AT LOCATION B)
P3-W	8.15×10^{-7}
L2	3.76×10^{-7}
L1	2.13×10^{-7}
P4-W	1.46×10^{-7}
L4	4.51×10^{-8}
TOTAL (%)	95
RELEASE CASE	SOCIETAL RISK (fatalities/year)
L2	1.61×10^{-4}
P3-W	4.75×10^{-5}
P4-W	3.34×10^{-5}
L1	1.13×10^{-5}
S2	7.93×10^{-6}
TOTAL (%)	94

From Table 4.4 it can be seen that the most important release case in terms of both individual and societal risk, are as follows:

- P3-W, P4-W: full-bore rupture and leak cases from fixed pipeline between spool-piece tie-in and jetty root station.

- L2, L1: full-bore rupture of loading arm, with delayed ESD and rapid ESD respectively.

L2 alone contributes 58% of the total societal risk due to the import facility. The most effective risk-reducing measures would be those which reduced the frequencies and/or consequences of these cases.

5. CONCLUSIONS

Base Case Risks

A risk assessment of the base case cumulative risks (individual and societal) in the Kwinana area shows that the individual risk levels are negligible for the majority of Kwinana area population, and that the societal risk levels are well below the tolerable limits for total industry in the area. The individual risk levels in the Kwinana Beach area (between the Bulk Cargo Jetty and Wells Park) are also below the tolerable limit, for recreational users and workers in the area. The individual risks for this area fall within the ALARP range, i.e. between 10^{-5}/year and 10^{-7}/year. The base case risks over Barter Road Beach are significantly lower due to the greater distance to the main industrial plants. Risks to recreational users of this area are generally below the negligible limit.

Import Case Risks

The ammonia import facility has been added to the cumulative risk model at the proposed frequency of 9 shipments per year. This is referred to as the import case. The cumulative individual risk contours are visibly increased between the base case and the import case; however, the increase occurs mainly towards the sea and is of little significance to the general population. The individual risks over the Kwinana Beach area are increased but remain mainly in the ALARP region, except for any offsite workers close to the BCJ. The import facility does not significantly alter the assessment of risk levels in the Barter Road Beach area.

The total societal risk for the area shows a more significant increase due to the import facility, with a 40% increase in the Potential loss of life. However, the total societal risk is still well below the tolerable limit for total industry and the societal risk for the import facility alone is well below that tolerated for a single existing facility. The import facility therefore does not impose a significant additional societal risk "burden"; there is still substantial capacity for further industrial growth from the point of societal risk.

The general conclusion regarding the ammonia facility is that at a level of 9 shipments per year, it would cause a slight increase in individual risk and a more significant increase in societal risk to the public in the Kwinana area. The import facility risks would be deemed tolerable if all reasonably practicable risk-reducing measures were implemented; this requires consideration of both the costs and risk benefits of possible measures.

Beach Area Risks

Although societal risks in both the base and import cases are well below criteria for upper limits of tolerability, the Kwinana Beach area is exposed to individual risk levels close to the upper limit of 1 x 10^{-5}/year. This is basically due to the short distance between the beach area and the main industrial areas.

The import facility alone causes an increase in individual risk levels at point B (which is at the southern boundary of the FPA land north of Wells Park of **2 x 10^{-6}/year** which is close to negligible when compared against the EPA proposed guideline risk levels for 'Active open areas' (which would put the central criterion for this type of activity at 10 x 10^{-6}/year) using the required risk contour basis. The cumulative risk levels over this point are of the order of 1 x 10^{-5}/year or in other words at the central point of the criterion. This will therefore fall within the band of 'ALARP' considerations as detailed in Ref.8 page ii. As the source of this risk is caused by the combined effects of a large number of different sources, a large number or risk reducing measures are possible for consideration under the ALARP principle.

Thus, the beach area does not have a substantial capacity to tolerate further major hazard industrial growth within the immediate vicinity without the application of these considerations to the existing industrial sites. New plants further away would not, however, have a great effect on this area. The IP14 area for example is about 1000m away, and new plants built there are unlikely to cause a significant increase in the existing beach area risk levels.

A further aspect of the beach area is that the total population there tends to show significant seasonal, weekly and daily fluctuations. The peak weekend population in summer may be much greater than the annual average. An analysis of the sensitivity of the total societal risk to variations in Wells Park population has been performed. This shows that the societal risk curve based on the annual average Wells Park population is not sensitive to the time-averaging calculation within the study. In addition, any increase in the time-averaged population in the Wells Park area would need to be significant (i.e. in comparison with average annual population growth rates) in order to be unacceptable. Therefore detailed consideration and analysis of proposals to use this area for purposes involving the presence of much larger numbers of people would be required.

6. RECOMMENDATIONS

6.1 Import Facility

The main effect of the import facility is to increase the societal risk; since it is still well within the ALARP region, further risk reducing measures should be applied only if they would cause a substantial reduction in the societal risk and not incur disproportionate expense or practical problems. The major risk contributors in the import facility are releases from the loading arm and the fixed pipe along the jetty. Remedial measures applying to these areas in particular, should be given consideration. A number of possible measures are suggested below. Estimates of the likely remedial effects of the measures are given, in terms of percentage reduction in the Potential loss of life for the import facility.

1. Direct link between ship and shore ESD systems, allowing either side to initiate ESD manually or automatically (see 3 and 4 below). It is recognised that this is generally not practical due to the incompatibility of ship and shore ESD systems, although this may change in the future if international standards (eg. within the IMO standards) are implemented. This measure would decrease the typical duration of case L2 (delayed ESD of loading arm rupture) ; the PLL for the facility would be decreased by about 25%.

2. Installation of automatic ESD system to shutdown ship's pumps and manifold valves upon a pressure drop or flow differential indication. This is not a requirement of IMO regulations, to which Australia is a signatory. It is therefore not likely that such a measure could be enforced. Case L2 would be almost eliminated and replaced by a case similar to L1, since operator intervention would not be relied on. The reduction in PLL would therefore be about 50%.

3. Ammonia detectors in vicinity of ship's pumps and loading arm to cause automatic ESD. Again, IMO regulations do not require these and the comment in recommendation 2 above also applies here. The effect of detectors would be similar to measure 2 above, but probably less reliable; a reduction of up to about 40% of the PLL could be achieved.

4. General inspection of pipeline during shutdown periods, to include periodic inspection for corrosion and other defects, using e.g. radiographic techniques. KNC already carry out weekly external inspections and annual thickness tests; the scope for risk reduction is therefore limited. A maximum reduction of about 5% of the PLL may be possible.

5. Possible exclusion zone or population control on beach area (see Section 6.2).

The measures suggested above are of a physical nature, directly affecting the frequency, consequences or impact of accidents on the facility. The improvement of safety-related management systems and procedures can also result in a reduction of accident frequencies. The scope for such improvement cannot be determined in this study since no assessment of the existing management systems has been performed. However, a summary of the recommended best management practices is given in Appendix III.

6.2 Kwinana Beach Area

The Kwinana Beach area is of concern because of the individual risk levels, in both the base case and import case. Although an exclusion zone during import operations would prevent public exposure to peak risks, this would not significantly reduce the societal risk because only a few people would be removed. There are only 16 people (on an annual average basis) in the beach area; since the main increase in societal risk is over a range of 20 to 130 fatalities, a beach exclusion zone would not greatly reduce the potential number of people exposed to import facility accidents. The problem is more related to the commulative industrial activities rather than the import facility alone. Since the critical parameter is the presence factor of individuals, future developments which might significantly increase the length of time spent by individuals in this area should be avoided.

Public exclusion zones are emotive measures and can generate an unnecessary risk aversion amongst the public. Therefore a careful balance should be maintained between avoiding complacency amongst the public and increasing the "fear of the industry" without any real justification. One alternative would be to ensure that unloading operations (and this includes presence of the ship at the jetty without unloading) should not be permitted during summer weekends, which is when population levels in this area might rise significantly above the average assumed in this analysis. Public access could then be prevented during the unloading operation (with due warning if possible) along the beach section to the north of Wells Park. Increased police patrols may also be coordinated into the emergency response plan, but again care must be taken not to cause unnecessary fear amongst the public.

The results of this study do not directly suggest that an exclusion zone is necessary in this whole area during ammonia ship unloading. The exclusion zone would have to be considerably enlarged in order to significantly affect the calculated societal risk impact of this operation. However it is to be expected that the process of considering options under the 'ALARP' process suggested by the EPA should identify the appropriate measures with which to proceed, by means of a comparative assessment of all the measures available.

REFERENCES

1. Industrial Risk Management, "Risk Analysis of Ammonia Import, Handling and Storage Facility at Kwinana" May 1989

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3. Technica C715, "Kwinana Cumulative Risk Analysis" April 1987

4. Technica C1628, "Kwinana Cumulative Risk Analysis Incorporating Ammonia Storage Facility" November 1988

5. Technica C2192, "Public Risk Criteria for the Kwinana Industrial Area" June 1990

6. Technica C702, "European Commission Benchmark Study of Ammonia Terminal" April 1989

7. Technica C2153, "Kwinana Cumulative Risk Analysis Update" August 1990

8. EPA, Western Australia, "Review of the guidelines for risk assessment in Western Australia",December 1990; a Public discussion document.

Appendix 2

Summary from "Review of the guidelines for risk assessment in Western Australia"

Constraining industrial risk

Reviewing new limits for industry

The EPA believes people should be safe from industrial risk.

Since 1987, when the EPA introduced risk criteria guidelines, risk assessment has been part of the environmental impact assessment process.

When new hazardous industries are proposed, project managers must do risk analyses to ensure their projects meet the EPA's guidelines.

Until now, these guidelines have been limited to the risk an industry has on people living nearby.

The guidelines stipulate that development is acceptable only if the chance of accidents causing the death of an individual in a residential area is less than one in a million per year.

Or, put another way, the risk must be constrained to about the chance of a person being killed by lightning.

We make our own choices about voluntary risks in life such as driving cars, crossing streets or playing sport.

They are risks over which we have some control.

But the EPA is concerned that people should not have to face the unacceptable, involuntary risks of life such as those posed by some hazardous industry over which individuals have little or no control.

Your views are now sought on expanding the EPA's guidelines so no West Australian faces an unacceptable risk from industry and so that industry, planners, and government have firm rules for development in a wider range of areas.

The review

The review will look at five issues — the EPA's current guidelines on individual risk; expansion of the current guidelines to include areas other than residential zones; expansion of the individual risk criteria to include risk to groups of people; expansion of individual risk to include the likelihood of injury; and the effects of industrial accidents on the natural environment.

1. Current guidelines

Under the EPA's current guidelines, it is unacceptable for any industrial development to pose an individual risk of death of greater than one in a million per year to people living in residential areas.

While the guidelines allow some flexibility for a marginally greater risk at the design stage of a project, the ultimate limit is one in a million per year.

The review will look at whether one in a million per year is still appropriate.

2. Expansion of current guidelines

Current guidelines are limited to the impact industries have on nearby homes.

Under the review, other areas are being considered for risk criteria.

For example, the impact of industry on hospitals, schools, tourist resorts, shops and offices, recreation areas, and even neighbouring industry will be discussed.

The EPA's proposed new constraints on industry are set out in the next column.

3. Societal risk

The EPA is considering whether other measures of industrial risk may be needed to determine the suitability of particular industries.

Societal risk considers the consequences of industrial accidents on groups of people, rather than on individuals alone.

It is based on the number of people likely to be exposed to a risk and the nature and scale of incidents which might cause death or injury.

Land Use	Current criteria	Suggested criteria
	(Individual risk of death per million per year)	
Hospitals, schools, child-care facilities, old-age housing	-	0.5
Residential	1	1
Residential, hotels, motels, tourist resorts	-	1
Commercial development, including retail centres, offices and entertainment centres	-	5
Sporting complexes and active open space	-	10
Other industrial areas	-	50

The EPA is looking at whether the risk to individuals (as outlined above), as well as the number of people living near a hazardous industry, should be considered when assessing the risk of that industry.

In this way, the suitability of a development could be judged on its location, its proximity to people and the risk to which those people would be exposed.

It also could provide a useful tool for sound land-use planning and emergency response decisions.

4. Injury risk

As well as hazardous industry's risk to human life, the EPA is considering the risk of injury.

Injury risk criteria could be applied for specific projects where the major likely impact from an accident is injury rather than death.

Injury risk criteria would be applied in a similar manner to individual risk and dealt with on an industry-by-industry basis.

5. The environment

A consideration in assessing risk is the potential impact an industrial accident might have on plants and animals, waterways, and the land.

As a result, the EPA is considering whether industry should be near sensitive, natural parts of the environment where the consequences of a high-risk accident could threaten the environment in the long-term.

Public comment

Your views are important to the EPA in its review of risk criteria.

Several seminars are being run by EPA staff to explain the issues under consideration and to give you the chance to make comments and offer suggestions.

A report, *Review of the Guidelines for Risk Assessment in Western Australia*, provides detailed and technical information about the new risk assessment proposals.

It is available from EPA offices.

Public submissions or comment should be made by **March 15, 1991.**

If you would like more information, please contact:
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Ph: (09) 222 7000
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Preamble to assist in public comments

Summary

The purpose of this paper is to seek public input into the review by the Environmental Protection Authority of the criteria and process of risk assessment and management in Western Australia. The paper is aimed at developers, consultants, and local and State government, and at anyone involved in or concerned with the development of hazardous industries.

This document contains:

- a Preamble, which discusses the issues on which the Authority is seeking comment;
- a copy of the present risk criteria in Bulletin 278;
- a copy of a report on options for risk criteria prepared for the Authority by risk consultants Technica of London; and
- a reprint document detailing the risk criteria used by the New South Wales Department of Planning.

The issues discussed below cover three main areas:

- whether the present criteria of individual risk of death in residential areas should be expanded to cover other land uses and other injury impacts;
- should societal risk (or the consequences of possible incidents) be considered; and
- does there need to be better protection of "buffer zones" around hazardous industry from conflicting land uses.

At the core of the Authority's present approach, outlined for new development in EPA Bulletin 278 (Appendix 1), is the identification of hazards and the quantification of risks outside the boundaries of a potentially hazardous development, and the assessment of that risk in terms of residential land use in the vicinity. The risk assessment guidelines set in Bulletin 278, which are related to the results of a Preliminary Risk Analysis, are as follows:

- a risk level in residential areas, due to hazardous industry, of less than oneinamillion deaths per year is low enough to be acceptable;
- a risk level of greater than ten-in-a-million deaths per year is high enough to be unacceptable;
- a risk level between one- and ten-in-a-million deaths per year may be acceptable if further safeguards can be incorporated. The assumption is that a Preliminary Risk Analysis is sufficiently conservative, so that safeguards incorporated during the detailed design stage can result in a final risk level less than one-in-a-million deaths per year.

The judgement on acceptability of risk forms part of the Authority's Report and Recommendations to the Minister for the Environment as the Authority's contribution to the Government's decision-making role.

There is now more than three years' experience with applying Bulletin 278. The Authority recognises that in that time there have been developments in both criteria and processes of risk assessment within and outside Western Australia. Therefore, the Authority considers it appropriate to review publicly the approach to risk assessment and the decision-making process.

In recent years the community has become increasingly aware of the risks from locating hazardous industries near populated or environmentally sensitive areas. The number of reported industrial accidents worldwide has further alerted us to the risks. This awareness has required a new approach to safety planning for hazardous industries.

One element of the new approach has been the need for criteria for acceptable risk. These criteria then need to be considered in a statutory framework which aims to ensure that the public and the environment are not exposed to unacceptable levels of risk.

This discussion paper is in two major parts:

Part 1: Criteria

Part 2: Process

The format of this paper is a series of questions to which the Authority is seeking broad community input. To assist in focussing that input the Authority has included information available to it, and has described its current thinking on these issues.

It would be preferable that even hazardous industry presented zero risk to the community. But in the case of hazardous industry, zero risk is virtually impossible to meet. The risks of accidents can always be reduced by applying more safeguards but zero risk could be achieved only by not having the industry at all.

The popular, and legitimate, question "Is it safe?" must be interpreted in the risk assessment as meaning "Are the risks low enough for the public to tolerate?" If so, the risks are said to be "tolerable". This is what risk criteria attempt to establish.

It is necessary to have a set of principles for the formulation of risk criteria and establishing a process of risk assessment. The following principles are suggested for assessing the risks from any hazardous industrial activity:

1 no individual should have to bear an unfairly high risk from industry;

2 no community should have to bear an unfairly high risk from industry;

3 the community should not have to bear risks where there are available reasonable alternatives with less risk; and

4 no risks should be imposed unnecessarily (unless they are clearly negligible).

The first principle is usually represented by individual risk criteria. The second may be covered by societal risk criteria. The other principles can be met in several ways, but a possible approach is to address them through ALARP ("as low as reasonably practicable") considerations.

The following qualitative guidelines are considered appropriate when assessing the risk implications of a development project of a potentially hazardous nature or suitability of a development in the vicinity of a potentially hazardous installation from a safety point of view:

a readily `avoidable' risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, where applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justifiable;

b the risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation or complex. In all cases, if the consequences of an identified hazardous incident are significant to people and the environment, then all feasible measures should be adopted so that the likelihood of such an incident occurring is made very low. This necessitates the identification of all contributors to the resultant risk and the consequences of each potentially hazardous incident. The assessment process should address the adequacy and relevancy of safeguards as they relate to each risk contributor;

c the consequences of hazardous events having a high probability of occurrence should, wherever possible, be contained within the boundaries of the installation; and

d where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.

In developing and using risk criteria, it is possible to define fixed values for "acceptable" risk levels or to describe the criteria as a range. Given the uncertainties inherent in existing risk analysis models in the early stages of a proposal, the Authority believes that a two order of magnitude band is suitable for both individual and societal risk. The Authority proposes that the band should be centred on the different criteria for different land uses. For proposals which fall within the upper part of the band above the central criterion, the Authority would recommend further work on risk reduction with the aim of achieving risk levels to below the central criterion. Where preliminary risk levels are just below the central criterion, the Authority would recommend that the risks be made "as low as reasonably practicable" (ALARP), ensuring that as uncertainty in the analysis is reduced (eg through auditing of Total Hazard Control Plans) the risk level approaches the lower limit of the band.

For example, if one-in-a-million is the central criterion for residential areas, then risk levels above ten-in-a-million would be unacceptable, and levels below one-in-ten-million would be negligible. Levels between these two values generally would be judged acceptable subject to conditions which became more stringent as the upper level was approached.

In discharging its responsibilities for risk assessment, the Authority has been confronted with some difficulties because residential areas were the only type of land use for which criteria were established in this State. Having reviewed other criteria in use elsewhere the Authority is suggesting the following individual fatality risk criteria for acceptable risk from industry on various land uses:

Land use	Suggested criterion (risk in a million/year)
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Risk imposed on adjacent industrial sites	50

The Authority is seeking comment on the application of these criteria in Western Australia. At this stage, the Authority proposes to use these criteria as the central value of the "acceptable" range as discussed above.

The Authority also is considering the development of societal risk criteria. There are two components to the societal risk concept. Firstly, the number of people exposed to levels of risk is important. Secondly, society is more averse to incidents which involve multiple fatalities or injuries than to the same number of deaths or injuries occurring through a large number of smaller incidents. To deal with this aspect of risk, the intensity of use and the density of people likely to be at risk need to be considered. The nature and scale of the incidents contributing to the particular risk levels at particular points, and the outcomes of those incidents in terms of fatality and injury, also need to be considered.

Societal risk analysis combines the consequences and likelihood information with population information. It is usually presented in the form of an 'F-N curve', which is a graph indicating the cumulative frequency (F) of killing more than a certain number of people (N).

Pending further refinements to the F-N approach , the Authority suggests that judgments on societal risk be made on the basis of a qualitative approach on the merit of each case rather than on specifically set numerical values.

The Authority is considering an assessment process where the individual fatality risk contours would be established. The density of members of the public in each land use type within each risk band should then be analysed and the suitability of a particular development judged on the basis of the location, density and vulnerability of the exposed population.

In practice, the frequency of each potential accident and the number of people that may be affected by each accident will be estimated wherever practicable and F-N curves will be generated and used as an input to the analysis. This will provide the experience necessary to allow a future decision on criteria to be made on the basis of experience.

The Authority is giving consideration to the desirability of applying criteria for risk of human injury. The Authority recognises that introduction of injury criteria will introduce an additional, possibly unwarranted, level of complexity into the preliminary risk assessment process. Therefore the Authority believes that injury risks criteria should not be part of the environmental impact assessment process in a quantitative way for every project with a risk component. It may be appropriate for specific projects where a major likely impact is in the form of human health (not death) effects, and it may appropriately form part of the regulatory processes which follow the initial government consent to a proposal.

Some activities involving hazardous materials can produce intermittent risks which cause a wide variation in risk with time. The peak risk per unit time in certain hours or days may be much higher than if the risk is averaged over a year or a lifetime. Risks are normally expressed as likelihoods per year based on total annual risks. The problem with this is that such criteria appear to allow highly hazardous activities to take place for a short time, concentrating an entire year's risk quota into perhaps a few hours. This may be reasonable, provided that this is coupled with ALARP ("as low as reasonably practicable") considerations (ie cost-benefit analysis of possible risk reducing measures). The importance of ALARP on a brief highly hazardous activity is that risk reduction measures such as exclusion zones may be shown to be very effective. Then it may in fact be preferable to concentrate the hazard when members of the public are not present than to spread it over a longer period and lose the opportunity to reduce the total societal risk. An additional problem with this approach is that highly hazardous activities and public exclusion zones, even brief ones, tend to raise public concern about the risks. Therefore, it is important that this approach be seen in a positive way, and for the regulatory authority to be confident that this approach really does reduce the total societal risk. However the Authority recognises that there may be some difficulty in the application of ALARP initially until some experience is developed in this State.

A further question is whether risk criteria should differentiate between new and existing industries. It is much easier to reduce risk at the design stage than to modify existing activities. For new industry it is also easier to withdraw from the proposal or move it somewhere else if risk reduction is uneconomic. Another reason for applying stricter criteria to new activities is that a reduction in risks from industrial activities has been achieved over the years, and the public may reasonably expect this to continue. Risk criteria for new plants could therefore be set at levels below those achieved by existing plants. However, when different criteria are applied to new and existing activities, there is a danger of the regulatory authority being accused of allowing existing plants to impose intolerable risks. Fear of such pressure may lead to the adoption only of standards which existing industry can meet, forming a very lenient standard for new plants. A solution to this problem is to present the differences in criteria between new and existing activities as a positive move to achieve lower risks in the future. In Western Australia, the Authority believes that there are few, if any, areas which do not already comply with the criteria suggested above. Should any such areas be identified, the Authority would recommend action be taken to address the situation. Therefore, the Authority does not perceive a need to adopt different criteria for new and existing industry in Western Australia.

A further issue is the application of criteria to non-hazardous developments in risk-affected areas. The Authority is of the view that, compared with other locations, there is less restriction in Western Australia on the availability of land to allow separation of hazardous industry. The Authority also recognises the importance of maintaining adequate buffer zones once hazardous industry has been developed. The Authority is seeking comment on having stricter criteria on future development of non-hazardous uses in the vicinity of existing hazardous industry.

The Authority is considering whether qualitative criteria can be applied to sensitive environmental areas, which relate to the potential effects of an accidental emission on the long term viability of the ecosystem or any species within it. The Authority believes that the analytical methodology may be applicable in environmentally sensitive situations, and would investigate this possibility. However, the development of criteria is not considered feasible at present.

There have been questions as to the reasons for doing risk analysis as part of the environmental assessment process. When planning a new hazardous industrial activity or reviewing an existing one, decisions sometimes have to be made about issues such as:

- whether or not the activity should be permitted at all;
- whether measures are necessary to reduce its risks;
- which of various options should be chosen; and
- what other land uses should be permitted nearby.

"Quantified risk analysis" (QRA) is a means of making numerical estimates of the risk from hazardous activities, and "assessment" then involves making a rational evaluation of their risk implications. QRA therefore can provide useful input to decision-making about such activities. Since much of the decision-making process is carried out before detailed design of an industry is completed, it is common practice to class the analysis at these early stages as a Preliminary Risk Analysis (PRA). This is the term used most frequently in the following discussion.

Risk analysis involves identifying the hazards which are present, estimating their frequencies and consequences, and combining them into suitable measures of risk. Assessment of the significance of the risks is then needed before the QRA can help in making decisions about the hazardous activities. Risk criteria are intended to help this critical step.

Although many of the principles stated in this document apply to existing industry of a hazardous nature, the main focus and scope of application relate to proposed development projects which are required to undergo formal assessment by the Environmental Protection Authority.

The issues and studies outlined usually will be applied in their entirety to developments requiring formal assessment under the provisions of the Environmental Protection Act when those developments could cause, or be affected by, significant risk levels. The Act requires documents, in which the development is described and analysed, to be prepared and publicly exhibited for development considered to have a significant potential for environmental impact. The system of referral of projects and setting of the level of assessment is under the control of the Minister for the Environment and the Environmental Protection Authority.

It is important to note that risk assessment, and indeed the complete environmental impact assessment process, is an advisory process. The Environmental Protection Authority provides advice, which incorporates extensive public consultation, to the final decision-makers.

Decisions concerning the location of a hazardous materials facility and surrounding land uses are planning decisions and, when properly implemented, land use planning becomes an essential and integral component of the hazard and risk management. In this process land use safety conflicts are prevented by identifying, quantifying and managing hazards and risks in the context of broader considerations.

The basic methodology of hazard analysis and quantified risk assessment involves: hazard identification, consequence and, probability/frequency analysis, and quantifying resultant risk levels. The consequence and probability estimations are cumulatively combined for the various hazardous incident scenarios and events to give a quantified risk level. Risk results are most commonly expressed in terms of human fatality. The analysis and results can, however, also be expressed in other terms such as levels of injury, property damage or environmental damage. Further details of what the Authority expects to be covered in a PRA can be obtained from the Authority in the form of generic guidelines for such analysis.

The results of the consequence and probability analysis should be combined and the risk results presented in the form of contours, societal risk curves or other appropriate format. The results should address, where appropriate, impacts on people, property and the environment.

Other related issues that should be addressed in a PRA include a description of all proposed safeguards, and an outline of organisational safety controls.

The consent authority should be able, from the PRA and other relevant information, to assess whether the proposed development is capable of operation and is likely to be operated by the particular proponent in the particular location without unacceptable risk impacts. This assessment would be against the qualitative and quantitative criteria set by the Authority.

The qualitative and quantitative results of the Preliminary Risk Analysis are applied by the Environmental Protection Authority in the environmental impact assessment process in two ways. Firstly, risk impacts at various distances from the proposed development and on various land uses and the environment in the vicinity of the development are measured against land use safety planning criteria. A judgement is then made about the suitability of the proposed development's location in relation to both existing and likely future land uses in the area. Also, the analysis should highlight, firstly, the major contributors to risk and their nature and extent and, secondly, areas where risk can be eliminated or cost-effectively reduced. One principle used here is that where safer alternatives are available without significant technical or economic cost they should be used regardless of the risk levels.

A fundamental issue is the role the suggested risk criteria fill in the assessment process. The implementation of the criteria must acknowledge the limitations and in some cases the theoretical uncertainties associated with risk quantification. Two approaches are usually adopted to account for such uncertainties: a 'pessimistic' approach - that is assumptions err on the conservative side with over-estimation of the actual risk; or 'best estimates' using realistic assumptions with an estimated risk that could either be an overestimate or an under-estimate of the actual risk.

To account for any uncertainties and limitations, when the Authority provides advice on risk analysis and evaluating risk implications of development proposals, it requires a proponent to use the most up-to-date and validated assessment tools and techniques. The assumptions used in the analysis are checked by the Authority to ensure that they err on the side of caution, ie the Authority prefers to adopt conservative assumptions that may reflect an over-estimation of the actual risk. This approach is justified on planning grounds.

The criteria suggested in Part 1 are set at a realistic level to reflect this conservative approach in the assessment process.

A degree of flexibility in the implementation and interpretation of the absolute values of the risk criteria may be justified in some cases. There may also be variations in local conditions. Consideration of vulnerability of people and situations is necessary.

The criteria are best implemented when used as targets rather than absolute levels. Nevertheless, any substantial deviations from such targets should be fully justified.

It is advisable that in all cases the assessment process emphasises the hazard identification and risk quantification process and procedures rather than entirely relying on absolute risk levels.

Given the probabilistic nature of the assessment process, care must be exercised in interpreting/assessing compliance with a risk criteria, particularly in terming plants which exceed the suggested criteria as 'unsafe'. Nevertheless, a resultant risk level higher than a suggested criterion indicates land use safety incompatibility and locational safety constraints.

The implementation of the risk criteria should differentiate between existing land use situations and new situations in terms of applicability to reflect a tighter locational and technological standards applying now than at earlier times. In the case of existing industry, compliance over time with a risk criterion is part of an overall strategy to mitigate existing risk levels by reducing both the risks and the number of people exposed to those risks.

The criteria suggested in Part 1 apply to new industry and surrounding land use proposals. In theory they should apply to existing situations, but this may not be possible in practice. For existing situations, an overall planning approach is necessary.

An issue considered by the Authority is how risk assessment should be used in the wider decision-making process. The integrated approach to risk assessment and management is based on the methodology outlined above and also on the following principles:

a It is necessary to identify hazards and in some cases quantify risks at an early stage of project formulation and as an integral part of the site selection process.

b Formal hazard identification and analysis determine the risk contributors and also the relevancy of the proposed safeguards and their adequacy in mitigating impact for the specific development at the specific location.

c Quantified risk analysis determines off-site 'residual risk', ie risk to people, the environment and other land uses. The assessment then accounts for the effectiveness, as well as the limitations, of technical hazards control. Assessment of quantified risk is therefore the central tool in determining the suitability of a proposed site to accommodate a hazardous activity, and as importantly specifies the strategic planning implications to surrounding land uses of such decisions.

d It is essential to account for the community's perception of risk in the location and assessment processes for hazardous industry. Hazard analysis and quantified risk assessment are valuable tools in communicating risk and accounting for community perception issues.

e It is necessary to ensure that safety requirements are accounted for through the complete development process for a hazardous facility including siting and feasibility study, design, construction and operation. It is also necessary for the requirements to cover both fixed safety equipment (hardware) as well as organisational safety measures (management, training, emergency planning, etc).

f The safety requirements should ensure the efficient co-ordination of various statutory requirements to avoid duplication and maximise their complementary implementation.

There has been some discussion as to the preferred place for risk assessment within the overall planning system. Basically the Authority manages the system of Preliminary Risk Analysis as one issue to be considered in the assessment of potentially hazardous industry. This management is done through the existing environmental impact assessment (EIA) process. The Authority, believes that the present practice should be continued.

Since what happens after the initial approval determines the risk levels imposed in practice, the Authority has an interest in ensuring that the downstream approval processes achieve at least the predicted safety standards.

There are three types of "follow-up" issues:

- the proposal must be designed to incorporate safety and, as a minimum, to meet the parameters used to make the initial assessment decision;
- there must be maintenance of plant safety standards during operation; and
- there are reactive issues for government to deal with such as controlling surrounding land uses and incorporating the proposal into off-site emergency planning.

It is essential that the safety assessment process continues throughout the design, construction and commissioning of a hazardous facility to refine and update the outcome of the development approval/environmental risk assessment process. A number of studies usually are recommended for inclusion in the overall safety assurance process through conditions and commitments attached to the Ministerial "Statement that a Proposal May Be Implemented". While the Authority is interested in making sure that this work is carried out effectively, it does not believe that it should be directly involved in this part of the process. It is appropriate that other statutory authorities discharge their legislative responsibilities with the minimum standard being to meet the parameters on which the assessment was based and the Ministerial Statement was issued.

It is also essential that the continued safety of the plant and its operations be ensured through periodic hazard auditing during the operational stage of the plant. Auditing should therefore be required by way of a condition set by the Minister for the Environment. At present, this is loosely covered by a Total Hazard Control Plan for major sites (sometimes specified in Ministerial conditions), company policies on plant and employee safety, DOHSWA controls, Pollution Control Licences and planning processes.

The two main issues to be dealt with externally to the risk assessment process by government agencies are land use planning of areas surrounding a hazardous industry, and off-site emergency planning. The first of these is discussed in detail under a separate heading. In terms of emergency planning, "acceptable risk" is not equivalent to "no risk". Therefore, there is a residual possibility, albeit a low one, that an incident may occur during the life of a hazardous industry which could have off-site consequences in the form of human injury or death. The Authority believes that it is necessary to recognise this possibility and to take steps to ensure that emergency response capabilities are developed in line with the level of residual risk.

The Authority believes that there should be inputs and controls on other land uses to avoid compromising public safety. At present, the assessment process deals with the cumulative risk from new hazardous industry on existing residential areas. Where a complex of hazardous industries exist, cumulative risk models have been developed. The range of criteria discussed above would cater for the cumulative impact of new industry on these other land uses.

There is a difficulty with conflicting existing land uses, eg a small number of residents affected by risk levels from significant industrial developments. The usual and acceptable outcome when such situations are identified is to move the residents to create an adequate buffer zone. A more difficult situation arises when a conflicting land use is permitted to develop near an existing hazardous site. This is a similar problem to residential encroachment on buffer zones for odours from noxious industry. However it is different in that risk is not as "tangible" as odour for consent authorities, developers, or purchasers of property. The only option at present is to withdraw any licences to operate a hazardous site.

There is informal, and growing, pressure on land use planners to incorporate this issue into the planning process. The Authority believes that the process should be formalised by the development of "exclusion zones" around all facilities with residual risk levels exceeding the criteria. For major industrial sites or complexes this could be achieved through incorporating the results of quantified risk analysis into planning schemes. The Authority believes that this would be a positive step towards the maintenance of public safety standards in Western Australia. The Authority recognises that work in this direction has commenced at government officer level, and encourages its further development.