Intermodal
Logistics Centre
at Enfield

APPENDIX K

Preliminary Hazard Analysis

PREFACE

The technical working papers for the proposed ILC at Enfield were prepared during the first half of 2005. These were prepared in response to the requirements for the preparation of an Environmental Impact Statement (EIS) under Part 4 of the Environmental Planning & Assessment Act, 1979 (EP&A Act). Specific requirements for the EIS were issued on 1 March 2005 by the (then) Director- General of Infrastructure, Planning and Natural Resources.

The EP& A Act was amended on 1 August 2005 by the creation of Part 3A of the Act, and the Department of Infrastructure, Planning and Natural Resources was dissolved on 26 August 2005 and replaced by the Department of Planning and the Department of Natural Resources.

The proposed ILC at Enfield has since been declared a major project, pursuant to SEPP (Major Projects) 2005 and Sydney Ports has subsequently lodged an application under Part 3A of the Act.

Editorial changes to the technical working papers to reflect the changes in legislation or changes in Government departments have not been made.

The following should be considered when reading the technical papers:

- The Director-General’s requirements issued under Part 4 are now deemed to have been issued under Part 3A, and any reference to the Director-General’s requirements should be read as a reference to Director-General’s requirements issued under Part 3A;

- Any reference to an EIS under Part 4 of the Act should be read as a reference to an Environmental Assessment under Part 3A of the Act;

- Any reference to the Department of Infrastructure, Planning and Natural Resources should be read as a reference to either the Department of Planning or the Department of Natural Resources, as appropriate.

QEST CONSULTING

Intermodal Logistics Centre at Enfield Environmental Impact Statement

Preliminary Hazard Analysis

Prepared for Sinclair Knight Merz

Job No: SKM1S
Revision No: 2

Prepared By: Robert Hutchison
Checked By: Philip Skinner
Approved By: David Hitchcock
Date: 20 May 2005

Northpoint, Level 19, 100 Miller St
North Sydney, NSW, 2060
Australia

QEST Consulting Pty Ltd ABN: 41 055 743 345

MELBOURNE	ADELAIDE	BRISBANE	PERTH	SYDNEY
Level 2	PO Box 516	Level 15, 10 Market Street	Level 2	Northpoint, Level 19
325 Flinders Lane	Plympton	Brisbane 4000	172 St Georges Tce	100 Miller Street
Melbourne 3000	SA 5038	GPO Box 167 Brisbane 4001	Perth 6000	North Sydney 2060
T: +61 3 9648 4400	**T:** +61 8 8297 0897	**T:** +61 7 3211 9210	**T:** +61 8 9481 3800	**T:** +61 2 9460 4922
F: +61 3 9648 4499	**F:** +61 8 8297 0897	**F:** +61 7 3211 9810	**F:** +61 8 9481 3899	**F:** +61 2 9460 4911

QEST CONSULTING

DOCUMENT REVISION RECORD

Rev	Description	Prepared by	Checked by	Approved by	Date
A	Draft Report	R. Hutchison	P. Skinner	D. Hitchcock	14 March 2005
B	Draft Report	R. Hutchison	P. Skinner	D. Hitchcock	8 April 2005
0	Draft Report	R. Hutchison	P. Skinner	D. Hitchcock	26 April 2005
1	Final Report	D. Hitchcock M. Mesiti	P. Skinner	R. Hutchison	11 May 2005
2	Minor typographical errors corrected	R. Hutchison	P. Skinner	D. Hitchcock	20 May 2005

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

EXECUTIVE SUMMARY

Qest Consulting Group (Qest) was commissioned by Sinclair Knight Merz (SKM) to support the development of the Environmental Impact Statement for the Intermodal Logistics Centre at Enfield by undertaking a Preliminary Hazard Assessment (PHA) of the proposed intermodal terminal at the former Enfield Marshalling Yards in western Sydney.

This PHA has been undertaken in accordance with the guidance provided by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR[1]) in Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – *Guidelines for Hazard Analysis* [i]. An assessment of risk has been undertaken in accordance with criteria published by the DIPNR in HIPAP No. 4 – *Risk Criteria for Land Use Safety Planning* [ii]. This assessment is of the intermodal terminal and excludes other areas of the Intermodal Logistics Centre.

The purpose of the terminal is to improve the transport links to and from port facilities at Port Botany and increase the use of rail. All of the containers handled at the site will transit Port Botany (either inbound or outbound). The PHA includes an assessment of the risk from the intermodal terminal and the transportation of dangerous goods along the existing rail route from Botany to Enfield and the roads close to the intermodal terminal.

Conclusion

The pattern of dangerous goods trade was based on the historical trade pattern through Port Botany scaled by total container trade. The assessment of the risk against the DIPNR risk criteria enabled the following conclusions to be reached:

- The risk results for the analysis, with no restriction in the type or package size of dangerous goods handled at the intermodal terminal presented an acceptable risk profile with respect to the New South Wales Land Use Planning criteria for fatality, injury and irritation. The risk analysis was based on the intermodal terminal site operating at full throughput capacity (300 000 TEU[2] p.a.).
- This result was based on there being no trade in Class 2.3 isotainers[3] or hydrogen fluoride isotainers through the intermodal terminal.
- The transportation of the containers with dangerous goods by road and rail to and from the site contributed an acceptably low level of risk.

[1] The Department of Infrastructure, Planning and Natural Resources, previously known as PlanningNSW and the Department of Urban Affairs and Planning.
[2] One TEU is equivalent to one twenty-foot container. A forty-foot container is equivalent to two TEU.
[3] Tank containers, which contain up to 24000 L of liquid or liquefied gas, are also known as isotainers or ISO Containers.

1. INTRODUCTION

Qest Consulting Group (Qest) has undertaken a Preliminary Hazard Analysis (PHA) of the proposed intermodal terminal at the former Enfield Marshalling Yards in western Sydney. This assessment excludes activities and operations of other areas of the Intermodal Logistics Centre, namely empty container storage, warehouse and light industrial areas as the detailed nature of activities in these areas is yet to be identified. Should the future operations of those facilities involve the likely handling of dangerous goods, separate assessment and approvals will be required on a case by case basis.

This report includes an assessment of the proposed intermodal terminal operations involving potentially hazardous materials. This assessment has been undertaken with reference to the Department of Infrastructure, Planning and Natural Resources (DIPNR's[4]) Hazardous Industry Planning Paper (HIPAP) No. 6 - *Guidelines for Hazard Analysis* [i]. An assessment of risk has been undertaken in accordance with criteria published by the DIPNR in HIPAP No. 4 – *Risk Criteria for Land Use Safety Planning* [ii].

1.1. Background

The proposed Intermodal Logistics Centre will provide facilities for intermodal exchange (transfer of containers between rail and road transport modes); empty container storage and distribution; warehousing for the unpacking/packing of containers; and light industrial /commercial premises. This approach minimises the external impacts of the facility and maximises efficiency and reliability of the freight logistics chain. The site will also include a dedicated area for community and ecological purposes.

Qest Consulting (Qest) was commissioned by SKM on behalf of Sydney Ports Corporation to undertake a Preliminary Hazard Analysis (PHA) of the new design of the proposed intermodal terminal. The PHA includes an assessment of the risk from the intermodal terminal at Enfield and the transportation of dangerous goods both along the existing rail route from Botany to Enfield and on the access roads to the site.

1.2. Aims and Objectives

The general aim of the PHA study is to assess the level of risk associated with the proposed facilities. The specific objectives of the study are to:

- Identify the hazardous incidents that relate to the operation of the intermodal terminal.
- Assess the significance of each incident in terms of its potential off-site impact.

[4] The Department of Infrastructure, Planning and Natural Resources, previously known as PlanningNSW and the Department of Urban Affairs and Planning.

- Quantify where appropriate and assess the off-site levels of risk to people, property and the environment due to the proposed plant and its operation, using iso-risk levels (individual risk contours).
- Provide a clear, concise report of the analysis in line with the requirements of HIPAP No. 6 [i].

In the management of the risks associated with the operation of the intermodal terminal specific risk management controls centred on the movement of dangerous goods may be required. In line with the need to manage the risks to an acceptable level from dangerous goods that may pass through the intermodal terminal the objective of the study is to identify any specific limitations on the class of materials, quantities or dwell time in order to meet the risk criteria.

2. SITE AND BUSINESS DESCRIPTION

2.1. Site Layout

A description of the proposal is provided in Chapter 4 of the EIS document [iii].

Figure 2.1 presents a computer generated drawing of the proposed layout of the intermodal terminal which forms a part of the proposed Intermodal Logistics Centre (ILC) at Enfield. This shows the intermodal terminal site boundary and other key features of the ILC.

2.2. Business Description

The intermodal terminal operations will consist of the operation of trains to and from Port Botany with containers loaded onto trains at the container terminals, routed to the intermodal terminal at Enfield, removed from the trains to the container holding areas as shown in Figure 2.1 for subsequent loading to truck and distribution by road.

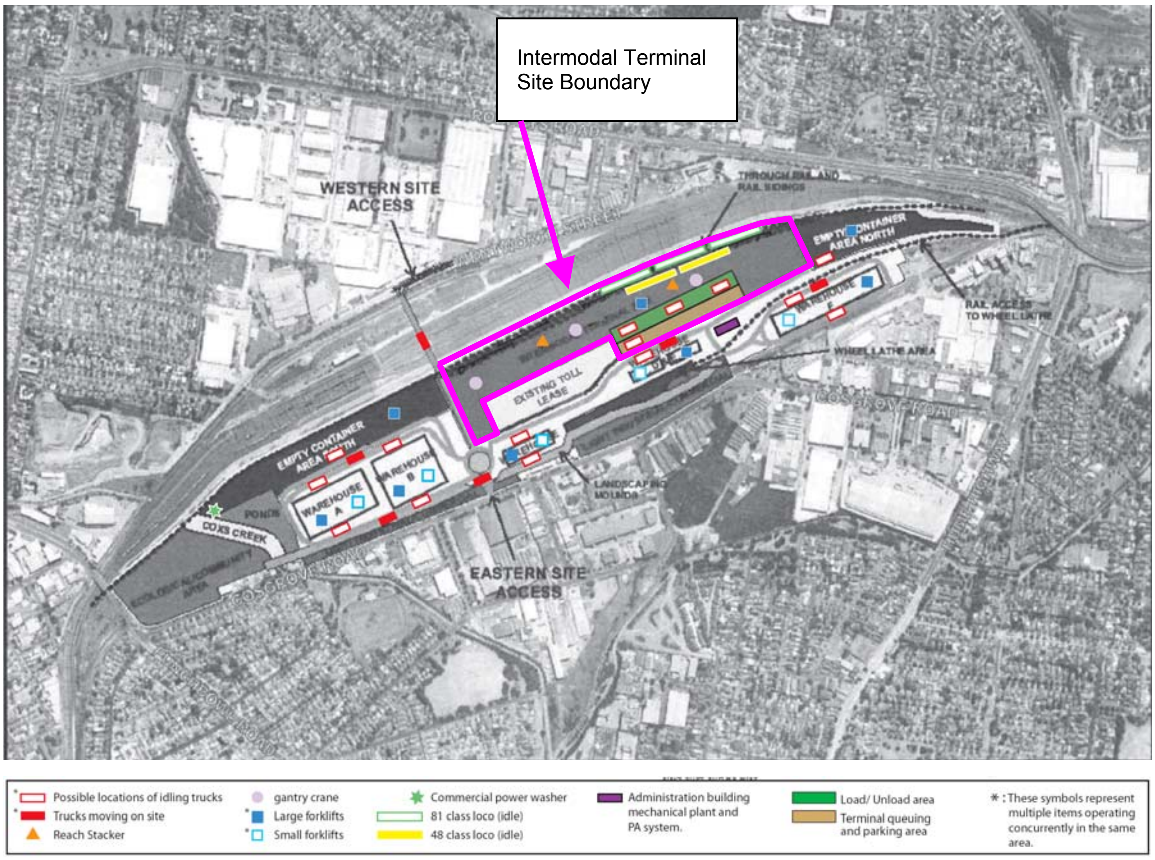
Additionally containers will be received at the intermodal terminal at Enfield from the road network, placed in the container holding areas for subsequent loading to train and railed to Port Botany. There will also be some dispatch of empty containers from the intermodal terminal onto intrastate freight trains. The long term capacity of the intermodal facility for the site is currently estimated at 300,000 TEU per annum in 2016/17.

The site will use gantry cranes or other lifting equipment for loading and unloading containers to/from rail and forklifts and reach stackers for moving containers on-site and loading and unloading from trucks.

There is no designated area for storage of dangerous goods containers either "red line"[5] or “green line”. Dangerous goods containers are assumed to be equally distributed amongst the container stacks. In the year 2016/17 the intermodal terminal is forecast to handle approximately 300 000 TEU each year. Based on the current level of dangerous goods passing through Port Botany approximately 2-3% of these containers contain some dangerous goods (~7 500 TEU p.a.). Most containers that contain dangerous goods only contain a relatively small quantity, although there are some containers carrying solely dangerous goods.

[5] In port areas Red line containers are not allowed to be stored on-site for more than 2 hours unless an exemption is previously approved by Sydney Ports Corporation. Green line containers may remain at the port for up to 5 days.

Figure 2.1 Proposed Enfield Intermodal Site Layout



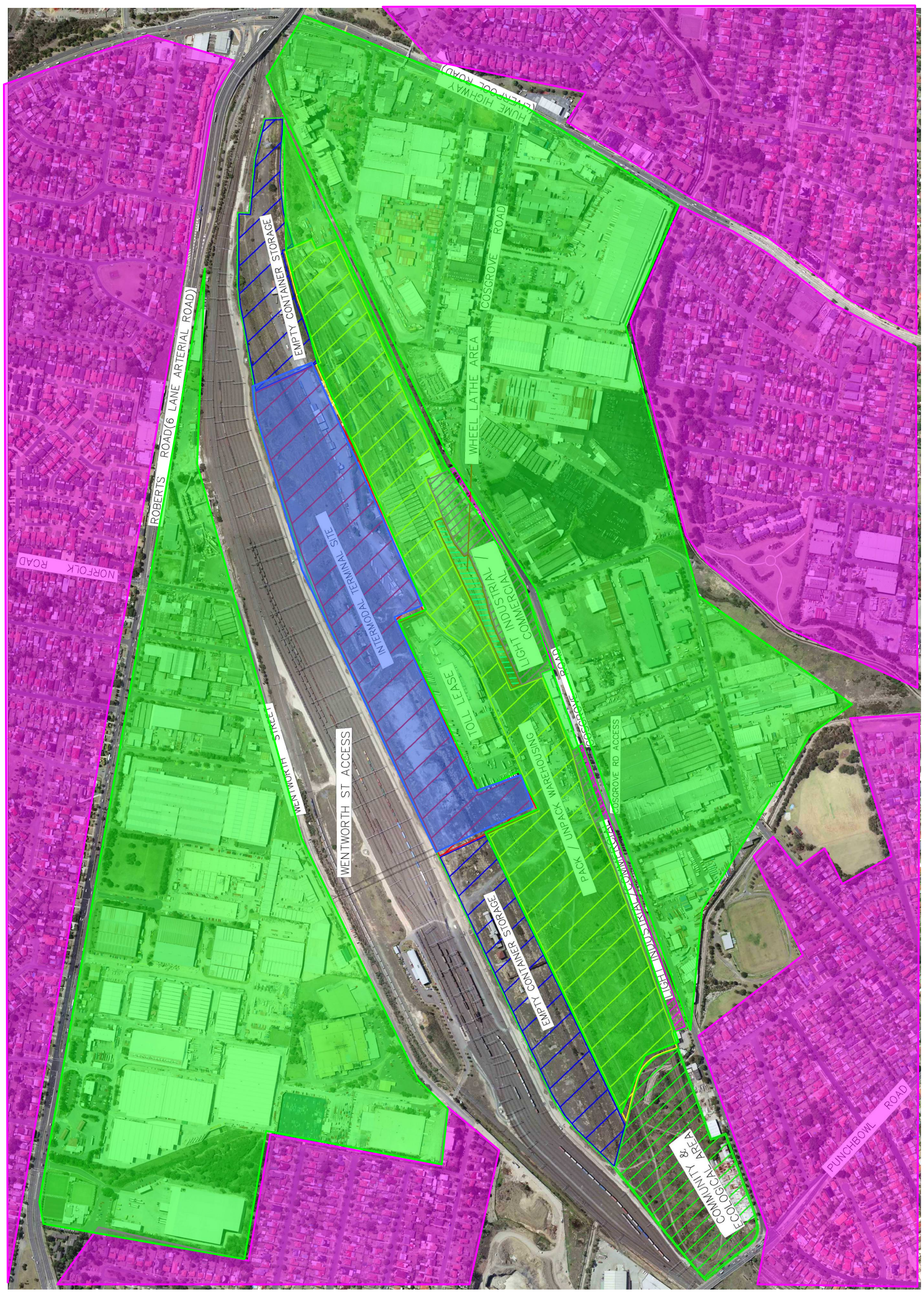
2.3. Surrounding Land Uses

The proposed intermodal terminal (which forms part of the proposed ILC) is located within the former Enfield Marshalling Yards. The new Enfield Marshalling Yards are located to the west, and the proposed intermodal terminal is surrounded by the other operations on the site. These operations include rail movements to the west (new Enfield Marshalling Yards) and (rail access from Port Botany) to the south of the site, container operations conducted by Toll Australia, warehousing operations to the east and a rail car maintenance facility (DELEC and wheel lathe areas) to the east. Further away from the site, to the west and east are light industrial areas which adjoin residential areas.

2.4. Land Uses

Figure 2.2 shows the land uses around the site. This shows that there is a buffer of industrial land immediately adjacent to the site with residences further away. Land that is vacant or with few people present is not shaded.

Figure 2.2 Land Uses



Residential	Industrial	Site

2.5. Populations

There are significant numbers of people located in the industrial areas. These people are predominantly present during business hours, with fewer people present at night and during the weekend. Conversely, the residences have fewer people present during the day, with more people present at night and during the weekend.

2.6. Local Environment

The site is a lower-lying section of land within a relatively flat section of Sydney. The land drains to the south east into Coxs Creek and then into Cooks River which discharges into Botany Bay.

2.7. Transportation Routes

The intermodal terminal will generate up to 10-20 (16 is most likely) train movements per day.

The road traffic will predominantly be through the western access road (Wentworth St) to Roberts Rd, although there may be some trucks that access the site via Cosgrove Rd. An average of 9 containers with dangerous goods will be transported each day.

2.8. Safety Systems

The safety systems on site that affect the potential for off-site risk are primarily associated with containment of spills and fire-fighting.

2.8.1. Bunding

A stormwater detention basin will be constructed at the southern end of the site to allow run-off to be intercepted prior to discharge. This will allow spills to be captured on-site and also allow for firewater to be collected and treated prior to discharge from the site.

2.8.2. Fire Detection and Protection

There is no specific fire detection system proposed for the site. However the presence of personnel at the site will detect fires or spills from containers. A fire hydrant system will be provided to enable the emergency services to fight any fires.

3. METHODOLOGY

3.1. Study Scope

The study assessed the risks to the public arising from both normal operations and atypical occurrences associated with the storage and handling of hazardous materials at the site.

The scope of the study included the following tasks:

1. Preliminary Hazard Analysis of the proposed intermodal terminal which forms part of the ILC at Enfield.
2. Qualitative assessment of the risks to the bio-physical environment from accidents on site involving dangerous goods including an assessment of both the acute and chronic effects using the guidance in HIPAP No. 6 [i]. The biophysical assessment has been undertaken with reference to the current status of the surrounding environment.
3. The analysis of the development impact in terms of societal risk has been undertaken based on estimated populations in the surrounding area.

3.2. Study Methodology

The methodology used in this study is that outlined in HIPAP No. 6 [i]. The PHA methodology used in this study is that of classical risk assessment. This is a systematic approach to the analysis of what can go wrong in complex industrial systems. The normal conditions of operation of the system are defined and then the following questions asked:

- What accidental events can occur in the system?
- How frequently would each event occur?
- What are the consequences of each event?
- What are the total risks (frequencies x consequences) of the system?
- What is the significance of the calculated risk levels?

These questions correspond to the five basic components of a PHA. Once a system has been analysed, if the risks are assessed to be too high according to some criteria, the system can be modified in various ways to attempt to reduce the risks to a tolerable level, and the risk levels recalculated. The process may therefore be viewed as iterative, where the design of the system may be changed until it complies with the needs of society. By objectively quantifying the risks from each part of the system, a quantitative risk analysis enables identification of the most effective measures to reduce risks.

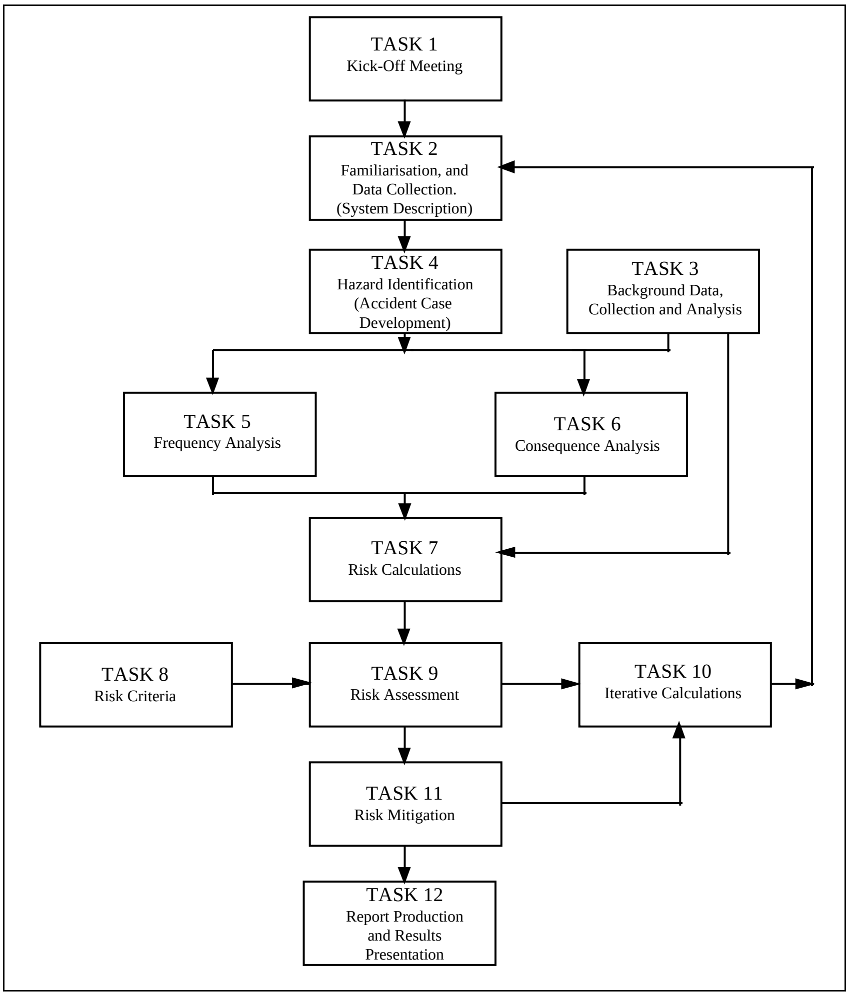
In its overall scheme, the methodology used follows the "classical" form of risk analysis and involves the following steps:

- System definition, in which information on the facility is collected and assimilated.

- Hazard identification, in which site events and external events are identified, which may lead to the release of hazardous material.
- Frequency estimation, in which the frequency (i.e. likelihood per year of occurrence) of each of the accidental events is estimated, based on historical failure data.
- Consequence modelling, in which all the possible consequences of each event are estimated.
- Risk calculation, in which the frequencies and consequences of each event are combined to determine levels of fatality risk.
- Risk assessment, in which the risks calculated are compared with risk criteria.

Figure 3.1 shows the project flow by task.

Figure 3.1 Typical Risk Analysis Methodology



The SAFETI package (Software for the Assessment of Fire, Explosion, and Toxic Impact) was used to undertake the project. This package is used by many chemical and petrochemical companies and government agencies in different countries around the world. In the past, SAFETI has been used in many QRAs[6] involving dispersion of flammable and/or toxic gases, such as ammonia, LPG and chlorine.

The SAFETI package comprises a suite of computer programs developed specially for QRA. The conceptual flow of data through the various programs follows logically through failure case definition, release modelling, consequence modelling and calculation of risk. Modelling of liquid releases, two phase (gas/liquid) releases and gas releases, instantaneous and continuous, are all included in the package. The physical conditions of the material, following the release, are calculated in order to evaluate the fraction flashed off upon release, droplet entrainment in a cloud, rain out and evaporation.

A suite of dispersion models handles dilution or entrainment of air. The models simulate four regimes of dispersion, which linked together model all the characteristics of a release:

- Turbulent jet dispersion (initial kinetic energy dominates).
- Hybrid dispersion (joint turbulent and dense gas behaviour).
- Dense cloud dispersion (density effects dominate).
- Passive dispersion (atmospheric turbulence dominates).

The results of the discharge and dispersion results are used to calculate the flammable effects (jet fires, pool fires, flash fires, BLEVEs and explosions). The effects are taken to be elliptical or a section of an ellipse in shape. The effect areas are used directly (in combination with the actual meteorological, population and ignition source data) to determine risk impact. The effect envelopes are superimposed over the population map for every weather type and for every wind direction.

[6] Quantitative Risk Assessment

4. FORMS OF RISK PRESENTATION

4.1. Introduction

There are a number of ways of presenting risk. In this section, some of the various forms of risk presentation are described in order to make the discussions that take place in subsequent sections easier to understand.

4.2. Individual Risk

Individual risk is the risk experienced by a single individual in a given time period. It reflects the severity of the hazards and the amount of time the individual is exposed to them. The number of people present does not significantly affect individual risk although there could be second order effects such as the number of surrounding persons affecting the chances of successful evacuation from a fire.

Individual risk is defined formally by the IChemE [iv] as the frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards. It is usually taken to be the risk of death, and usually expressed as a risk per year.

Individual risk is presented in this report in the form of individual risk of fatality contours over a map of the intermodal terminal site and surrounds. Contours of injury and irritation risk are also included.

4.3. Societal Risk

Societal (or group) risk is the risk experienced in a given time period by the whole group of personnel exposed. It reflects the severity of the hazard and the number of people exposed to it. It is usually taken to refer to the risk of death, and usually expressed as a risk per year.

Societal risks are defined by the IChemE [iv] as the relationship between the frequency and the number of people suffering a given level of harm from the realisation of specified hazards. This definition excludes single-figure measures such as annual fatality rate (see below) and so the wider definition above is preferred.

Societal risks may be expressed in the form of:

- Annual fatality rates, in which the frequency and fatality data are combined into a convenient single measure of group risk.
- FN curves, showing the relationship between the cumulative frequency (F) and number of fatalities (N).

These are described in the following sections.

4.3.1. Annual Fatality Rate/ Expectation Value

The annual fatality rate (AFR) is the long-term average number of fatalities per year due to a particular cause. For a particular event, it is equal to the frequency of the event (f), multiplied by the number of fatalities caused (N). The fatality rates of all relevant events may be summed to give the total AFR for the accident type or the activity as a whole.

AFR is a concise measure of group risk, which is convenient for illustrating the main contributors to the risk. It has what is arguably a drawback, in that it treats all fatalities as equally important, irrespective of the number of lives that may be lost simultaneously in a major accident.

The AFR is also known as the potential loss of life (PLL) per year - a term proposed by Shell, and widely used. It emphasises that the fatalities are not inevitable with good safety management. However, PLL tends to suggest (and is sometimes used for) the maximum number of fatalities in a single accident. In this study, PLL is used as a synonym for AFR.

4.3.2. FN Curves

FN curves are frequency-fatality plots, showing the cumulative frequencies (F) of events involving N or more fatalities. They are derived by sorting the frequency-fatality (F-N) pairs from each outcome of each accidental event, and summing them to form cumulative frequency-fatality (F-N) co-ordinates for the plot. The cumulative form is used to ensure that steadily declining (monotonic) curves are obtained even when some sizes of accident do not occur in the analysis.

FN curves are graphical measures of group risk that show the relationship between frequency and size of the accident. Unlike the annual fatality rate, an FN curve allows a judgement to be made on the relative importance of different sizes of event. Drawbacks of FN curves are that they are awkward to derive and potentially confusing to interpret.

5. HAZARD IDENTIFICATION

Hazard identification has been undertaken based on a review of the proposed activities at the intermodal terminal. This identification process was undertaken with reference to similar studies undertaken by Qest involving the analysis of port and container operations. Further consideration of the hazards associated with each of the dangerous goods classes was carried out.

5.1. Review of Basic Activities

Based on discussions with Sydney Ports Corporation during the course of the kick off meeting and through subsequent discussions, the following primary activities were identified:

- Shuttle freight train unloading/loading via forklift, reach stacker and/or gantry crane to the storage stacks.
- Loading/unloading of container trucks via forklift and/or reach stacker to/from the storage stacks.
- Storage of containers in the stack waiting export or import.
- Transportation on-site via trucks and rail cars.
- Diesel Fuel storage (for on-site vehicle use)[7].

There are three major hazards associated with the activities on the site. These are:

1. Damage to containers and potential loss of containment caused by dropping of a container during a lift or impact of a container on a solid object during a lift;
2. Damage to containers and potential loss of containment caused by a vehicle accident on-site;
3. A "spontaneous" leak occurring from a container during the storage of the container on-site.
4. Loss of containment from a diesel fuel tank leading to a pool fire.

There is the potential for these incidents to escalate if a fire occurs on-site.

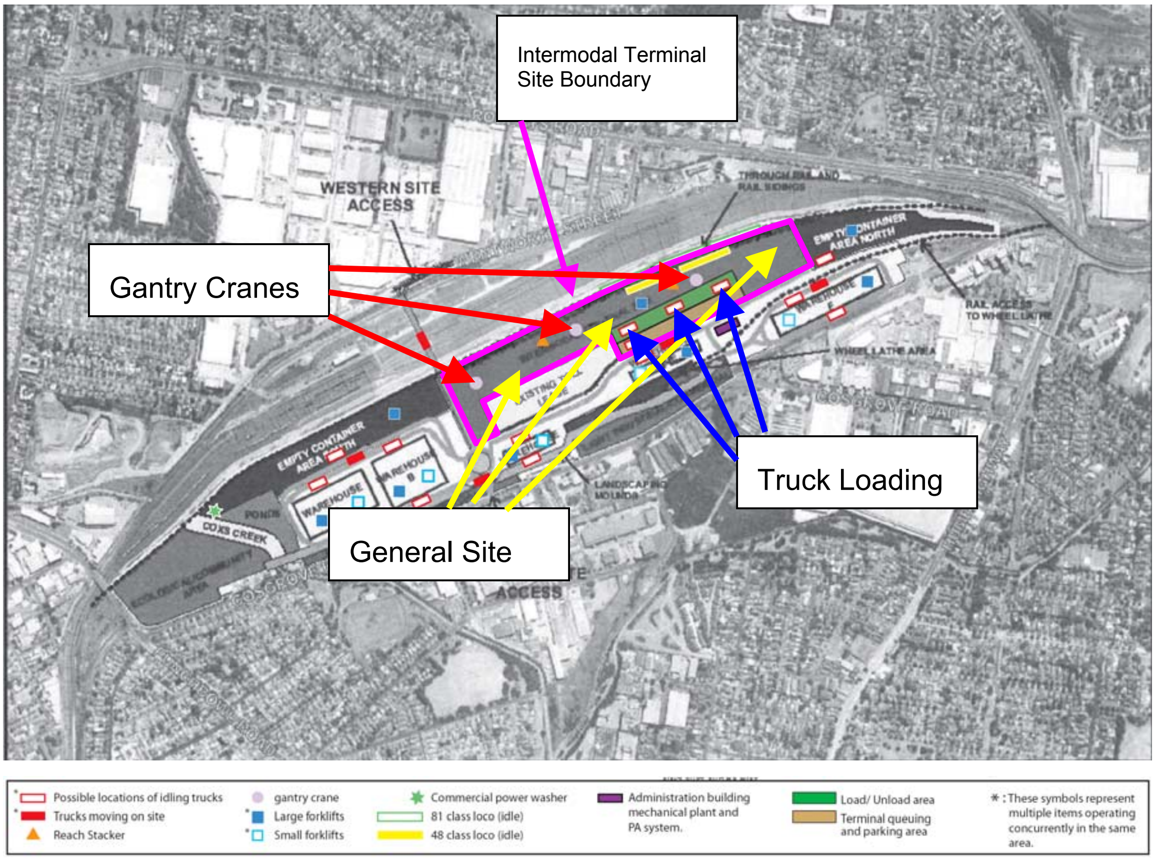
5.2. Site Location of Incidents

The locations on the site of the incidents that could occur are in three areas, each with approximately equal likelihood. Figure 5.1 shows the modelling locations on the site.

[7] Following development of the design, the diesel storages will be located off-site from the intermodal terminal on the adjacent empty container storage facilities and on the eastern side of the ILC site.

1. The gantry cranes or other devices lifting containers onto and off rail cars could drop the containers or strike another object. There are three gantry crane locations modelled in this analysis.
2. The loading or unloading of road vehicles. There is the potential for dropping of containers during this process or a vehicle accident. Three locations along the truck loading/unloading bay have been modelled in this analysis.
3. The general storage areas on-site. Some containers are stored for a period in stacks on-site before being loaded onto trucks or rail cars. This spread location has been modelled using three locations through the extent of the site.

Figure 5.1 Modelling Locations On-Site



5.3. Screening of Hazardous Scenarios

There are a very large number of products that are moved through the site. It is not possible to model all the potential scenarios for all the possible incidents. Thus, several of the potential incidents have been screened out based on either the consequences not extending off-site, or the likelihood being so low that it does not contribute to the off-site risk. This methodology is consistent with the principles of the Multi-Level Risk Assessment guidelines [v].

The first rule applied is that if a total loss of containment of the largest package in a single container cannot result in an off-site consequence, that container is not considered to pose a significant off-site risk. Thus, no further modelling is carried out for that container. During the modelling of consequences of package rupture, the following potential scenarios were examined:

Table 5.1 Potential Hazard Scenarios

Class of Material	Potential Scenarios
Class 1 Explosives	Explosion of part or all of the container load
Class 2.1 Flammable Gases	Jet fire, flash fire, Vapour Cloud Explosion or BLEVE[8].
Class 2.3 Toxic Gases	Toxic gas cloud
Class 3 Flammable Liquids	Jet fire, pool fire or flash fire.
Class 4 (Flammable Solids, Spontaneously Combustible, or Dangerous When Wet)	Explosion or fire.
Class 5 (Oxidising Agents or Organic Peroxides)	Fire or Explosion
Class 6.1 Toxic Materials	Fire involving this material.
Class 7 Radioactive	Spill causing contamination
Class 8 Corrosives	Spill causing injury

Due to the nature of the dangerous goods classification system, a non-dangerous good is very unlikely to be able to produce any of these effects causing off-site fatalities, injuries or irritation.

The materials that are most likely to be able to produce off-site fatal effects include compressed flammable gases (Class 2.1), toxic gases (Class 2.3) and explosive materials (Class 1), as well as other highly hazardous materials. Other dangerous goods such as lower hazard flammable liquids (Class 3 packaging groups II and III), lower hazard reactive materials (Class 4 packaging groups II and III) and lower hazard oxidising agents (Class 5.1 packaging groups II and III) are generally considered to have localised consequences in the event of a worst case credible incident.

A spill of Class 6, 7 or 8 materials will generally only produce very local effects. A Class 6 packaging group I material such as solid or dissolved sodium cyanide will not kill people unless they ingest the material or they inhale the very small quantities of hydrogen cyanide

[8] Boiling Liquid Evaporating Vapour Explosion

gas produced. In any case, the effects are very localised to the source of the spill and the likelihood of killing a person off-site is very low. Similarly, a spill of a corrosive material will only kill a person if the material covers a large proportion of their skin. Again, off-site fatal effects are very unlikely. The detailed packaging and transport regulations for radioactive materials make a hazardous incident very unlikely and the consequences of release of radioactive material are considered to pose a fatal hazard range of only a short distance. Dangerous goods under these categories have not been assessed further in the analysis with the exception of toxic materials being involved in a fire.

Under the consultant brief the following parameters, taken from AS3846 *The Handling and Transport of Dangerous Cargoes in Port Areas*, have been included in the PHA:

- *Class 1 dangerous goods to be handled in accordance with Section 4 with Class 1.4 goods not limited by time or quantity excepting for the five-day limit proposed for all dangerous goods on the facility.*
- *The materials specified in Clause 5.2.1 and Table 5.1 not be time limited except for the five-day limit as required by the National Standard.*
- *The quantity of Class 5.1 PG 1 dangerous cargoes not be limited as specified in Clause 5.2.3*
- *The quantities of Ammonium Nitrate and Calcium Hypochlorite not be limited as specified in Section 6.*
- *Low specific activity (LSA) radioactive substances belonging to Schedules 5, 6 and 7 for Class 7 materials as provided in Clause 7.3.1 (b) not be time limited excepting for the five day limit proposed for all dangerous goods on the facility*
- *Containers of dangerous goods be dispersed among the general cargo on-site governed by the separation requirements of Clause 5.4.1 and Table 5.2.*

The hazards identified for this site are summarised in Table 5.2 below.

Table 5.2 Hazard Identification Summary

Activity	Hazard	Cause	Consequences
Truck/train unloading via forklift, reach stacker and/or crane gantry.	Loss of containment of dangerous goods during unloading.	Loss of control of container due to operator error.	Container drops or impact with ground, train, truck or other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
		Impact with other container, train or gantry structure.	
Transportation of container on-site via forklift and/or reach stacker.	Loss of containment of dangerous goods during transport.	Container handling vehicle accident (traffic), impact with other vehicle.	Container drop or impact with ground, train, truck or other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
		Forklift, reach stacker and/or crane gantry failure.	
		Impact with other container during manoeuvring.	
Stacking of containers via forklift, reach stacker and/or crane gantry.	Loss of containment of dangerous goods during stacking operations.	Unstable container stack.	Container drop or impact with ground, stack or other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
		Impact with other container during manoeuvring.	
		Misalignments with lower containers.	
Loading of dangerous goods onto truck via forklift, reach stacker and/or crane gantry.	Loss of containment of dangerous goods during truck loading operations.	Forklift, reach stacker and/or crane gantry car failure.	Container drop or impact with ground, truck or other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
		Container handling vehicle accident (traffic), impact with other vehicle.	
		Misalignment with truck (operator error, truck move)	
Loading of trucks and rail cars via forklift, reach stacker and/or crane gantry.	Loss of containment of dangerous goods during loading.	Loss of control of container due to operator error.	Container drop or impact with other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
		Impact with other container, or gantry structure.	
Transportation on-site via trucks and rail cars.	Loss of containment of dangerous goods during transportation on-site.	Truck accident (traffic). (Excessive speed, drugs, fatigue, inexperience).	Truck impact with other vehicle or other obstacle. Potential loss of containment of dangerous goods leading to possible fire, explosion or toxic gas release.
Diesel fuel storage	Loss of containment.	Tank failure, over filling, operator error, equipment failure plus others.	Pool fire.
Vehicle movements on-site	Vehicle fire	Electrical fault, overheating of brakes, fuel leaks	Vehicle fire that could involve containers of dangerous goods.

5.4. Dangerous Goods Trade Analysis

Key to the analysis of the risk from the intermodal terminal is the expected volume of trade in dangerous goods, the type of goods traded and the volumes transported at any one time. The trade profile of the intermodal terminal in terms of the volume and type of dangerous goods is considered the key input into the analysis.

To assist Qest in their analysis, Sydney Ports Corporation provided Qest with a copy of the Port Botany manifest for the entire year 2004. It was assumed that the volume and type of dangerous goods traded during this period was typical. Analysis of the manifest showed that the dangerous goods trade included small numbers of isotainers[9] of potentially high hazard products traded through Port Botany. Such high-risk products include Class 2.1 flammable gas isotainers and Class 2.3 toxic gas isotainers.

The growth in container volumes passing through the proposed intermodal terminal will commence at 100 000 TEU at start-up of the facility in 2007/08 and reach the capacity of the site (300 000 TEU) in 2016/17.

An analysis of the trade through Port Botany in 2004 is provided in Appendix II. This was used to estimate the dangerous goods trade through the intermodal terminal at start-up in 2007 and at capacity in 2017. This is shown in

Table 5.3 and highlights the number of containers with flammable liquids and the number of containers with ammonium nitrate and other Class 5.1 materials. The number of containers with flammable gases is significant but this is dominated by very small package sizes. The number of Class 2.3 toxic gases movements is relatively small but is modelled in detail due to the potential for toxic effects at some distance from the site.

The size of the containers was considered during the analysis of trade. Although the trade volume through the intermodal is estimated based on TEUs, the majority of the trade is anticipated to be in 40' containers. However, the container size for the dangerous goods trade may not be predominantly 40' as more dense materials, such as liquids or powders would exceed the weight limits for road vehicles if packed into 40' containers. An example of this is a tank container (isotainer). Although there may be some tank containers above TEU size that pass through the intermodal terminal, the majority of bulk liquids and liquefied gases are expected to be in 20' container equivalents, as the standard tank container capacity is much more common.

In the area of containers of packaged goods, the size of the container affects the risk of accidents. The overall likelihood of accidents is reduced through a reduction in the number of lifts for the same quantity of materials. If one 40' container is used instead of two 20' containers, the likelihood of dropping is reduced by half. The consequences of dropping a 40' container compared to a 20' container are anticipated to be a slightly higher likelihood of

[9] Tank containers, which contain up to 24000 L of liquid or liquefied gas, are also known as isotainers or ISO Containers.

releasing the contents of a single package and the potential for releasing the contents of more than one package. Overall, the risk associated with the use of 40' containers is considered to be lower than the use of 20' containers due to the lower drop or impact likelihood.

Table 5.3 Dangerous Goods Trade Estimate for the Intermodal Terminal*

Dangerous Goods Class	Description	Representative Material	Modelled Unit size (te)	Annual No. of Container Movements		
				Port Botany 2004	Intermodal 2007	Intermodal 2017
5.1	Ammonium Nitrate	TNT	2	3027	225	675
1	Explosives	TNT	3	200	15	45
1	Explosives	TNT	13	56	4	12
1	Explosives	TNT	22	13	1	3
2.1	Flam. Gases	propane	0.1	2338	174	521
2.1	Flam. Gases	propane	0.5	82	6	18
2.1	Flam. Gases	butylene	12.5	2	0	0
2.1	Flam. Gases	dimethyl ether	23	12	1	3
2.3	Toxic Gases	chlorine	0.07	11	1	2
2.3	Toxic Gases	hydrogen sulphide	0.033	7	1	2
2.3	Toxic Gases	carbon monoxide	0.01	19	1	4
2.3	Toxic Gases	ammonia	0.01	39	3	9
2.3	Toxic Gases	ethylene oxide	0.023	26	2	6
2.3	Toxic Gases	ammonia	0.034	4	0	1
2.3	Toxic Gases	sulphur dioxide	0.061	16	1	4
2.3	Toxic Gases	methyl bromide	0.1	13	1	3
2.3	Toxic Gases	ammonia	0.1	60	4	13
2.3	Toxic Gases	ammonia	0.5	13	1	3
2.3	Toxic Gases	ethylene oxide	0.75	5	0	1
8	Corrosive with Toxic Gases	hydrogen fluoride	0.05	21	2	5
3	Flam. Liquids	acrylonitrile	0.2	401	30	89
3	Flam. Liquids	acrylonitrile	20	14	1	3
3	Flam. Liquids	octane	0.2	17770	1321	3963
3	Flam. Liquids	octane	20	1028	76	229
ALL	TOTAL			25177	1871	5614

* Refer to Appendix II

5.5. Rail Transportation Analysis

Based on the results of the risk assessment of the intermodal terminal a quantitative analysis of the risk from the trade passing through the intermodal terminal was undertaken. The aim of the transportation analysis was to demonstrate that the risk to the land neighbouring the existing rail corridor and the road routes to and from the site are tolerable. The analysis was undertaken on the rail line between Enfield and Port Botany assuming that the level of risk was equal at any point along the route.

Details of the frequency analysis for rail accidents is contained in Appendix III. For the rail route from Port Botany, there will be a total of approximately 5614 containers carrying dangerous goods carried on the rail line each year (see

Table 5.3), which is equivalent to 15.4 container movements per day.

The dangerous goods that will be transported using this route will be the full trade of dangerous goods through the intermodal. The modelling of the dangerous goods that will be carried from the terminal will be the same as modelled for the on-site scenarios. This is shown in Table 5.4.

Table 5.4 Modelling of Rail Transport for Intermodal Terminal Site

DG Class	Description	Representative Material	Modelled Quantity	Moves p.a. (2017)	Total Leak Frequency (p.a.)		
					25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				3.8E-09
		TNT	3 tonnes				5.0E-08
		TNT	13 tonnes				1.3E-08
		TNT	23 tonnes				3.3E-09
2.1	Flammable Gases	propane	100 kg		5.7E-07	-	5.7E-08
		propane	500 kg		2.0E-08	-	2.0E-09
		butylene	12.5 te		1.1E-09	2.9E-09	4.4E-10
		dimethyl ether	23 te		8.4E-09	2.2E-08	3.3E-09
2.3	Toxic Gases	chlorine	70 kg		2.2E-09	-	2.2E-10
		hydrogen sulphide	33 kg		2.2E-09	-	2.2E-10
		carbon monoxide	10 kg		4.4E-09	-	4.4E-10
		ammonia	10 kg		9.9E-09	-	9.9E-10
		ethylene oxide	23 kg		6.6E-09	-	6.6E-10
		ammonia	34 kg		1.1E-09	-	1.1E-10
		sulphur dioxide	61 kg		4.4E-09	-	4.4E-10
		methyl bromide	100 kg		3.3E-09	-	3.3E-10
		ammonia	100 kg		1.4E-08	-	1.4E-09
		ammonia	500 kg		3.3E-09	-	3.3E-10
		ethylene oxide	750 kg		1.1E-09	-	1.1E-10
		hydrogen fluoride	50 kg		5.5E-09	-	5.5E-10
3	Flammable Liquids	acrylonitrile	200 kg		9.8E-08	-	9.8E-09
		acrylonitrile	20 te		8.4E-09	2.2E-08	3.3E-09
		octane	200 kg		4.4E-06	-	4.4E-07
		octane	20 te		6.4E-07	1.6E-06	2.5E-07

5.6. Road Transport Analysis

An analysis of the road transportation risks associated with the movement of dangerous goods was also undertaken for the roads immediately around the site. Where the local access roads met major truck transport corridors, the risks associated with movement of dangerous goods from trucks accessing the intermodal terminal were much less than the risks associated with the general dangerous goods traffic. This provided a natural point at which to terminate the transportation analysis. The increase in road traffic of heavy vehicles, either articulated or rigid on the nearby major arterial roads[10] was less than 5% when the ILC is at capacity. On Cosgrove Rd, which services the site from the east and north, the increase in road traffic of heavy vehicles is also less than 5% of the existing heavy vehicle traffic. From the perspective of risk analysis, this is an insignificant increase in numbers of heavy vehicles and the risk increase due to the slight increase in vehicles carrying dangerous goods on those roads is considered negligible.

For the minor roads that access the site, namely Wentworth St / Norfolk Rd the increase in numbers of truck movements is not insignificant. However, there will only be a total of 9 trucks movements (inwards plus outwards) carrying dangerous goods each day[11].

Due to the uncertainties in the estimates of movements, all these movements are assumed to travel along the single road (Wentworth St). Thus the calculation of risk will be conservative[12].

The dangerous goods that will be transported using this route will be the full trade through the intermodal, which will total approximately 5614 containers p.a. (see

Table 5.3). The modelling of the dangerous goods that will be carried from the terminal will be the same as modelled for the on-site scenarios (see Appendix III for more details). This model is shown in Table 5.5.

[10] The major arterial roads are the Hume Highway, Roberts Rd, Punchbowl Rd & King Georges Rd.
[11] Using the ratio of 1.65 containers per truck movement, 15.4 containers per day will require 9.3 truck movements per day.
[12] Although some trucks will use Cosgrove Rd, the risks will be significantly lower than that calculated for Wentworth St. As the risks associated with the use of Wentworth St have been shown to be acceptable (see Section 9.5), the risks associated with trucks using Cosgrove Rd are also acceptable.

Table 5.5 Modelling of Road Transport for the Intermodal Terminal Site

DG Class	Description	Representative Material	Modelled Quantity	Moves p.a. (2017)	Total Leak Frequency (p.a.)		
					25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				5.3E-09
		TNT	3 tonnes				2.4E-07
		TNT	13 tonnes				6.5E-08
		TNT	23 tonnes				1.6E-08
2.1	Flammable Gases	propane	100 kg		2.8E-06	-	2.8E-07
		propane	500 kg		9.7E-08	-	9.7E-09
		butylene	12.5 te		4.8E-07	3.4E-07	2.6E-07
		dimethyl ether	23 te		3.6E-06	2.6E-06	2.0E-06
2.3	Toxic Gases	chlorine	70 kg		1.1E-08	-	1.1E-09
		hydrogen sulphide	33 kg		1.1E-08	-	1.1E-09
		carbon monoxide	10 kg		2.2E-08	-	2.2E-09
		ammonia	10 kg		4.9E-08	-	4.9E-09
		ethylene oxide	23 kg		3.2E-08	-	3.2E-09
		ammonia	34 kg		5.4E-09	-	5.4E-10
		sulphur dioxide	61 kg		2.2E-08	-	2.2E-09
		methyl bromide	100 kg		1.6E-08	-	1.6E-09
		ammonia	100 kg		7.0E-08	-	7.0E-09
		ammonia	500 kg		1.6E-08	-	1.6E-09
		ethylene oxide	750 kg		5.4E-09	-	5.4E-10
		hydrogen fluoride	50 kg		2.7E-08	-	2.7E-09
3	Flammable Liquids	acrylonitrile	200 kg		4.8E-07	-	4.8E-08
		acrylonitrile	20 te		3.6E-06	2.6E-06	2.0E-06
		octane	200 kg		2.1E-05	-	2.1E-06
		octane	20 te		2.7E-04	2.0E-04	1.5E-04

5.7. Fire and Smoke Analysis

There is the potential for a fire to occur in a container or, more likely, in a vehicle (crane, forklift, reach stacker, truck). The likelihood of a fire involving a container was estimated (Appendix IV) and was applied across the site.

The size of the fires considered included the more likely smaller fires involving 1 tonne of materials and the less likely fire engulfing the entire 20 tonnes in the container.

Table 5.6 Class 6.1 Toxic Material Fire Modelling

Material	Common Package	Annual Movements at Capacity	Likelihood of Fire Involving Part of the Container	Likelihood of Fire Involving All of the Container
Carbamate Pesticides	IBC	22	3.42E-06	3.80E-07
Acrylamide	bags	25	3.87E-06	4.30E-07
Organophosphorous Pesticides	drums	19	2.88E-06	3.20E-07
Toluene Diisocyanate	drums & tanks	73	1.08E-05	1.20E-06
Total		139	2.16E-05	2.40E-06

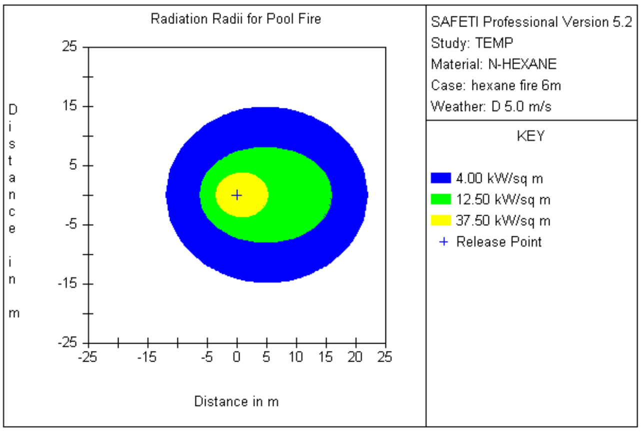
This shows that the likelihood of significant fires on the site is rare but that the likelihood is not so low that the potential can be ignored. The risks associated with smoke from fires has been included in the modelling.

5.8. Diesel Storage

The only other hazardous materials associated with the intermodal terminal facility are proposed storage tanks of 25 m^3 of diesel fuel for the locomotives, which would be located mostly in the areas used for storage of empty containers within the ILC.

The loss of containment from the diesel fuel storage tank may lead to a pool fire. Consequence modelling of the worst-case potential fire scenarios has been undertaken using SAFETI risk modelling software. Diesel was modelled as hexane, the diameter of the bund was assumed to be 6 m and the wind was assumed to be 5 m/s. The results of the fire modelling are presented below.

Figure 5.2 Diesel Fuel Tank Fire Modelling Results



Based on the dangerous heat intensity of 12.5 kW/m^2 for a pool fire the potential consequences for a fire involving the diesel storage tank will have negligible off-site impacts provided that the tank is located more than 16 m from the property boundary.

6. KEY MODELLING ASSUMPTIONS

In the process of undertaking the quantitative risk assessment of the intermodal terminal a number of key modelling assumptions have been identified, which affect the risk results. These assumptions are listed below.

1. The study focus is on release events capable of producing an off-site fatality risk; not all events that pose only an on-site fatality risk were analysed.
2. The manifest provided by Sydney Ports Corporation for Port Botany for 2004 was analysed by QEST. This dangerous goods trade profile has been used as the basis for the PHA.
3. As an exception to Assumption 2, all tank containers or isotainers of Class 2.3 and hydrogen fluoride were excluded from the analysis because they will not be permitted to pass through the intermodal terminal.
4. The package sizes for each of the dangerous goods classes was estimated based on the dangerous goods transported during 2004.
5. Class 1 – Explosives have been modelled in three package sizes: 3 tonnes, 13 tonnes and 23 tonnes. In the event of an incident involving Class 1 goods the entire inventory has been assumed to be involved in a single explosion.
6. Class 1 – Explosives. In the event of a dropped container, 1 in a thousand incidents have been assumed to result in a detonation.
7. Class 2.1 – Flammable Gases have been modelled in four package sizes: 23 tonne isotainers of dimethyl ether, 12.5 tonne isotainers of butylene, 500 kg of propane and 100 kg of propane.
8. Class 2.2 – Non-flammable Gases have been screened out of the analysis on the bases that they will have no off-site consequences.
9. Class 2.3 – Toxic Gases have been modelled in numerous package sizes based on the actual sizes of goods transported through Port Botany in 2004. All movements of isotainers of toxic gases has been excluded from the analysis as they will be prohibited from transport through the intermodal terminal.
10. All class 2.3 materials not modelled specifically and included as “Other” have been modelled as ammonia.
11. Class 5.1 – Oxidising Materials. Explosions of ammonia nitrate (AN) have been identified as a hazard associated with the transportation of ammonium nitrate. An explosion of two tonnes of ammonium nitrate has been assumed to be the largest credible accidental explosion scenario.
12. Explosions are modelled with two fatal effect-zones:

R1: inner zone, with high fatalities. This is typically set at the overpressure to cause heavy building damage. For this study, heavy damage is assumed to occur at an over pressure of 5-psi

R2: outer zone, with lower fatalities. This is typically set at the overpressure to cause repairable building damage. For this study, light damage is assumed to occur at an over pressure of 2-psi.

13. The locations of the releases have been centred on 9 spots on the site (3 gantry crane locations, 3 road vehicle loading locations and 3 general storage locations).

7. LIKELIHOOD ANALYSIS

7.1. Human Error

The probability of human error for the operations proposed at the intermodal terminal can be estimated from the following data on the probability of failure for tasks of varying complexity [Brazendale]:

Table 7.1 Human Error Probabilities

Task Type	Human Error Probability
Simple, frequently performed, minimal stress	0.0001
More complex, less time available, some care needed	0.001
Complex, unfamiliar, little feedback, distractions	0.01
Highly complex, considerable stress, little time	0.1
Extreme stress, rarely performed task	1.0

The types of human error which dominate the potential for loss of containment of dangerous goods are related to errors during moving containers using gantry cranes, reach stackers, forklift trucks, rolling stock, rigid tray trucks and semi trailers.

In this case, most of the identified human error scenarios fall into the category of “Simple, frequently performed, minimal stress” or “Some care needed” and therefore a value of 0.0001 to 0.001 has generally been used. Thus, with 5614 containers with dangerous goods moved each year, it would be expected that between 1 and 6 errors would occur each year.

However, when engaging the attachments to lift a container using the gantry crane or the reach stacker, there are engagement latches that confirm attachment before the container can be lifted. This provides a higher reliability that the container will not be dropped during the lift process.

The potential for impacts arise during the movement of containers on-site. The training and skill of the operators provides the main prevention against vehicle impacts. The site layout also contributes to the potential for vehicle impacts.

There is also provision for feedback to the operators, which enables the operator to be alerted to an error that they have made and correct it before it causes an accident. This is an important design feature for operations that rely on personnel for some of the important tasks.

Appendix III gives more details of the likelihood of accidents happening. The types of accidents that are analysed are:

1. Dropped or impacted containers. Containers can be dropped or hit during most of the movement operations on-site.

2. Containers with Class 1 materials could explode when dropped.
3. Ammonium nitrate could potentially explode under specific accident conditions.
4. More details are provided on the likelihood of road accidents and rail accidents. This includes the potential for isotainers to be damaged and leak during accidents.

8. RISK CRITERIA

8.1. Individual Fatality Risk

The individual fatality risk imposed by a proposed (or existing) industrial activity should be low relative to the background risk. This forms the basis for the following individual fatality risk criteria adopted by DIPNR in New South Wales.

Land Use	Risk Criterion [per million per year]
Hospitals, schools, child care facilities and old age housing developments	0.5
Residential developments and places of continuous occupancy, such as hotels and tourist resorts	1
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	5
Sporting complexes and active open space areas	10
Industrial sites	50 *

* HIPAP 4 does allow for some flexibility in the interpretation of this criterion. For example, 'where an industrial site involves only the occasional presence of people, such as in the case of a tank farm, a higher level of risk may be acceptable'.

8.2. Injury Risk

In HIPAP 4, injury risk criteria are presented for exposure to toxic gas/vapour/smoke, heat radiation and explosion overpressure.

8.2.1. Acute Toxic Exposure: Serious Injury

The first acute toxic exposure risk criterion is concerned with serious injury, as follows:

> *Toxic concentrations in residential areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.*

8.2.2. Acute Toxic Exposure: Irritation or Other Physiological Response

The second acute toxic exposure risk criterion is concerned with lower concentration effects that may result in an acute physiological response (e.g. irritation) rather than serious injury. This risk criterion is as follows:

> *Toxic concentrations in residential areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.*

8.2.3. Heat Radiation or Explosion Overpressure

The risk of heat radiation exceeding 4.7 kW/m^2 or explosion overpressure exceeding 7 kPa should not exceed fifty chances in a million (50×10^{-6}) per year at residential areas.

8.3. Risk of Property Damage and Accident Propagation

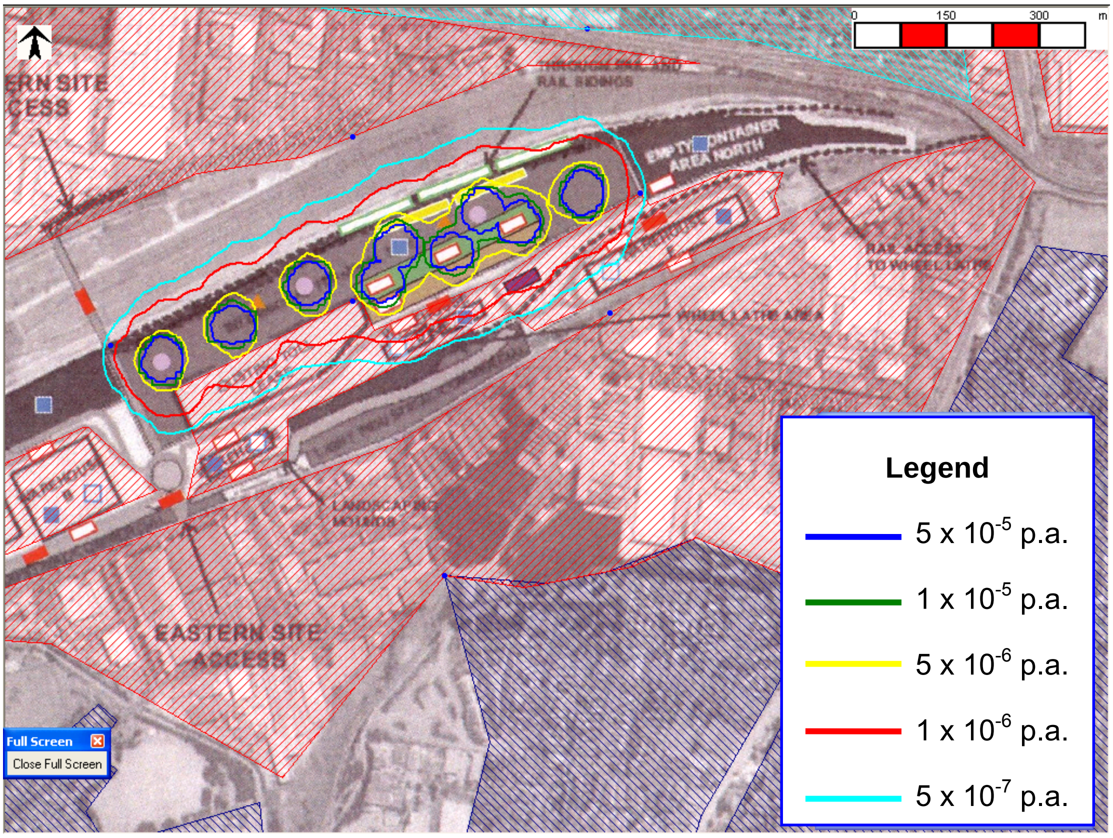
Heat radiation exceeding 23 kW/m^2 may cause unprotected steel to suffer thermal stress that may cause structural damage and an explosion overpressure of 14 kPa can cause damage to piping and low pressure equipment. The risk of heat radiation exceeding 23 kW/m^2 or explosion overpressure exceeding 14 kPa should not exceed 50 in a million (50×10^{-6}) per year at the boundary to neighbouring industrial facilities.

9. RISK ANALYSIS

9.1. Individual Fatality Risk

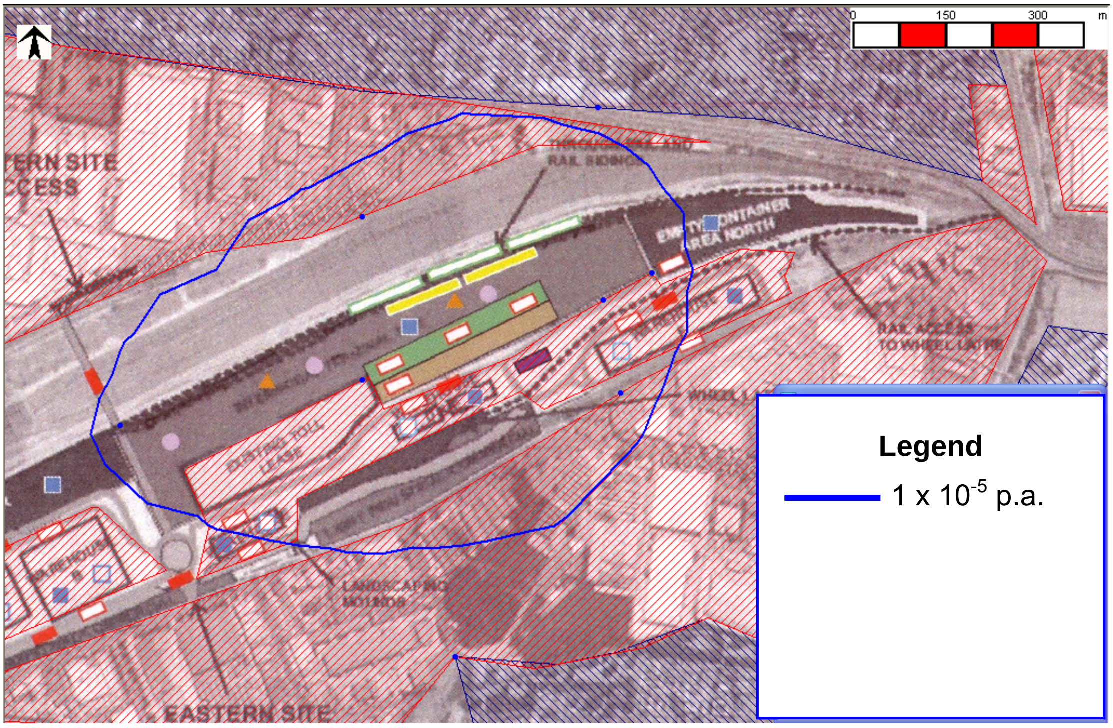
The risk results presented in Figure 9.1 are Location Specific Individual Fatality Risk per year contours for the proposed intermodal terminal based on trade levels at capacity of 300,000 TEU per year.

Figure 9.1 Proposed Intermodal Terminal Fatality Risk Contour



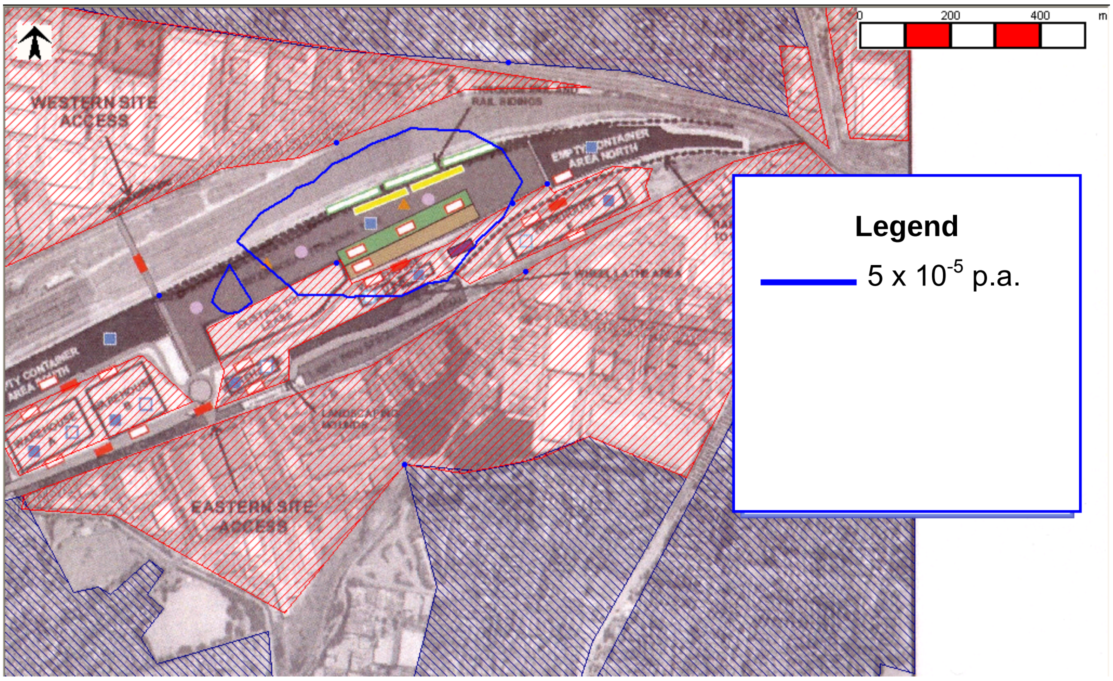
This shows that the risk of fatality at the site boundary does not exceed 50 in a million p.a. and that the contours for 1 in a million p.a. and 0.5 in a million p.a. are contained within industrial zoned land.

Figure 9.2 Proposed Intermodal Terminal Injury Risk Contour



The individual risk of injury contour is presented in Figure 9.2. Inspection of the risk contours against the aerial photo shows that the ten in a million (1 x 10^{-5}) contour does not extend to residential zoned land or to residences. Therefore, with respect to the risk criteria presented in Section 8.2, the injury results meets the acceptable limits for risk of injury.

Figure 9.3 Proposed Intermodal Terminal Irritation Risk Contour

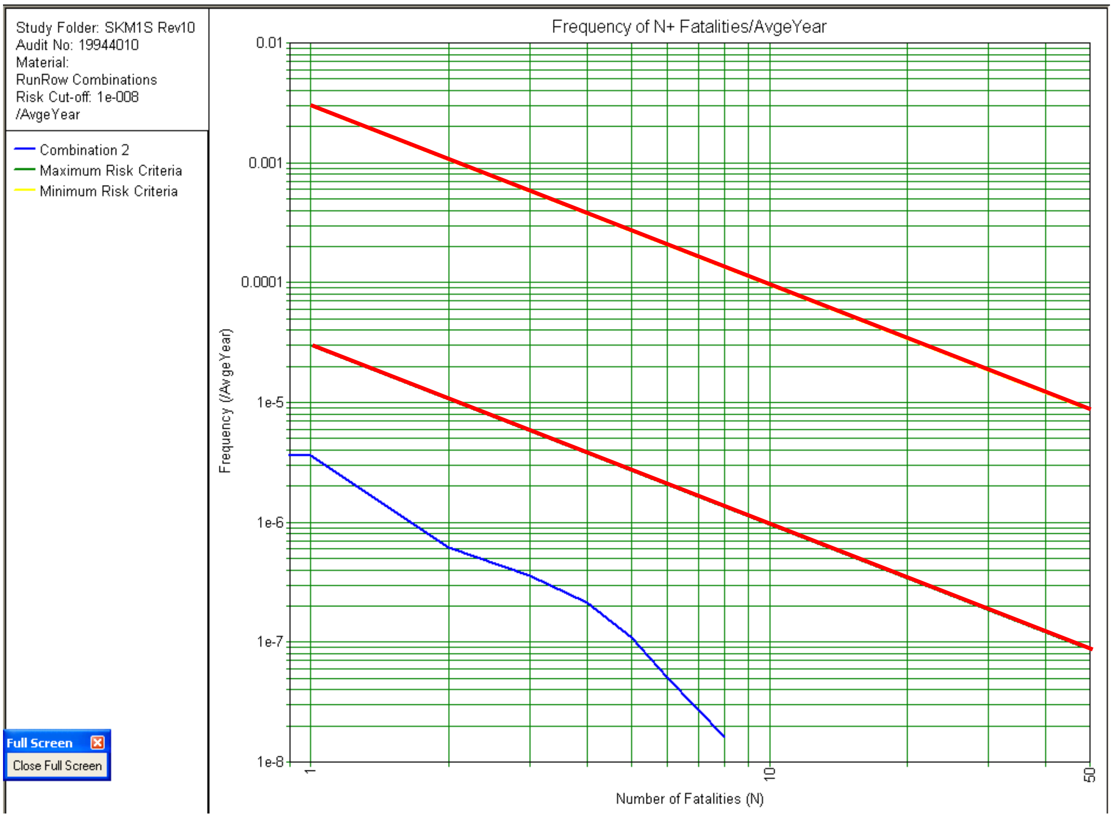


The individual risk of irritation contour is presented in Figure 9.3. Inspection of the risk contours against the aerial photo shows that the fifty in a million (5×10^{-5}) contour does not extend to any residential zoned land or to any residences. Therefore, with respect to the risk criteria presented in Section 8.2, the irritation results meets the acceptable limits.

9.2. Societal Risk

The societal risk results have been calculated based on the assumed off-site population in the form of an F-N Curve. The results of the proposed development are presented in Figure 9.4.

Figure 9.4 Proposed Intermodal Terminal Societal Risk Curve



The societal risk curve for the operations at intermodal terminal based on the capacity trade level (300 000 TEU p.a.) show that there is a very low likelihood of killing a person not on the site due to a dangerous goods incident. There is currently less than four chances in one million p.a. of an incident killing any people off-site.

The criteria line drawn on Figure 9.4 are the illustrative criteria lines presented in the Port Botany Land Use Safety Study.

Using these criteria lines, the societal risks associated with the operations at the proposed intermodal terminal at capacity are considered negligible. Thus, as long as the risks of the operation are managed effectively to ensure that they are kept as low as reasonably practicable, the operation would meet the illustrative criteria published by DUAP.

9.3. Risks to Biophysical Environment

Some of the materials handled at the intermodal terminal have the potential to adversely impact on the natural environment. In particular numerous chemicals are handled which could harm both aquatic, bird and plant life if there is a spill which finds its way into the water courses that are near the site. The more obvious examples are acidic/alkaline materials

(Class 8), toxic chemicals (especially Class 6) and hydrocarbon products (e.g. Class 3 oil spill type events).

The HIPAP 4 criteria for assessment of risk to the biophysical environment relate only to the possibility of a threat to the long-term viability of a species or ecosystem. It only relates to risks from accidental events – environmental impacts due to planned changes in the environment, or continuous / anticipated operational emissions are considered elsewhere in the EIS. The wording of HIPAP4 in respect of environmental risk can be paraphrased as:

- The consequences of the more likely accidental emissions must not threaten the long-term viability of the ecosystem or any individual species.
- The likelihood of impacts (which threaten the long-term viability of the ecosystem or species) must be substantially lower than the background risk.

Due to the unpredictable nature of container trade it is impossible to predict precisely which materials will be handled (since this is governed by international shipping rules and by the variations of trade). It is not practical to conduct a detailed quantitative assessment of the risks to the environment since the consequences cannot be predicted with any certainty and frequency estimates are limited to consideration of generic classes of Dangerous Goods. The primary concern for this assessment is the possibility that an accidental event could cause such major damage as to destroy the entire ecosystem or species. For this to happen, the following would be required:

- A major loss of containment event resulting in contamination of a significant length of the water course (say effects extending into Cooks River and for a significant distance downstream)
- The damage to be irreversible (the HIPAP4 criteria relate only to long-term damage)

The primary potential incident types can be summarised as follows:

- Loss of containment from container cargoes, especially Classes 3, 6 and 8. Harmful effects are also possible from other DG classes but the likelihood of major damage is very low (see Appendix III). This potential incident is discussed in more detail below.
- Loss of containment from truck transportation. The likelihood of this is very low compared to spills on the road system off-site (which would be expected to find their way into the creek or river, via the stormwater system), hence the risk of this type of event at the intermodal terminal is much lower than the background risk.
- Diesel spill from diesel storage. Effects would be reversible and fairly localised. Modern facility design in accordance with AS 1940 and associated bunding requirements and clean-up capability should ensure that the likelihood of a major spill is low. There are numerous fuel storage tanks of this type in many industrial facilities around Sydney. The risk from the proposed installation is therefore considered low, and significantly lower than the background level of risk.
- Fire in container storage areas. Major fires in container stacks are very infrequent since there is little opportunity for initiating mechanisms and even if a fire starts in one

container, it is very unlikely to spread to others (since the container shell provides a fire barrier). The primary environmental concern is contaminated firewater runoff, in particular if a major fire develops involving containers of dangerous goods (especially Class 6). It is recommended, that this issue be addressed comprehensively as part of the fire system design. This issue is normally dealt with by a standard condition of development consent requiring a Fire Safety Study (HIPAP 2).

Any of the above scenarios that occur on the proposed facility will be captured by the first-flush system installed for treatment of stormwater and spills incidents. A more detailed description of this system is provided in the *Stormwater Quality and Soil and Water Management* section of the EIS.

9.3.1. Dangerous Goods Accidents

The main materials handled on the site that could affect the environment are toxic materials (Class 6.1) and some other materials could have lesser effects on the environment (Class 2.3 toxic gases, Class 3 liquids, Class 5.1 oxidising agents and Class 8 acids and alkalis). The potential environmental impacts from these materials are discussed below.

Class 6.1 Toxic Materials

The Class 6.1 toxic materials that could impact the environment include organophosphate pesticides, carbamate pesticides, toluene diisocyanate and dichloromethane. Of these only TDI and dichloromethane are liquids. The quantities traded, if spilt into a watercourse could cause significant destruction of the flora and fauna. However, the stormwater management system on-site will provide an ability to capture any spills of materials on-site.

Class 2.3 Toxic Gases

Sulphur dioxide is a Class 2.3 material that can impact on the environment. It can cause acid rain[13], which can damage plants. Potentially, even a single instance of a release can have significant effects[14]:

> "Sulfur oxide emissions cause adverse impacts to vegetation, including forests and agricultural crops. … Trees and other plants exposed to wet and dry acid depositions at some distance from the source of emissions may also be injured. Impacts on forest ecosystems vary greatly according to soil type, plant species, atmospheric conditions, insect populations, and other factors that are not well understood. Agricultural crops may also be injured by exposure to depositions."

However, as the site is within a residential area of Sydney, there are no forests or agricultural areas nearby. The plants that could be affected would be the gardens, including vegetable gardens, of the residences downwind of the release.

[13] http://www.epa.gov/air/urbanair/so2/hlth1.html
[14] http://wbln0018.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/41_sulfu.pdf

The concentrations for damage to plants (1850 μg/m^3 for 1 hour ≡ 1 ppm for 1 hour) are similar to the concentrations that cause irritation to people. Thus the area that is within the irritation contour also provides an estimation of the risk to plants. As this area only extends a short distance from the site, the risk to the bio-physical environment from an accidental release of Class 2.3 toxic gases is considered acceptable.

Class 3 Flammable Liquids

Spills of flammable liquids mainly have a fire risk. However, oil spills also have an environmental hazard associated with them. Oil spills are very unsightly and also can poison fish and damage plant life.

Due to the flammability risk associated with any spill of flammable liquids, the emergency plan will act to contain the spill and the stormwater management system will enable any spills to be contained for later recovery.

Class 5.1 Oxidising Agents

Some oxidising agents are also pollutants. Ammonium nitrate is significant due to the quantities that are traded through the port. The effects of spills of this material are similar to the effects of Class 6.1 materials but are less severe.

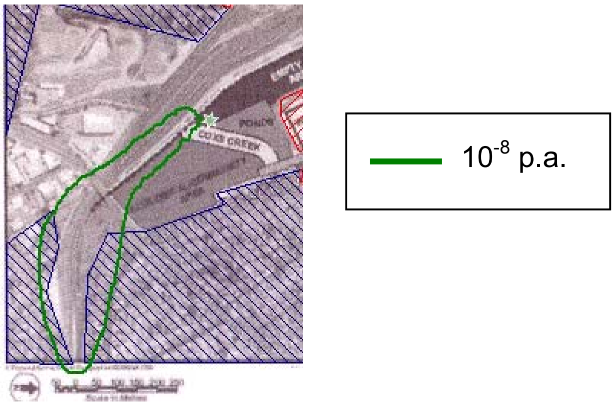
Class 8 Corrosive Materials

Some corrosive materials such as acids and alkalis are also pollutants. The effects of spills of this material are similar to the effects of Class 6.1 materials but are less severe.

9.4. Rail Transportation Risk Assessment

An analysis of the risk to the surrounding land along the rail line from Port Botany to Enfield was undertaken. The frequency of accidents involving containers of dangerous goods is given in Table II.6.3. This shows that the total leak frequency for the rail transport is 8.3 x 10^{-6} per km per annum. This is a sufficiently low likelihood that when coupled with the wind directions, the likelihood of ignition for the flammable materials and the hazard ranges, the risks to residents near the rail corridor are adequately low. This was confirmed by quantitative modelling of the rail risks for a short section of rail near the facility. The risk level around the rail corridor did not exceed 5 x10^{-8} p.a. (see Figure 9.5). This is a very low level of risk.

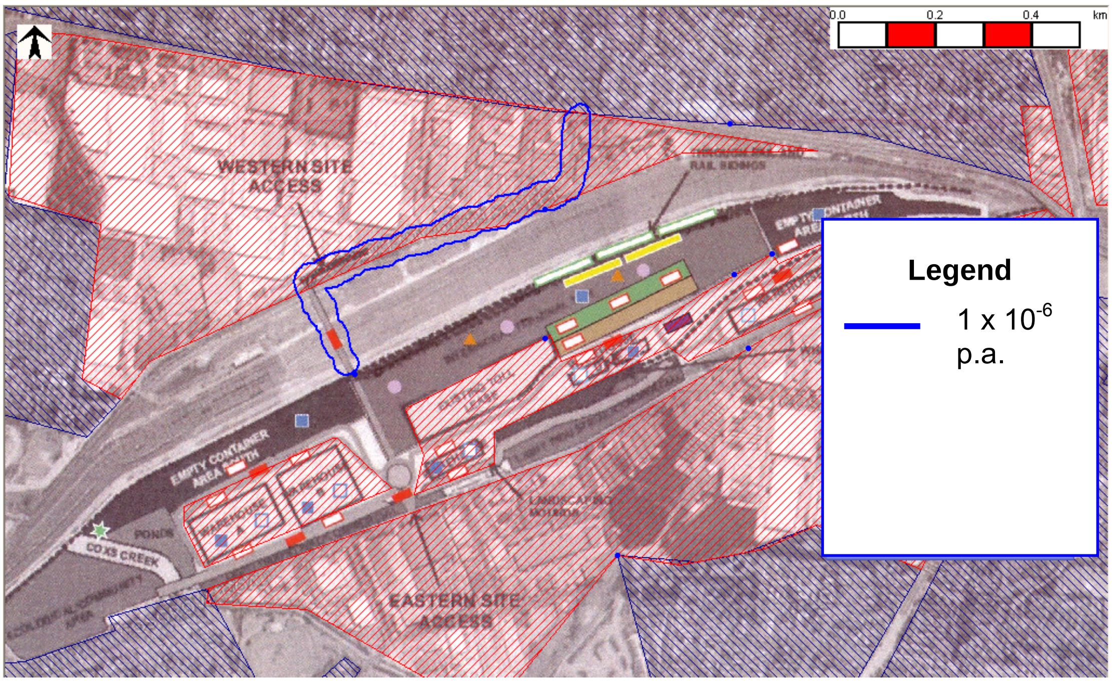
Figure 9.5 Rail Transportation Fatality Risk Levels



9.5. Road Transportation Risk Assessment

The risk of fatality associated with road transport was modelled as is shown in Figure 9.6. This shows that the fatality risk caused by trucks carrying dangerous goods to people located in areas adjoining the road is low. The risk level does not exceed 5 x 10^{-6} p.a. at any location and is generally less than 1 x 10^{-6} p.a. for distances further than 30 m from the centre of the roadway. The width of the corridor around the road is approximately 60 m.

Figure 9.6 Individual Fatality Risk Associated with Road Transport



10. RISK ASSESSMENT

In this section the results of the analysis are compared to the risk acceptance criteria presented in the Hazardous Industries Planning Paper No 4.

10.1. Individual Fatality Risk

The risk results for the proposed intermodal terminal at Enfield have been presented in Figure 9.1 for the site at capacity (300 000 TEU p.a.). This assumes that no Class 2.3 toxic gas isotainer or hydrogen fluoride isotainer will pass through the intermodal terminal.

The individual risk contour for 0.5 x 10^{-6} per year (0.5 chance in a million per year) for sensitive populations does not encroach on any sensitive facilities and is confined to industrial zoned land.

The 1 x 10^{-6} per year (one chance in a million per year) contour does not encroach on any residential populations.

The 5 in a million per year contour does not encroach on any commercial developments.

The 10 in a million per year contour does not encroach on any sporting complexes or open space areas.

The 50 in a million per year contour does not extend off-site.

Qest considered that the risk of fatality to the surrounding population from the proposed intermodal terminal, based on a trade throughput of 300,000 TEU per annum, should be considered acceptable on safety grounds.

10.2. Individual Injury Risk

The individual risk of injury results are presented in Figure 9.2. Inspection of the risk contours notes that the criteria risk level of ten in a million (1 x 10^{-5}) does not extend to residences or to residential zoned land. Therefore, with respect to the risk criteria presented in section 8, the injury results meet the acceptable limits for risk of injury.

10.3. Individual Irritation Risk

The individual risk of irritation results for toxic exposures are presented in Figure 9.3. Inspection of the risk contours notes that the criteria risk level of fifty in a million (5 x 10^{-5}) does not extend to residences or residential zoned land. Therefore, with respect to the risk criteria presented in section 8, the irritation risk results meet the acceptable limits for toxic exposures in residential areas.

10.4. Risk of Property Damage / Accident Propagation

As noted in 10.2 above the criteria risk level of 50 in a million does not extend off-site. Therefore, the criteria in section 8 are satisfied.

10.5. Transportation Risk

The risks from rail transportation was assessed to be adequately low based on the very low likelihood of loss of containment incidents involving containers on rail cars.

The risk from trucks carrying containers of dangerous goods on the access road to/from the site was considered. The analysis calculated the risk level to be significantly below the average road fatality rate in NSW and generally below the acceptable limit for risk exposures to the public in residential areas from fixed installations. Currently there are no quantitative risk criteria for the assessment of the risk to the public from transportation activities in New South Wales. Based on the relatively low risk levels, the risk to the public from the road transportation of dangerous goods should be considered acceptable.

11. REFERENCES

i DUAP 1996, *Guidelines for Hazard Analysis,* NSW Department of Planning: Hazardous Industry Planning Advisory Paper No. 6

ii DUAP 1990, *Risk Criteria for Land Use Planning*, NSW Department of Planning: Hazardous Industry Planning Advisory Paper No. 4

iii Intermodal Logistics Centre at Enfield EIS, Chapter 4

iv IChemE 1992, Nomenclature for Hazard and Risk Assessment in the Process Industries, Institution of Chemical Engineers, Rugby, UK.

v DUAP 1997, *Multi-Level Risk Assessment*.

Appendix I

Background Data

TABLE OF CONTENTS

I.1. INTRODUCTION

This appendix presents the background information required to undertake the quantitative risk assessment.

Figure I.1.1 presents an aerial photo of the proposed site for the intermodal terminal within the proposed Intermodal Logistics Centre. Figure I.1.2 presents a layout of the intermodal terminal following completion of the proposed development. Figure I.1.3 shows the rail route from Port Botany

Figure I.1.1 Proposed Intermodal Logistics Centre

Figure I.1.2 Proposed Intermodal Terminal Site Layout

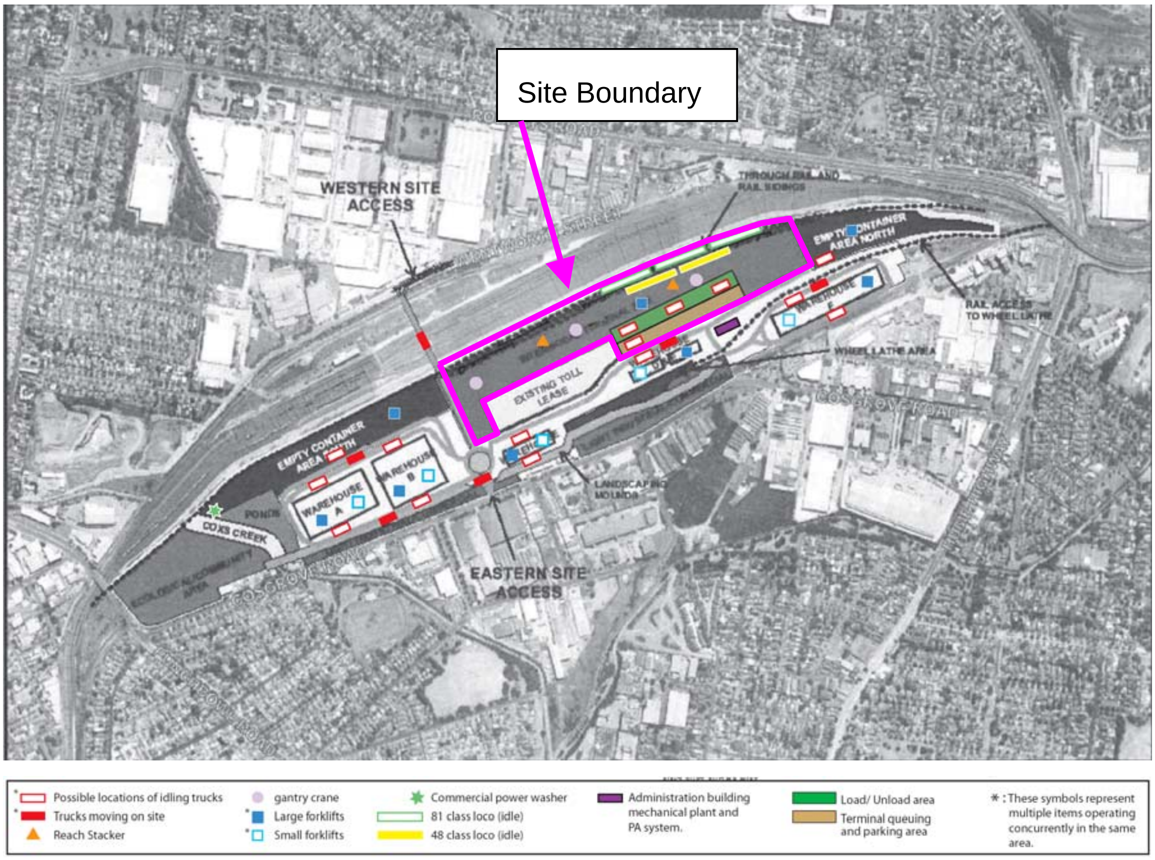


Figure I.1.3 Proposed Rail Transportation Route

I.2. BACKGROUND DATA

I.2.1. Geographical Data

This section describes the parameters used for the on-site and off-site terrain.

I.2.1.1. On-site and Off-site Terrain

The intermodal terminal is proposed to be located within the proposed Intermodal Logistics Centre (ILC) at the site of the former Enfield Marshalling Yards.

The land surrounding the proposed ILC site is currently used for mixed purposes, as evident from the aerial photo shown in Figure I.1.1. The site itself is currently used for a mixture of industrial uses. Existing residential areas are located on all sides of the proposed ILC site with some separation being provided on all boundaries through a combination of commercial and industrial uses.

I.2.2. Meteorology

I.2.2.1. Data Requirements

Meteorological data is required at two stages of the risk assessment. First, various parts of the consequence modelling require specification of wind speed, atmospheric stability, ambient temperature, ambient humidity and ambient pressure. Second, the impact (risk) calculations require wind-rose frequencies for each combination of wind speed and stability class used.

For the dispersion modelling, suitable combinations of wind speed and stability class are chosen. These combinations must reflect the full range of observed variations in these quantities; at the same time it is neither necessary nor computationally efficient to consider every combination observed. The procedure used groups the observed combinations of wind speed and stability into representative weather classes which together cover all conditions observed. The classes chosen must be sufficiently different to produce significant variations in dispersion modelling results but must not smooth out important variations between the speed-stability combinations grouped into each. In particular, the conditions most likely to give rise to large effect distances (and hence the possibility of significant offsite risks) must not be grouped with those leading to shorter effect distances.

The choice of weather classes to meet these conditions for the assessment of the intermodal terminal is given below. Once the weather classes have been chosen, frequencies for each wind direction associated with each of the selected weather classes are calculated by summing the frequencies in the appropriate wind-speed stability classes.

I.2.2.2. Wind and Weather Stability Category Data Sources

The data used for compiling the wind and weather stability data for the intermodal terminal were obtained from AusPlume data for 1991 and are presented in Table I.2.1 along with wind roses in Figure I.2.1 and Figure I.2.2. Business hours have been assumed to be after 8:00 am and before 6:00 pm Monday to Friday, as this models the general populations in the nearby area.

Table I.2.1 Meteorological Data

Outside of Business Hours (72.8% of week)

Weather Class and Speed	Wind Direction																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A1.5	1.43%	0.29%	0.37%	0.77%	1.31%	0.52%	0.42%	0.40%	0.40%	0.32%	0.29%	0.72%	1.16%	1.53%	1.28%	0.86%	12.09%
B2.4	0.86%	0.00%	0.00%	0.00%	0.61%	0.34%	0.40%	0.45%	0.47%	0.19%	0.25%	0.83%	1.15%	0.93%	0.61%	0.34%	7.41%
C3.1	0.00%	0.00%	0.00%	0.00%	0.07%	0.15%	0.84%	1.25%	0.02%	0.00%	0.13%	0.88%	1.13%	0.37%	0.25%	0.02%	5.10%
D2.7	0.10%	0.00%	0.00%	0.00%	0.17%	0.74%	2.43%	3.15%	0.89%	0.05%	0.40%	2.24%	4.67%	1.60%	1.21%	0.39%	18.04%
E1.5	0.12%	0.00%	0.02%	0.03%	0.76%	1.48%	1.52%	1.08%	0.72%	0.71%	1.20%	5.04%	3.59%	2.64%	2.73%	0.96%	22.59%
F1.5	2.14%	1.84%	2.56%	3.79%	3.37%	1.50%	1.15%	1.09%	1.87%	1.82%	1.63%	1.73%	3.39%	2.36%	2.54%	1.99%	34.77%
Total	4.65%	2.12%	2.95%	4.60%	6.28%	4.73%	6.75%	7.43%	4.38%	3.08%	3.91%	11.44%	15.07%	9.43%	8.62%	4.55%	100.0%

Business Hours (27.2% of week)

Weather Class and Speed	Wind Direction																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A1.5	3.46%	1.26%	1.57%	6.30%	7.51%	2.25%	2.02%	1.44%	1.71%	1.08%	1.35%	3.19%	3.96%	5.26%	5.13%	2.88%	50.38%
B2.4	0.76%	0.00%	0.00%	0.00%	3.91%	2.79%	3.19%	1.71%	1.57%	0.54%	0.76%	3.33%	4.18%	2.56%	1.08%	0.85%	27.26%
C3.1	0.04%	0.00%	0.00%	0.00%	0.13%	1.17%	3.01%	4.00%	0.18%	0.00%	0.18%	1.71%	2.88%	0.13%	0.09%	0.00%	13.54%
D2.7	0.04%	0.00%	0.00%	0.00%	0.00%	0.45%	0.72%	0.99%	0.09%	0.04%	0.00%	0.36%	0.40%	0.45%	0.00%	0.04%	3.60%
E1.5	0.04%	0.00%	0.00%	0.00%	0.09%	0.18%	0.31%	0.13%	0.09%	0.04%	0.09%	0.27%	0.13%	0.13%	0.13%	0.22%	1.89%
F1.5	0.63%	0.00%	0.04%	0.36%	0.54%	0.04%	0.09%	0.18%	0.13%	0.27%	0.00%	0.18%	0.27%	0.27%	0.22%	0.09%	3.33%
Total	4.99%	1.26%	1.62%	6.66%	12.19%	6.88%	9.36%	8.46%	3.78%	1.98%	2.38%	9.04%	11.83%	8.82%	6.66%	4.09%	100.0%

Figure I.2.1 Wind Rose For Business Hours

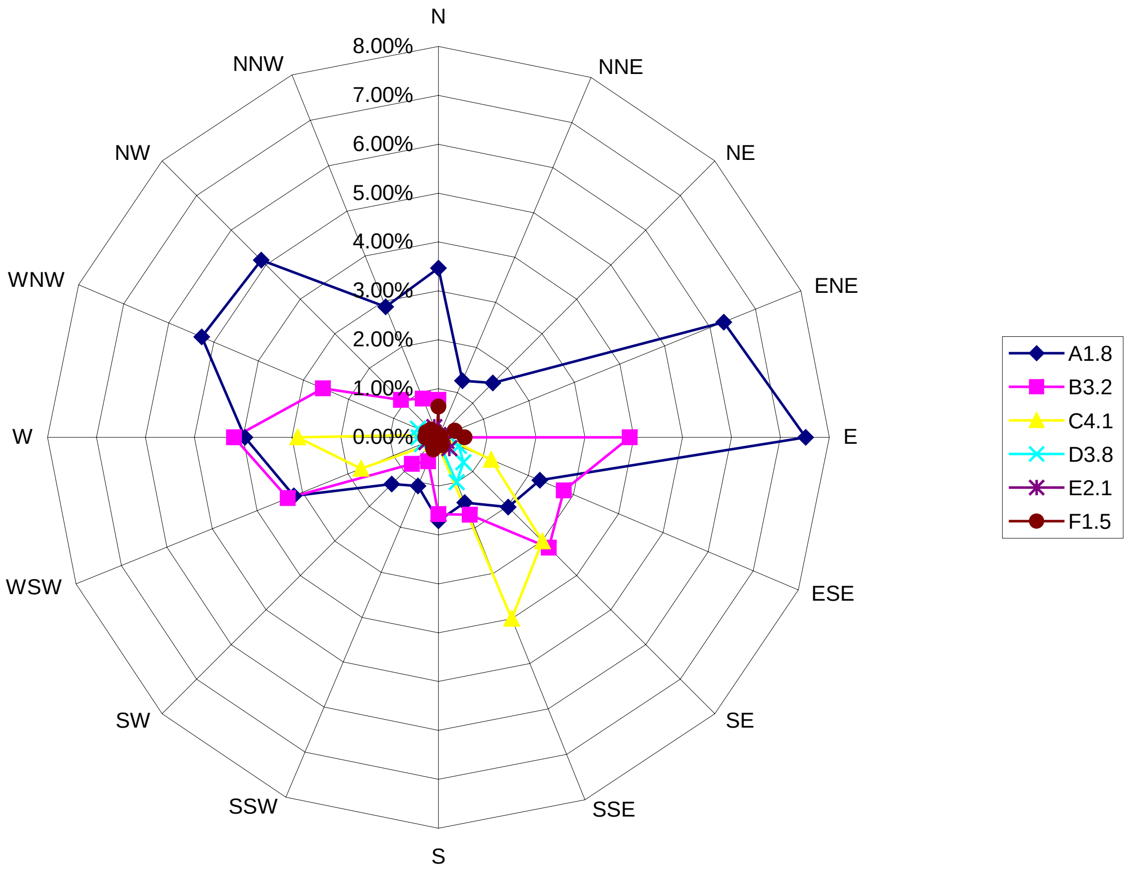
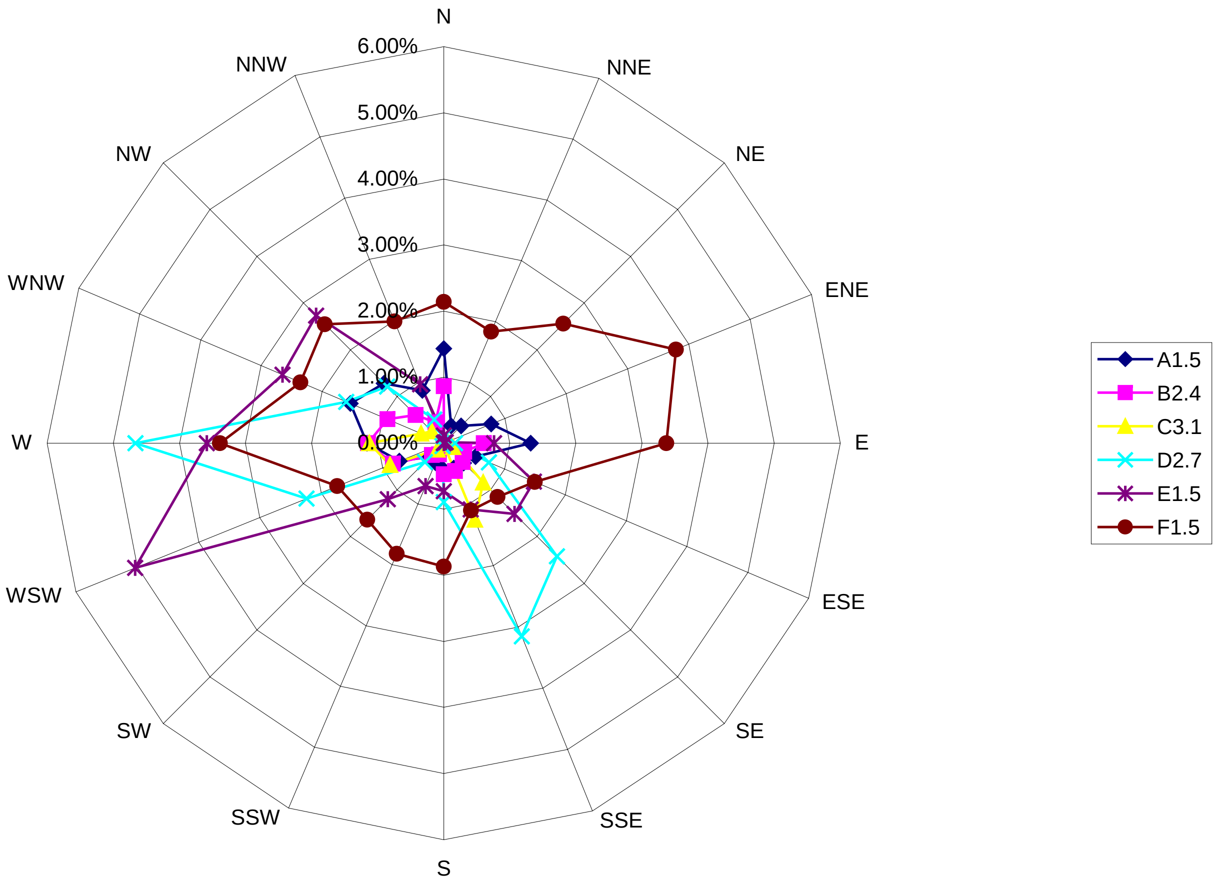


Figure I.2.2 Wind Rose For Out Of Business Hours



The wind roses show the percentage of time that the wind, in each of the stability class groups, is blowing from the direction indicated. This shows that although the prevailing winds during the day are from the east and north-west, the stable winds predominantly blow only during the night and from the east and west. Thus any releases of toxic gases will be likely to extend further to the west or east before being dissipated by the wind compared to the north or south.

I.2.2.3. Atmospheric Parameters

It is also necessary to define various parameters for the atmosphere. For this study the following values are used for these parameters:

- Atmospheric Pressure: 1.01325 x 105 N/m^2
- Atmospheric Temperature: 25 °C
- Atmospheric Humidity: 60%

I.2.3. Topographical Parameters

I.2.3.1. Surface Roughness

The topographical parameter used in the analysis is the surface roughness. This parameter is used in the consequence modelling. A lower surface roughness parameter produces less turbulence in the atmospheric modelling and thus greater consequence distances.

It determines the amount of turbulence generated by wind of a given velocity as it passes over the ground. The degree of roughness relates to a comparison of the average height of surface "protuberances" with the depth of the laminar sub-layer in the air stream. There are two alternative means of "measuring" the roughness, either a roughness length or a roughness parameter. The roughness length, Zo, is approximately 1/30 of the effective average height of the protuberances. The roughness parameter is a measure of the root mean square fluctuating velocity as a fraction of the mean velocity at 10 m height above ground. It is given by:

$$\text{Roughness Parameter} = \frac{0.4}{\ln(10/zo)}$$

The surface roughness parameter is a more practical value to use and SAFETI requires this value to be input.

Table I.2.2 Typical Surface Roughness Parameters

SURFACE	SURFACE ROUGHNESS PARAMETER
Sea	0.06
Flat land with few trees	0.07
Open farm land	0.09
Open countryside	0.11
Woods, rural area or industrial site	0.17
Urban area	0.33

The turbulence in the wind is generated over a terrain between 1000 and 2000 m upwind of the point of interest. The releases under consideration can have significant consequences for up to about 1 km downwind of the site. So the surface roughness to use is that of the site and its surroundings within about 2 kilometres.

The area of Enfield is relatively flat. The area consists of industrial and commercial land with residential areas further out. A surface roughness factor of 0.17 (an industrial site) has therefore been used in the modelling of the release cases at the site, to account for the range of land uses.

I.2.4. Offsite Population

The only population considered was the offsite population in the surrounding area. The area of Strathfield LGA is 14.1 square km and the total population in 2001 was 28206[1]. This equates to an average population of residents of 20 per hectare. However, the large buildings of apartments near Strathfield railway station skew the average numbers. Near the ILC site, the residences are generally detached dwellings. The assumptions made below are in line with this average value but are conservative estimates to account for the uncertainty in the information.

In defining the offsite population for the intermodal terminal area regard was taken of the hazard range shown by individual risk contours in previous comparable risk studies. These showed risk contour hazard distances to the lowest defined criteria level (0.5 x 10^{-6} per year) of up to 1 km. To ensure that all events will be covered, the limit for population data was set at 2.0 km away from the plant centre. Table I.2.3 shows the population densities used in this study. Land areas that are usually vacant or undeveloped are not shaded.

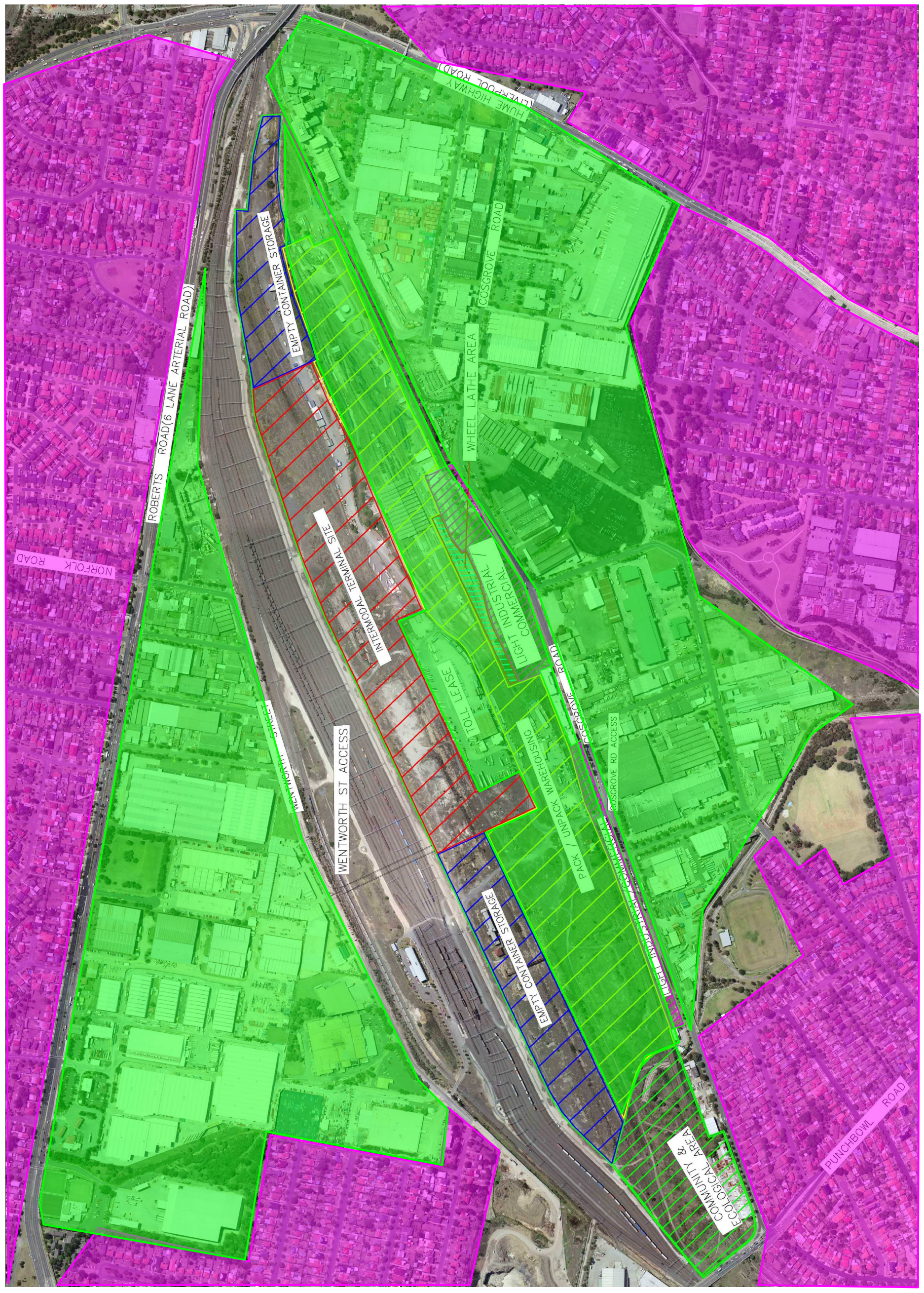
Table I.2.3 Population Densities

ZONE	AVERAGE POPULATION DENSITY	
	Outside Business Hours	In Business Hours
Residential	25 / ha	10 / ha
Industrial	1 / ha	10 / ha

A visual image of the population model applied in the SAFETI is presented in Figure I.2.3.

[1] Strathfield Municipal Council web site (accessed on 30 March 2005) http://www.strathfield.nsw.gov.au/about/02/1031186816_4306.html

Figure I.2.3 Population Data



Residential Industrial

I.3. IGNITION

In order to calculate the risk from flammable materials, a likelihood of ignition was applied. The likelihood of ignition of any release is correlated with the size of the release. Small releases are less likely to be ignited whereas large releases have a higher likelihood of ignition. However, analysis of historical accidents has shown that even large releases of flammable materials have been ignited only 30% of the time. Delayed ignition sources generated as functions of human activity have also been modelled in SAFETI via the use of the population model. People based offsite on the industrial / commercial and residential areas are treated as ignition sources by SAFETI.

Overall, the ignition rates for releases of flammable materials do not contribute significantly to hazards off-site – the main off-site hazards relate to toxic gas releases.

Appendix II

Dangerous Goods Movements Analysis

TABLE OF CONTENTS

II.1. INTRODUCTION

This appendix presents the analysis of movements of containers with dangerous goods (DG) that passed through Port Botany during 2004. This is scaled to match the number of movements of DGs that will pass through the intermodal terminal at the end of this appendix (Section II.4, Table II.4.3)

This analysis of movements allowed the large number of DG movements to be simplified into a set of representative scenarios for modelling.

II.2. DANGEROUS GOODS MOVEMENTS

Key to the analysis of the risk from the intermodal terminal is the expected volume of trade in dangerous goods, the type of goods traded and the volumes transported at any one time. The trade profile of the intermodal terminal in terms of the volume and type of dangerous goods is considered as the key input into the analysis.

The Port Botany manifest for the entire year 2004 was used to estimate the pattern of trade for the intermodal terminal[1]. It was assumed that the proportion and type of dangerous goods traded during this year could be taken as typical of any year. Thus the proportion of movements of flammable liquids through the port was assumed to be constant. As the number of movements through the intermodal terminal increases, the number of flammable liquids movements will increase in proportion.

The exceptions to this assumption were the requirement that Class 2.3 isotainers not be handled at the intermodal terminal and that explosives, (other than Class 1.4) may be only kept on site for up to 2 hours (kept in an isolated stack position awaiting loading onto a train).

In 2004, a total of 1 348 000 TEU passed through Port Botany. There were 655 000 TEU exported and 693 000 TEU imported. Of these, 352 000 TEU were empty (mainly being returned overseas). 33 000 TEU carrying dangerous goods passed through the port during 2004. Of all the containers that moved through Port Botany in 2004, 2.5% contained dangerous goods. For comparison, 3.3% of the full containers moved through Port Botany in 2004 contained dangerous goods. Based on this trade pattern it is estimated that 2-3 % of the containers will have some quantity of dangerous goods in them.

The dangerous goods trade through the intermodal terminal when at capacity (300 000 TEU p.a.) would be significantly less in volume than the dangerous goods trade through Port Botany in 2004. The dangerous goods trade through the intermodal terminal was modelled as a proportion of the total dangerous goods trade through Port Botany in 2004, based on a ratio of the intermodal terminal capacity of 300,000 TEU and the TEU throughput for Port Botany in 2004 of 1,348,800 TEU[2].

During 2004 there were only small numbers of high-hazard dangerous goods transported through Port Botany. Such materials that could be loaded/unloaded at the proposed intermodal terminal include isotainers of Class 2.1 flammable gases, Class 3 liquids, containers of Class 1.4 explosives and ammonium nitrate, and cylinders of Class 2.3.

Dangerous goods entering and leaving Port Botany are categorised by Sydney Ports Corporation into red line and green line dangerous goods, based on the hazards posed by having the goods on the site for various periods. Sydney Ports Corporation has required that all green line dangerous goods be kept on-site for a maximum period of 5 days, whereas red line dangerous goods must be kept on-site for a maximum period of 2 hours. At the proposed intermodal terminal all containers, regardless of their potential dangerous goods contents will be handled in a consistent manner, with two exceptions: Class 2.3 Toxic Gases in tanks (isotainers) will not be permitted on-site, and Class 1.1, 1.2 and 1.3 Explosives must only be stored on-site for a maximum of 2 hours. Under the proposed plan to operate the intermodal terminal all other containers will remain on-site for an average of 3 days with a maximum of 5 days in accordance with the "dangerous goods in transit" provision of the National Standard for the Storage and Handling of Workplace Dangerous Goods.

[1] There were a small number of errors identified in the manifest – a small number of containers were listed as having absurd cargo weights (e.g. 19 000 tonnes). Following discussion with Sydney Ports, all nett cargo weights were limited to 23 tonnes).

[2] 300 000/1 348 000 = 22.3%.

II.3. DANGEROUS GOODS MOVEMENT ANALYSIS

The analysis of DG movements through Port Botany is divided into sections based on the primary DG Class of the material.

II.3.1. Class 1 Materials (Explosive)

Table II.3.1 shows that there were 269 container movements carrying explosives during 2004. The average Net Explosive Quantity (NEQ) per container was 3.2 tonnes, with 43% of the containers having less than 500 kg NEQ. 30% had between 500 kg and 3 tonnes and 20% between 3 and 13 tonnes. For the intermodal terminal, the Class 1.3 explosives would be permitted on site for a maximum of 2 hours.

Table II.3.1 Transportation of Dangerous Goods of Class 1

DG Class	Number of Containers	Total NEQ (te)	Average NEQ (te)	<500 kg NEQ	>500 – 3te NEQ	3te-13 te NEQ	13te – 23te NEQ
1.3	49	422	8.6	3	10	31	5
1.4	220	429	2.0	114	73	25	8
Total	269	851	3.2	117	83	56	13

Movements of explosives in quantities less than 3 tonnes are modelled as 3 tonnes, movements between 3 tonnes and 13 tonnes are modelled as 13 tonnes and movements greater than 13 tonnes are modelled as 23 tonnes. TNT is used as the representative material for all explosives.

II.3.2. Class 2.1 Materials (Flammable Gases)

Table II.3.2 shows that there were 2434 containers with Class 2.1 materials transported in 2004. Of these, only two materials were carried in tank containers (dimethyl ether and butylene). The rest of the materials were carried in smaller containers such as compressed gas cylinders and aerosols. The transportation of aerosols and lighters is dominated by small packages (<1 litre). The package size of the compressed gas cylinders varies from <1 litre to drums of hundreds of kg.

Table II.3.2 Transportation of Dangerous Goods of Class 2.1

Material	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
Aerosols	2120	6026	2.8	801	698	556	65
Butylene	5 (tanks	25.8	5.2	2	1	2	0
Dimethyl ether	14 (tanks	160	11.4	1	1	5	7
Lighters	74	387	5.2	23	7	32	12
Other	221	795.2	3.6	139	23	52	7
Total	2434	7393	3.0	966	730	647	91

For this analysis:

- All aerosols and lighters were assumed to be in 100 kg packages,
- Butylene movements above 3 te were assumed to be in 12.5 te tanks[3], the rest in 100 kg packages
- Dimethyl ether movements above 3 te were assumed to be in 23 te tanks, the rest in 100 kg packages
- Small shipments of other gases (<500 kg net weight) were assumed to be in 100 kg packages and all the larger movements were assumed to be in multiples of 500 kg drums.

Butylene and dimethyl ether above 3 te were modelled as themselves. All other gases (aerosols, lighters, etc) were modelled as propane.

II.3.3. Class 2.3 Materials (Toxic Gases)

Table II.3.3 shows the toxic gas trade through Port Botany for 2004. Although tanks (isotainers) can be used for transportation of sulphur dioxide and ammonia, no tanks of Class 2.3 materials will be permitted on the intermodal terminal.

Although hydrogen fluoride is classified as a corrosive material, due to its toxic vapours, it has been included in this analysis as a toxic gas.

Table II.3.3 Transportation of Dangerous Goods of Class 2.3

Material	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
Aerosols	39	60.8	1.6	17	16	6	0
Ammonia	12	18.7	1.6	4	5	3	0
Carbon Monoxide	19	7.3	0.4	17	1	1	0
Chlorine	11	0.2	0.02	11	0	0	0
Ethylene Oxide	31	10.1	0.3	26	5	0	0
Hydrogen Sulphide	7	5.7	0.8	5	1	1	0
Methyl Bromide	13	161	12.4	0	2	1	10
Sulphur Dioxide	16	43	2.7	9	3	3	1
Other	65	20.2	0.3	60	2	3	0
Total	213	327	1.5	149	35	18	11
Hydrogen Fluoride	21	84	4.0	14	2	1	4

The aerosols are transported in packages that are less than 1L in volume. The ammonia is transported in cylinders and drums of capacity ranging from 34 kg to 500 kg and potentially in tanks (but these would not be permitted at the intermodal terminal). Carbon monoxide is

[3] The movements of butylene above 3 te through Port Botany in 2004 were in 12.5 te tanks.

carried in G size cylinders of capacity 48L (10 kg). The chlorine quantities carried were either in very small containers less than 20 kg or in cylinders of capacity 70 kg (two movements). Ethylene oxide is transported in drums of capacity 544 kg and 750 kg and cylinders of capacity 23 kg. Hydrogen sulphide is transported in cylinders of capacity 48L (33 kg). Methyl bromide is transported in drums of 100 kg capacity. Sulphur dioxide is transported in cylinders of capacity 48L (61 kg). Hydrogen fluoride is transported in cylinders of capacity 50 kg.

For this analysis:

- All aerosols were assumed to be ammonia in 10 kg packages[4],
- Ammonia movements below 500 kg were assumed to be in 34 kg cylinders and movements above 500 kg were assumed to be in 500 kg drums,
- Carbon monoxide was assumed to be in 10 kg cylinders,
- Chlorine was assumed to be in 70 kg cylinders,
- Movements of ethylene oxide less than 500 kg was assumed to be in 23 kg cylinders and movements greater than 500 kg were assumed to be in 750 kg drums,
- Hydrogen sulphide was assumed to be in 33 kg cylinders,
- Methyl bromide was assumed to be in 100 kg cylinders,
- Sulphur dioxide was assumed to be in 61 kg cylinders,
- Movements of other toxic gases less than 500 kg were assumed to be ammonia in 100 kg cylinders[5] and movements greater than 500 kg were assumed to be ammonia in 500 kg drums.
- Hydrogen fluoride was assumed to be transported in 50 kg cylinders.

Using the surrogates for the gases, the modelling was undertaken for the following cases.

Table II.3.4 Modelling of Class 2.3 Toxic Gases

Material	Surrogate	Container Sizes
Aerosols	Ammonia	10 kg
Ammonia	Ammonia	34 kg & 500 kg
Carbon Monoxide	Carbon Monoxide	10 kg
Chlorine	Chlorine	70 kg
Ethylene Oxide	Ethylene Oxide	23 kg & 750 kg
Hydrogen Sulphide	Hydrogen Sulphide	33 kg
Methyl Bromide	Methyl Bromide	100 kg
Sulphur Dioxide	Sulphur Dioxide	61 kg
Other	Ammonia	100 kg & 500 kg
Hydrogen Fluoride	Hydrogen Fluoride	50 kg

II.3.4. Class 3 Materials (Flammable Liquids)

Table II.3.5 shows the transportation of dangerous goods of Class 3. The package size inside the general containers is considered most likely to be standard 200 L drums, except

[4] This was based on the package sizes used for Class 2.3 aerosols.
[5] The range in package sizes for the other toxic gases was greater than the range in package sizes for ammonia, thus the package size modelled was 100kg for other toxic gases and 34kg for ammonia.

where the container type was listed as "tank". The surrogate material for all spills of packaging group I is taken to be acrylonitrile as it is both flammable and toxic. The other packaging group materials are modelled as octane, which is a packaging group II material, similar in properties to petrol. This table shows that there are many more movements of the lower hazard packaging group II and III material than the higher hazard packaging group I materials.

Table II.3.5 Transportation of Dangerous Goods of Class 3

Pkg Group/ Type	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 kg – 3te NW	3te-13 te NW	13te – 23te NW
I drums	314			134	19	133	28
I tanks	18			2	2	3	11
I total	332	2210	6.7	136	21	136	39
II drums	7422			4533	1566	874	449
II tanks	636			7	9	26	594
II total	8058	28828	3.6	4540	1575	900	1043
III drums	8519			4269	1907	1254	1089
III tanks	420			7	5	19	389
III total	8939	38955	4.4	4276	1912	1273	1478

Movements of materials greater than 3 te in tanks were considered to be 20 te. All other movements were considered to be in 200 kg drums.

II.3.5. Class 4 Materials (Flammable Solids, Spontaneously Combustible, Dangerous When Wet)

Table II.3.6 shows the transportation of containers carrying Class 4 materials. There were 1893 containers carrying these materials. The dangerous properties of these materials are mainly that they can cause fires and in some circumstances cause explosions.

Table II.3.6 Transportation of Red Line Dangerous Goods of Class 4

Class/ Packaging Group	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
4.1 I	5	0.05	0.01	5	0	0	0
4.1 II	308	1155	3.8	190	37	38	43
4.1 III	695	10119	14.6	98	83	45	469
4.2 I	51	65	1.3	43	0	8	0
4.2 II	67	841	12.6	8	6	15	38
4.2 III	26	364	14.0	4	0	5	17
4.3 I	27	69	2.5	15	0	11	1
4.3 II	184	3133	17.0	19	2	3	160
4.3 III	521	10979	21	3	7	6	505
Other[6]	9	81	9.0	0	2	6	1
Total	1893	29617.5	86.71	385	137	137	1195

6 Only classified as a dangerous good for sea transport, not road or rail transportation.

Due to the very wide range of hazardous properties of this Class of materials, the packaging group I materials have been modelled by the surrogate acrylonitrile, which is a liquid with both flammable and toxic properties. The packaging group II and III materials have been modelled as octane, which is a flammable liquid. As the predominant package for these materials is drums, 200 kg has been used as the package size. Thus the modelling of flammable liquid spills and fires has been increased by the number of containers listed in Table II.3.6.

II.3.6. Class 5.1 Materials (Oxidising Agents)

Table II.3.7 shows the transportation of containers with Class 5.1 material. The packaging group I material is dominated by one material with 21 of the 23 movements of 13 te – 23 te being tanks of hydrogen peroxide. Calcium hypochlorite was the main packaging group II material transported in large quantities: 251 of the 454 movements of 13 te – 23 te were calcium hypochlorite. The packaging group III material movements were dominated by ammonium nitrate. There were 873 movements of ammonium nitrate and 215 of ammonium nitrate fertilizers of the 1373 movements between 13 te and 23 te.

Table II.3.7 Transportation of Dangerous Goods of Class 5.1

Packaging Group	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
I	61	459	7.5	35	1	2	23
II	896	9438	10.5	230	96	116	454
III	1848	29664	16.1	274	134	40	1400
Total	2805	39561	14.1	539	231	158	1877

The off-site hazards associated with Class 5.1 materials predominantly relate to the potential for explosions or initiating/escalating fires. Ammonium nitrate is the dominant material overall in this Class and has been used as the surrogate material. In the modelling of the explosions, the TNT equivalence model has been used.

II.3.7. Class 5.2 Materials (Organic Peroxides)

The quantities of Class 5.2 materials were minor with the following numbers of containers. As the hazard of organic peroxides is mainly due to the potential for an explosion, these materials have been included in the Class 5.1 modelling.

Table II.3.8 Transportation of Dangerous Goods of Class 5.2

Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
222	787	3.5	130	38	32	22

II.3.8. Class 6.1 Materials (Toxic)

Table II.3.9 shows the movements of containers with Class 6.1. For packaging group I material, there were no tanks carrying significant quantities of material. For this packaging group, all the packages have been assumed to be in 200 L drums. For packaging group II, 33% of the loads above 13 te were in tanks and for packaging group III, less than 10% were in tanks.

Table II.3.9 Transportation of Dangerous Goods of Class 6.1

Packaging Group	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
I	582	8511	14.6	135	11	17	419
II	692	6063	8.8	261	83	81	267
III	1335	8805	6.6	617	205	116	397
Total	2609	23401	9.0	1013	299	214	1083

The transport of packaging group I material is dominated by solid sodium cyanide (used in mining), which comprises 95% of the total and is normally contained in drums inside a shipping container of approximately 20 te net weight. For packaging group II, toluene diisocyanate is the major component comprising 53% of the total (in 21 te net weight containers packaged in drums). The next most common material in packaging group II, comprises only 16%. For packaging group III, 80% is sent in full container loads of approximately 20 te net weight in bags, drums or packages. Dichloromethane is the most common packaging group III material (18%), followed by sodium fluorosilicate (13%).

The off-site hazard of these materials to people is mainly due to the potential for these materials to be involved in fires. Such fires can produce smoke containing toxic compounds.

Conversely, the off-site hazard to the environment is associated with the potential for spills to be washed into the stormwater drains, and affecting watercourses.

The materials that were considered for their potential to produce toxic smoke were the following based on the quantities transported and their potential to produce toxic smoke.

Table II.3.10 Materials Considered for Smoke Production

Material	Common Package	Total Transport Quantity (2004)
Carbamate Pesticides	IBC	1004 te
Acrylamide	bags	1127 te
Organophosphorous Pesticides	drums	851 te
Toluene Diisocyanate	drums & tanks	3255 te

II.3.9. Class 7 Materials (Radioactive)

Table II.3.11 shows that there are relatively few containers carrying radioactive materials. There were 8 containers in 2004 carrying radioactive materials; all of them were low specific activity materials. It was assumed that higher activity radioactive material (such as spent fuel elements) would be trucked or railed directly to Port Botany, rather than trans-shipped at the proposed intermodal terminal because this would minimise the transportation time and coordination required.

Table II.3.11 Transportation of Dangerous Goods of Class 7

Schedule	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
5	8	76	9.5	0	0	8	0
4 (empty packages)	5	0.005	0.001	5	0	0	0

II.3.10. Class 8 Materials (Corrosive)

Table II.3.12 shows that there are a significant number of containers carrying Class 8 materials. The transportation of hydrogen fluoride comes under this category but for the purposes of risk from transported related activities, the toxic gas hazard dominates the risk. Thus movements of hydrogen fluoride are included within the modelling of Class 2.3 dangerous goods (see section II.3.3). However, the bulk of hydrogen fluoride is carried in tanks (isotainers) that would not be permitted into the intermodal terminal. The other containers of hydrogen fluoride are packages, assumed capacity of 50 kg.

Table II.3.12 Transportation of Dangerous Goods of Class 8

Packaging Group	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
I	112	461	4.1	66	15	11	20
II	2985	18804	6.3	1273	547	370	795
III	4053	30636	7.6	1379	715	699	1260
HF 8 pg I	21	84	4.0	14	2	1	4
Total	7171	49985	22	2732	1279	1081	2079

The packaging group I material is led by organic acids (38%) followed by nitric acid (15%). Over half of the packaging group I goods are transported in drums. The range of materials in Packaging group II is diverse (the highest quantity of material comprises only 11% of the total) and the types of packaging is also diverse. Conversely, packaging group III is mainly comprised of loads of wet acid batteries (54%) in packages.

The off-site risk to people and the environment is minimal with these materials. The predominant risk is associated with burns to skin following a spill. Such risks are very localised. There is also an environmental risk associated with spills of corrosive materials into waterways.

II.3.11. Class 9 Materials (Miscellaneous)

The trade in Class 9 dangerous goods is shown in Table II.3.13. These materials have much lower risk and no potential for significant offsite consequences in the event of an accidental release was identified. Thus Class 9 materials have been excluded from the analysis of the risk to neighbouring offsite populations.

Table II.3.13 Transportation of Dangerous Goods of Class 9

Packaging Group	Number of Containers	Total Net Weight (te)	Average Net Weight (te)	<500 kg NW	>500 – 3te NW	3te-13 te NW	13te – 23te NW
-	8010	71401	8.9	2939	344	1615	3112
II	19	90	4.7	5	6	6	2
III	2818	18982	6.7	955	531	490	842
Total	10847	90474	8.3	3899	881	2111	3956

II.4. SELECTION OF REPRESENTATIVE MATERIALS

Table II.4.1 summarise the representative materials used in the modelling of accident scenarios.

Table II.4.1 Representative Materials per Dangerous Goods Class

Dangerous Goods Class	Description	Representative Material	Unit Size
1	Explosives	TNT	3 tonnes, 13 tonnes and 23 tonnes
2.1	Flammable Gases	Propane Butylene Dimethyl ether	100 kg and 500 kg propane, 12.5 te butylene, 23 te dimethyl ether
2.2	Non-flammable Gases	Screened out	
2.3	Toxic Gases	Chlorine, Hydrogen sulphide Carbon monoxide Ethylene oxide Methyl Bromide Sulphur dioxide Ammonia Hydrogen fluoride	70 kg chlorine 33 kg hydrogen sulphide 10 kg carbon monoxide 23 kg and 750 kg ethylene oxide 100 kg methyl bromide 61 kg sulphur dioxide 10 kg, 34 kg, 100 kg and 500 kg ammonia. 50 kg hydrogen fluoride
3	Flammable Liquids	Acrylonitrile Octane	200 kg and 20 te acrylonitrile 200 kg and 20 te octane
4	Flammable Solids, Spontaneously Combustible, Dangerous When Wet	As per Class 3	200 kg and 20 te acrylonitrile 200 kg and 20 te octane
5.1	Oxidising Materials	TNT	2 te TNT
5.2	Organic Peroxides	TNT	2 te TNT
6.1	Toxic Materials	See Smoke Analysis	
7	Radioactive Materials	Screened out – see II.3.9	
8	Corrosive Materials	Screened out – see II.3.10	
9	Miscellaneous Materials	Screened out – see II.3.11	

The number of movements of the various dangerous goods through Port Botany in 2004 have been aggregated to produce the following list of movements of the various surrogate materials.

Table II.4.2 Movements of Representative Materials per Dangerous Goods Class

Dangerous Goods Class	Description	Representative Material & Size	Number of Movements
1	Explosives	3 tonnes TNT 13 tonnes TNT 23 tonnes TNT	117+83=200 56 13
2.1	Flammable Gases	100 kg propane 500 kg propane 12.5 te butylene 23 te dimethyl ether	2120+74+3+2+139=2338 23+52+7=82 2 12
2.3	Toxic Gases	70 kg chlorine 33 kg hydrogen sulphide 10 kg ammonia 10 kg carbon monoxide 23 kg ethylene oxide 34 kg ammonia 61 kg sulphur dioxide 100 kg ammonia 100 kg methyl bromide 500 kg ammonia 750 kg ethylene oxide 50 kg hydrogen fluoride	11 7 17+16+6=39 17+1+1 26 4 16 60 13 8+5=13 5 21
3	Flammable Liquids	200 kg acrylonitrile 20 te acrylonitrile 200 kg octane 20 te octane	314+2+2+5+51+27=401 3+11=14 7422+8519+7+9+7+5+308+695+67+26+184+521=17770 26+594+389+19=1028
4	Flammable Solids, Spontaneously Combustible, Dangerous When Wet	Included in Class 3	
5.1	Oxidising Materials	2 tonnes TNT	1848+896+61+222=3027
5.2	Organic Peroxides	Included in Class 5.1	
8	Corrosive	Hydrogen fluoride included in Class 2.3	

Before being incorporated into the model, these movements were scaled based on the ratio of movements through Port Botany in 2004 compared to that forecast for intermodal terminal. The following table shows the modelling undertaken for the various release scenarios on the intermodal terminal site.

Table II.4.3 Modelling of Representative Materials for Enfield Intermodal Terminal Site

Dangerous Goods Class	Description	Representative Material & Size	Number of Movements at Start-Up of Intermodal	Number of Movements at Capacity of Intermodal
1	Explosives	2 tonnes TNT	225	675
		3 tonnes TNT	15	45
		13 tonnes TNT	4	12
		23 tonnes TNT	1	3
2.1	Flammable Gases	100 kg propane	174	521
		500 kg propane	6	18
		12.5 te butylene	0	0
		23 te dimethyl ether	1	3
2.3	Toxic Gases	70 kg chlorine	1	2
		33 kg hydrogen sulphide	1	2
		10 kg carbon monoxide	1	4
		10 kg ammonia	3	9
		23 kg ethylene oxide	2	6
		34 kg ammonia	0	1
		61 kg sulphur dioxide	1	4
		100 kg methyl bromide	1	3
		100 kg ammonia	4	13
		500 kg ammonia	1	3
		750 kg ethylene oxide	0	1
		50 kg hydrogen fluoride	2	5
3	Flammable Liquids	200 kg acrylonitrile	30	89
		20 te acrylonitrile	1	3
		200 kg octane	1321	3963
		20 te octane	76	229

QEST CONSULTING

Appendix III

Frequency Analysis

TABLE OF CONTENTS

III.1. INTRODUCTION

Frequency estimates can be developed using historical data at the site, experience in other similar locations or using fault trees. None of these estimation methods produce exact results and have ranges of uncertainty around them. Notwithstanding this, many estimates have been accepted as appropriate for Preliminary Hazard Analyses (PHA) as they have passed through several stages of scrutiny and refinement. This process involves estimation by risk experts, review by operations' personnel and review by the regulator. At each review the estimates have the opportunity to be scrutinised and refined. Once the frequency estimates have been through the reviews by the experts they are accepted as appropriate estimates.

In this study, there are two main initiators of incidents:

- Dropped or impacted containers associated with crane lifts. The crane lifts include those undertaken by forklifts, reach stackers and gantry cranes.
- Transportation accidents associated with vehicle movements. Such vehicle movements include road trucks and rail cars.

III.2. DROPPED OR IMPACTED CONTAINERS

Containers may be dropped from cranes, forklift trucks, or rail mounted gantries. The likelihood of such drops is low due to the positive engaging checks that are required to be energised before the lifts can be commenced. The more likely drop scenarios are where a container is raised slightly under another container, is lowered onto the edge of another container or hits an object during a traverse associated with the lift. The likelihood of such drops is difficult to estimate. Experience from the offshore industry suggested a dropped object frequency of 1×10^{-5} per lift (DNV, 2001).

Previous work for another Australian Port (DNV, 1993) established that they had experienced eight reports of dropped containers over a10 year period. This was used to estimate a likelihood of dropping containers: 6.7×10^{-6} per transfer between the ship and the truck or rail car including any set-downs or raises associated with intermediate storage. This frequency is similar to the figure from the offshore industry but specific to the port activities and is considered more appropriate for this study.

The severity of the damage to the container was also recorded. No loss of outer containment in the 8 drops was noted and a probability of 0.1 was conservatively estimated for loss of outer containment in this study. It is considered that isotainers could be more vulnerable to loss of containment than standard containers if they fell on a sharp object. However, given the uncertainties involved, a total release frequency for isotainers of 6.7×10^{-7} per transfer is considered a reasonable estimate.

Sydney Ports Corporation does not have detailed historical records of container damage or drops and thus the experience quoted above was applied to the future intermodal terminal operation.

For containers of drummed material, a conditional probability of drums leaking of 0.5 was assumed following loss of outer containment. Thus a release frequency of 3.4×10^{-7} per transfer for drums is estimated. It was also assumed that only 1 drum in a container will leak in a release case.

Based on the distribution of leak sizes for pressure vessels, the relative likelihood of different size leaks, for both isotainers and drums, was assumed to be: 25 mm leak 25%, 100 mm leak 65%, rupture 10%. See section III.5.4 for the reasoning behind the distribution of hole sizes.

III.2.1. Explosions of Class 1 materials in Dropped Containers

If a shipping container with Class 1 material is dropped, there is a potential for it to be detonated.

Previous work (DNV, c1996) discussed test drops of cartridge explosives on to a hard flat surface from a height of 11 m. Of the 1150 drops, none resulted in detonation. Based on this result a conservative estimate of 1 in 1000 is applied in this study. Thus if a shipping container with Class 1 material is dropped, it is assumed that there is a 0.001 chance of it detonating the explosives. It is assumed that the entire content of the shipping container detonates in one explosion.

Combining the likelihood of dropping a container and the likelihood of it exploding, the likelihood of a container carrying explosives detonating during transfer is 6.7×10^{-9} per transfer.

III.3. EXPLOSIONS OF AMMONIUM NITRATE IN SHIPPING CONTAINERS

There are a number of conditions that are necessary before an explosion involving ammonium nitrate during either transportation or storage could occur. Contamination with organic material changes the sensitivity of ammonium nitrate and this is recognised in the change of dangerous goods class from ‘oxidising agent’ for pure ammonium nitrate to ‘explosive’ for ammonium nitrate contaminated with organic material. However, even when contaminated with organic materials, ammonium nitrate is still difficult to explode and requires additional factors.

Melting of ammonium nitrate increases its sensitivity to strong impact and also facilitates contamination with nearby materials. Confinement of ammonium nitrate that is being heated is known to produce explosions but the degree of confinement required (50 bar) is very difficult to achieve in accident scenarios.

Strong impact can cause detonation or deflagration of ammonium nitrate. However, for prills of ammonium nitrate (UN 1942) a significant quantity of primer explosive is required. This is not likely to occur in an accident scenario. In addition, such explosions do not propagate through the entire mass of ammonium nitrate but decay and do not involve all the ammonium nitrate. For molten ammonium nitrate, a very high-energy projectile such as a high-velocity bullet can cause detonation. For contaminated ammonium nitrate in the solid form, a smaller quantity of primer explosive is required. For molten contaminated ammonium nitrate the impact provided by an exploding fuel tank or gas cylinder can initiate an explosion.

Historically, an accidental explosion of ammonium nitrate is usually a deflagration rather than a detonation and usually does not involve all the material.

The history of accidents involving ammonium nitrate show that, despite increasing manufacture, transport and usage of ammonium nitrate, the number of accidents has decreased during the last 25 years. The decrease in accidents is considered to be due to the major increases in understanding of the properties of ammonium nitrate and the subsequent changes to manufacture, storage and transportation practices. The consequences of more recent ammonium nitrate incidents have also been less severe than those that occurred in the first half of the 20^{th} Century. The improvements to emergency response during this time have also prevented accidents being exacerbated by incorrect responses.

III.3.1. Frequency Analysis

The analysis of the likelihood of an ammonium nitrate explosion has been undertaken using fault tree analysis techniques. The fault tree presented in Figure III.3.1 was prepared following a review of the hazards of ammonium nitrate. From the hazard review, a series of event sequences were developed to produce the fault tree. The estimation of the individual event probabilities provides a path to estimate the likelihood of an ammonium nitrate explosion due to the activities undertaken at the proposed intermodal terminal.

A summary of the fault tree branch probabilities applied in the analysis is presented in Table III.3.1

Figure III.3.1 Ammonium Nitrate Explosion Incident Fault Tree

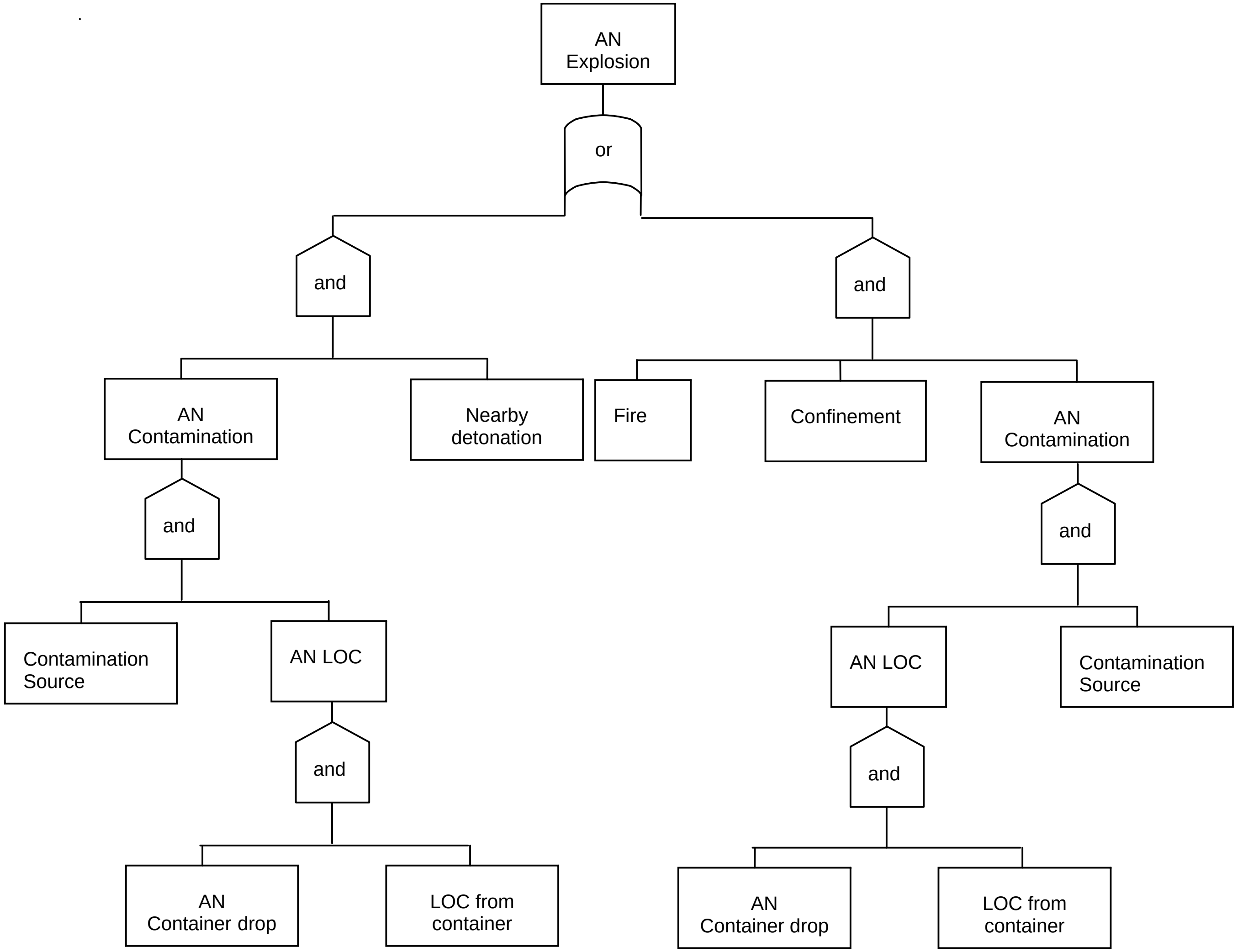


Table III.3.1 Fault Tree Branch Probabilities

EVENT	PROBABILITY	COMMENT
Probability of adjacent detonation	1/1000	Assumed a nearby fire causes a detonation of a separate material. Estimate of 1 in 1000.
Confinement	1/20	All AN is assumed to be transported in containers. A conservative estimate that 5% of the time sufficient confinement is provided by the containers to assist a fire to produce an explosion of contaminated AN.
Probability of nearby fire	1/100	Assumed that fire occurs nearby. Estimate of 1 in 100.
Ammonium Nitrate container drop	6.7×10^{-6} p.a.	As per the container drop frequency from historical sources.
Loss of containment of AN	1/10	Assumes that 1 in 10 dropped containers will results in AN being released from bags and containers.
Presence of contamination sources	1/100	Following a drop of a container the potential exist for impact with vehicles and other containers. Impact may result in the loss of containment of a potential contamination source.

Based on the fault tree branch probabilities presented in Table III.3.1 the probability of an ammonium nitrate explosion has been estimated at 1×10^{-11} per ammonium nitrate container movement. As there will be approximately 3027 movements per year of ammonium nitrate (and other materials modelled as ammonium nitrate) through the intermodal terminal, when at capacity in 2016/17, an explosion frequency of 3 in 100 million per year (3×10^{-8} p.a.) has been estimated for the entire intermodal terminal. This frequency is significantly lower than the criteria levels of one in a million (1×10^{-6} p.a.) for residential areas and 0.5 in a million (5×10^{-7} p.a.) for sensitive developments. Based on this frequency estimation the risk from ammonia nitrate explosions is considered negligible and therefore has been screened from further analysis.

III.4. ROAD TRANSPORT FREQUENCY DATA

III.4.1. Introduction

This section presents data drawn from NSW and overseas sources on the likelihood of dangerous goods incidents initiated by road accidents.

III.4.2. Vehicle Accident Rate Data

Data obtained from the various sources are discussed in this section.

III.4.2.1. Truck Accident Rates in NSW

The City South Freight Strategy published by Department of Urban Affairs & Planning (DUAP) in 1998, quotes truck accident rate targets of a maximum of 80 crashes per 100 million vehicle kilometres. This is equivalent to 8 x 10^{-7} crashes per vehicle km. This estimate is compared below with experience in the UK.

The M5 East Motorway Environmental Impact Statement (EIS) conservatively estimated the truck accident rate to be 5.4 x 10^{-6} per vehicle km. This is a factor of 7 greater than the target published by DUAP. The difference is considered to be due to the conservatism applied in the EIS because of the uncertainty of the estimates.

The M5 East Motorway EIS also considered the potential for leaks from a tanker following an accident. It reported that 95% of accidents would not result in a leak, 4.5% of accidents would result in a pinhole leak, 0.35% would result in a 50 mm hole and 0.15% would result in a complete rupture of the container.

The conservative accident rate for trucks in NSW developed as part of the M5 East Motorway EIS (5.4 x 10^{-6} per truck km) is considered an appropriate estimate of the total accident rate for trucks carrying dangerous goods travelling to and from the intermodal terminal at Enfield.

Following an accident, the likelihood of a release of material from a drum or cylinder within the shipping container is discussed in the M5 East Motorway EIS and is estimated to be 10%. This likelihood of release is broken down into minor leaks, 10mm hole leaks and 25mm hole leaks. The probability of a minor leak from a cylinder was considered to be 9%, the probability of a 10 mm leak was considered to be 0.9% and the probability of a 25 mm leak was considered to be 0.1%. Using the truck accident rate in the EIS, the leak rate from a truck is estimated to be 5.4 x 10^{-7} per vehicle km (5.4 x 10^{-6} per vehicle km x 10% = 5.4 x 10^{-7} per vehicle km.)

III.1.1.1. UK Heavy Vehicle Accident Rates

Table III.4.1 presents traffic accident data for the UK, for which an analysis was published (Department of Environment, Transport and Regions 1998). The table gives the involvement rates for different classes of vehicles and severity of road traffic accident.

Table III.4.1 Road Traffic Accident Frequency, 1997 (per 100 million vehicle km)

VEHICLE TYPE	ALL CASUALTY ACCIDENTS	SERIOUS/FATAL ACCIDENTS	FATAL ACCIDENTS
Cars	92	13	1.1
Buses/coaches	230	31	2.6
Light goods vehicles	50	7.8	0.8
Heavy goods vehicles	45	10	1.8
All motor vehicles	92	14	1.3

This table shows that the likelihood of all casualty accidents involving heavy goods vehicles is 4.5 x 10^{-7} per vehicle km in the UK.

III.1.1.2. The Netherlands Vehicle Accident Rates

The TNO Purple book provides guidance on the frequency of vehicle accidents involving leaks of material from vehicles carrying dangerous goods inside a built up area is 3.5 x 10^{-9} per vehicle km for cylinders and 1.2 x 10^{-8} per vehicle km for drums.

III.1.1.3. Bulk Compressed or Liquefied Gases Tanker Accidents

The UK HSC (1991)[1] published rates of puncture/rupture of bulk gas tankers: 4.8 x 10^{-10} per tanker km. for LPG/ammonia tankers and 8 x 10^{-11} per tanker km for chlorine tankers. The lower rates for bulk compressed or liquefied gas tankers take account of the lower probability of accidents involving these vehicles due to more stringent scrutiny of the drivers by the authorities and the transporters. The lower rates also take account of the protection of the tanker to resist leakage even when involved in an accident.

DNV Technica (c1996) compared various sources of leak frequency data for LPG road tankers, and developed a fault tree model to take account of the main influences. Table III.4.2 gives the failure case frequencies for a road tanker with passive fire protection.

Table III.4.2 LPG Road Tanker Leak Frequencies

FAILURE CASE	LEAK FREQUENCY (per loaded vehicle km)
BLEVE	2.7 x 10^{-12}
Cold rupture	2.6 x 10^{-9}
Large liquid leak	1.8 x 10^{-8}
Large vapour leak	2.1 x 10^{-9}
Brief liquid leak	6.8 x 10^{-9}
TOTAL	3.0 x 10^{-8}

This table shows a much higher estimate of the leakage rate compared to that estimated by the UK HSC – a factor of 60 higher.

[1] Quoted in M5 East Motorway EIS, 1995.

III.4.3. Explosion of Class 1 Materials Due to Road Accident

If a vehicle transporting Class 1 material is involved in an accident, there is a potential for it to be detonated.

Using the same reasoning as applied in Section III.2.1, if a shipping container with Class 1 material is involved in a road accident, it is assumed that there is a 0.001 chance of it detonating the explosives.

Combining the likelihood of a container being involved in a road accident (5.4×10^{-6} per truck km) and the likelihood of it exploding, the likelihood of a container carrying explosives detonating during road transport to the intermodal terminal was estimated at 5.4×10^{-9} per truck km.

The likelihood of an explosion associated with a vehicle transporting ammonium nitrate is extremely low. The same fault tree given in Figure III.3.1 is used with the term for a drop of a container of ammonium nitrate is replace by the term for a road accident of a vehicle carrying a container of ammonium nitrate. The explosion likelihood is 7.8×10^{-12} per vehicle km. This likelihood is sufficiently low to exclude it from any further risk analysis.

III.4.4. Loss of Containment from Isotainers

For trucks travelling to and from the intermodal terminal at Enfield, bulk liquid tankers will not be used. Isotainers (tank containers) will be used where bulk liquids are to be transported. These will be loaded onto trucks appropriate for carrying isotainers of dangerous goods.

Even in the event of a vehicle accident, there may not be a release of dangerous goods. The likelihood of a release of dangerous goods from a road tanker is considered appropriate to apply to a truck carrying an isotainer of dangerous goods.

The following frequencies are applied to truck movements of isotainers:

Table III.4.3 Truck Movements of Isotainers Leak Frequencies

FAILURE CASE[2]	LEAK FREQUENCY (per loaded vehicle km)
25 mm leak	1.2×10^{-6}
100 mm leak	8.6×10^{-7}
Rupture	6.5×10^{-7}

III.4.5. Loss of Containment from Containers of Drums or Cylinders

The M5 East Motorway EIS estimate of leak likelihood is significantly greater than the generic value given in the TNO Purple Book of 1.2×10^{-8} per vehicle km for drums and 3.5×10^{-9} per vehicle km for cylinders. These discrepancies are significant – a factor of 45 lower for drums and a factor of 150 for cylinders.

The reasons for the significant differences may be:

- higher accident rates in NSW compared to The Netherlands,
- high conservatism applied to the estimate of accident rate in the M5 East Motorway EIS,

[2] This has been revised slightly to provide data for 25 mm holes and 100 mm holes rather than only 50 mm holes.

- high conservatism applied to the estimate of the likelihood of leakage from a package following an accident, but is most likely due to
- the definition of significant leak used in the TNO data is a leak of >100 kg.

In addition, the above release rates take no account of the protection provided by the shipping container. In this study, the protection provided by a shipping container has been assumed to reduce the leak frequency of drums and cylinders travelling within a container by a factor of 10.

In this assessment the following leak likelihoods have been applied to truck movements of cylinders and drums in containers based on the conservative leak rates assumed in the M5 East Motorway EIS.

Table III.4.4 Leak Frequencies of Cylinders and Drums Carried in Containers in Trucks

FAILURE CASE	Cylinder or Drum Leak Frequency (per loaded vehicle km)	
Vehicle Accident Rate	5.4×10^{-6} per vehicle km	
Protection provided by shipping container	90%	5.4×10^{-7} per vehicle km
Negligible leaks	98.9%	5.35×10^{-7} per vehicle km
25 mm leak	1%	5.4×10^{-9} per vehicle km
Rupture	0.1%	5.4×10^{-10} per vehicle km

III.5. RAIL TRANSPORTATION FREQUENCY DATA

III.5.1. Introduction

This section presents a small selection of available data drawn from NSW and overseas sources on the likelihood of incidents initiated by rail accidents.

III.5.2. Train Accident Rates

In the absence of a detailed analysis of local data, Qest have estimated train accident frequencies from data for the UK (HSE 1997). Table III.5.1gives the accident rates for different types of train accidents.

Table III.5.1 Summary of Railway Accident Involvement Rates (per 100 million train km)

ACCIDENT TYPE	PASSENGER TRAINS	FREIGHT TRAINS
Collision (train-train) (involvement)	3.2	17
Collisions (train-projection from train/buffer)	24	
Derailments	7.2	128
Running into obstructions	166	
Fires on train	72	47
Total Accident Rate	272.4	382

Thus for a freight train, the total accident rate is 3.8×10^{-6} per train km.

This data can be compared to the generic accident rates quoted by the TNO Purple Book. The accident frequencies are 1.1×10^{-6} per car per km on the main railway. As there are numerous cars per train, the TNO data is conservative and has been used in the calculations considered below.

III.5.3. Explosion of Class 1 Due to Rail Accident

If a train transporting Class 1 material is involved in an accident, there is a potential for it to be detonated.

Using the same reasoning as applied in Section III.2.1, if a shipping container with Class 1 material is involved in a rail accident, it is assumed that there is a 0.001 chance of it detonating the explosives.

Combining the likelihood of a container being involved in a rail accident and the likelihood of it exploding, the likelihood of a container carrying explosives detonating during transport to the intermodal terminal was estimated at 1.1×10^{-9} per car km.

The likelihood of an explosion associated with a train transporting ammonium nitrate is extremely low. The same fault tree given in Figure III.3.1 is used with the term for a drop of a container of ammonium nitrate is replaced by the term for a rail accident of a rail car carrying a container of ammonium nitrate. The rail accident rate is 3.8×10^{-6} per car km (see above) and this leads to an explosion likelihood of 5.7×10^{-12} per rail car km. This likelihood is sufficiently low to exclude it from any further risk analysis.

III.5.4. Rail Isotainer Leaks

The Advisory Committee on Dangerous Substances (ACDS 1991) estimated frequencies of tank shell punctures and equipment leaks from tank wagons carrying dangerous goods, based on modified UK data. The punctures are taken to be 50 mm diameter holes (90%) or catastrophic ruptures (10%).

Table III.5.2 ACDS Rail Tanker Leak Frequencies

TANKER TYPE	TANK SHELL PUNCTURE (per loaded tank wagon km)	EQUIPMENT LEAK (per loaded tank wagon hour)
Petrol	6.3×10^{-8}	2.1×10^{-8}
Ammonia	2.5×10^{-9}	1.3×10^{-9}

The TNO Purple Book also gives the likelihood of a leak of >100 kg of material from a pressurised tank car and from an atmospheric pressure tank car to be 0.001 and 0.1 respectively. This produces a similar leak estimate compared to that quoted above. The TNO estimate has been used in the following analysis.

In this assessment the following leak likelihoods have been applied to train movements of isotainers based on the leak rates discussed above and the assumed distribution of leak sizes (25 mm – 25%; 100 mm – 65%; rupture – 10%).

Table III.5.3 Leak Frequencies of Isotainers Carried on Trains

FAILURE CASE	Compressed Gas Isotainer Leak Frequency (per car km)	Flammable Liquid Leak Frequency (per car km)
25 mm leak	2.8×10^{-9}	2.8×10^{-8}
100 mm leak	7.2×10^{-9}	7.2×10^{-8}
Rupture	1.1×10^{-9}	1.1×10^{-8}

III.5.5. Drum and Cylinder Leaks

For the analysis of the likelihood of a release from either drums or cylinders of both Class 2.1 and 2.3 dangerous goods the container in which the drums or cylinders are being transported would provide additional protection in the event of an train related accident, such as a collision or derailment.

For the purposes of the analysis of the likelihood of leak from drums and cylinders inside containers, and in the absence of specific historical data it has been assumed that the frequency of leak from drums and cylinders be based on the ratio of train accident rates (1.1×10^{-6} per car km) compared to truck accident rates (5.4×10^{-6} per truck km). This ratio is 20%.

Hence the recommended leak frequency data for drums and cylinders carried in containers on trains is assumed to be that presented in Table III.5.4.

Table III.5.4 Leak Frequencies of Cylinders and Drums Carried in Containers on Trains

FAILURE CASE	Cylinder or Drum Leak Frequency (per loaded vehicle km)
25 mm leak	1.1×10^{-9}
Rupture	1.1×10^{-10}

III.6. APPLICATION OF FREQUENCIES TO MODELLING

The leak frequencies calculated above were applied to the leak scenarios on-site as are shown on the following table. Numbers are expressed in exponential format.

Table III.6.1 Modelling for Enfield Intermodal Terminal Site

DG Class	Description	Representative Material	Quantity	Moves p.a.	Leak Frequency per Movement			Total Leak Frequency (p.a.)		
					25 mm	100 mm	Rupture/ Explosion	25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				1.0E-11			6.8E-09
		TNT	3 tonnes				6.7E-09			3.0E-07
		TNT	13 tonnes				6.7E-09			8.4E-08
		TNT	23 tonnes				6.7E-09			1.9E-08
2.1	Flammable Gases	propane	100 kg		8.5E-08	2.2E-07	3.4E-08	4.4E-05	1.2E-04	1.8E-05
		propane	500 kg		8.5E-08	2.2E-07	3.4E-08	1.6E-06	4.0E-06	6.2E-07
		butylene	12.5 te		1.7E-07	4.4E-07	6.7E-08	7.5E-08	1.9E-07	3.0E-08
		dimethyl ether	23 te		1.7E-07	4.4E-07	6.7E-08	4.5E-07	1.2E-06	1.8E-07
2.3	Toxic Gases	chlorine	70 kg		8.5E-08	2.2E-07	3.4E-08	2.1E-07	5.4E-07	8.3E-08
		hydrogen sulphide	33 kg		8.5E-08	2.2E-07	3.4E-08	1.3E-07	3.4E-07	5.3E-08
		carbon monoxide	10 kg		8.5E-08	2.2E-07	3.4E-08	3.6E-07	9.4E-07	1.4E-07
		ammonia	10 kg		8.5E-08	2.2E-07	3.4E-08	7.4E-07	1.9E-06	3.0E-07
		ethylene oxide	23 kg		8.5E-08	2.2E-07	3.4E-08	4.9E-07	1.3E-06	2.0E-07
		ammonia	34 kg		8.5E-08	2.2E-07	3.4E-08	7.6E-08	2.0E-07	3.0E-08
		sulphur dioxide	61 kg		8.5E-08	2.2E-07	3.4E-08	3.0E-07	7.9E-07	1.2E-07
		methyl bromide	100 kg		8.5E-08	2.2E-07	3.4E-08	2.5E-07	6.4E-07	9.9E-08
		ammonia	100 kg		8.5E-08	2.2E-07	3.4E-08	1.1E-06	3.0E-06	4.5E-07
		ammonia	500 kg		8.5E-08	2.2E-07	3.4E-08	2.5E-07	6.4E-07	9.9E-08
		ethylene oxide	750 kg		8.5E-08	2.2E-07	3.4E-08	9.5E-08	2.5E-07	3.8E-08
		hydrogen fluoride	50 kg		8.5E-08	2.2E-07	3.4E-08	4.0E-07	1.0E-06	1.6E-07
3	Flammable Liquids	acrylonitrile	200 kg		8.5E-08	2.2E-07	3.4E-08	7.6E-06	2.0E-05	3.0E-06
		acrylonitrile	20 te		1.7E-07	4.4E-07	6.7E-08	5.2E-07	1.4E-06	2.1E-07
		octane	200 kg		8.5E-08	2.2E-07	3.4E-08	3.4E-04	8.8E-04	1.3E-04
		octane	20 te		1.7E-07	4.4E-07	6.7E-08	3.8E-05	1.0E-04	1.5E-05

Table III.6.2 Modelling for Road Transport on Wentworth St

DG Class	Description	Representative Material	Quantity	Moves p.a.	Leak Frequency per vehicle km			Total Leak Frequency (per road km p.a.)[3]		
					25 mm	100 mm	Rupture/ Explosion	25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				7.8E-12			5.3E-09
		TNT	3 tonnes				5.4E-9			2.4E-07
		TNT	13 tonnes				5.4E-9			6.5E-08
		TNT	23 tonnes				5.4E-9			1.6E-08
2.1	Flammable Gases	propane	100 kg		5.4E-9	-	5.4E-10	2.8E-06	-	2.8E-07
		propane	500 kg		5.4E-9	-	5.4E-10	9.7E-08	-	9.7E-09
		butylene	12.5 te		1.2E-6	8.6E-7	6.5E-7	4.8E-07	3.4E-07	2.6E-07
		dimethyl ether	23 te		1.2E-6	8.6E-7	6.5E-7	3.6E-06	2.6E-06	2.0E-06
2.3	Toxic Gases	chlorine	70 kg		5.4E-9	-	5.4E-10	1.1E-08	-	1.1E-09
		hydrogen sulphide	33 kg		5.4E-9	-	5.4E-10	1.1E-08	-	1.1E-09
		carbon monoxide	10 kg		5.4E-9	-	5.4E-10	2.2E-08	-	2.2E-09
		ammonia	10 kg		5.4E-9	-	5.4E-10	4.9E-08	-	4.9E-09
		ethylene oxide	23 kg		5.4E-9	-	5.4E-10	3.2E-08	-	3.2E-09
		ammonia	34 kg		5.4E-9	-	5.4E-10	5.4E-09	-	5.4E-10
		sulphur dioxide	61 kg		5.4E-9	-	5.4E-10	2.2E-08	-	2.2E-09
		methyl bromide	100 kg		5.4E-9	-	5.4E-10	1.6E-08	-	1.6E-09
		ammonia	100 kg		5.4E-9	-	5.4E-10	7.0E-08	-	7.0E-09
		ammonia	500 kg		5.4E-9	-	5.4E-10	1.6E-08	-	1.6E-09
		ethylene oxide	750 kg		5.4E-9	-	5.4E-10	5.4E-09	-	5.4E-10
		hydrogen fluoride	50 kg		5.4E-9	-	5.4E-10	2.7E-08	-	2.7E-09
3	Flammable Liquids	acrylonitrile	200 kg		5.4E-9	-	5.4E-10	4.8E-07	-	4.8E-08
		acrylonitrile	20 te		1.2E-6	8.6E-7	6.5E-7	3.6E-06	2.6E-06	2.0E-06
		octane	200 kg		5.4E-9	-	5.4E-10	2.1E-05	-	2.1E-06
		octane	20 te		1.2E-6	8.6E-7	6.5E-7	2.7E-04	2.0E-04	1.5E-04

[3] The Total Leak Frequency (per road km p.a.) is calculated by the multiplication of the Moves p.a. with the leak frequency per vehicle kilometre

Table III.6.3 Modelling for Rail Transport from Port Botany to Enfield

DG Class	Description	Representative Material	Quantity	Moves p.a.	Leak Frequency per vehicle km			Total Leak Frequency (per rail km p.a.)		
					25 mm	100 mm	Rupture/ Explosion	25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				5.7E-12			3.8E-09
		TNT	3 tonnes				1.1E-9			5.0E-08
		TNT	13 tonnes				1.1E-9			1.3E-08
		TNT	23 tonnes				1.1E-9			3.3E-09
2.1	Flammable Gases	propane	100 kg		1.1E-9	-	1.1E-10	5.7E-07	-	5.7E-08
		propane	500 kg		1.1E-9	-	1.1E-10	2.0E-08	-	2.0E-09
		butylene	12.5 te		2.8E-9	7.2E-9	1.1E-9	1.1E-09	2.9E-09	4.4E-10
		dimethyl ether	23 te		2.8E-9	7.2E-9	1.1E-9	8.4E-09	2.2E-08	3.3E-09
2.3	Toxic Gases	chlorine	70 kg		1.1E-9	-	1.1E-10	2.2E-09	-	2.2E-10
		hydrogen sulphide	33 kg		1.1E-9	-	1.1E-10	2.2E-09	-	2.2E-10
		carbon monoxide	10 kg		1.1E-9	-	1.1E-10	4.4E-09	-	4.4E-10
		ammonia	10 kg		1.1E-9	-	1.1E-10	9.9E-09	-	9.9E-10
		ethylene oxide	23 kg		1.1E-9	-	1.1E-10	6.6E-09	-	6.6E-10
		ammonia	34 kg		1.1E-9	-	1.1E-10	1.1E-09	-	1.1E-10
		sulphur dioxide	61 kg		1.1E-9	-	1.1E-10	4.4E-09	-	4.4E-10
		methyl bromide	100 kg		1.1E-9	-	1.1E-10	3.3E-09	-	3.3E-10
		ammonia	100 kg		1.1E-9	-	1.1E-10	1.4E-08	-	1.4E-09
		ammonia	500 kg		1.1E-9	-	1.1E-10	3.3E-09	-	3.3E-10
		ethylene oxide	750 kg		1.1E-9	-	1.1E-10	1.1E-09	-	1.1E-10
		hydrogen fluoride	50 kg		1.1E-9	-	1.1E-10	5.5E-09	-	5.5E-10
3	Flammable Liquids	acrylonitrile	200 kg		1.1E-9	-	1.1E-10	9.8E-08	-	9.8E-09
		acrylonitrile	20 te		2.8E-9	7.2E-9	1.1E-9	8.4E-09	2.2E-08	3.3E-09
		octane	200 kg		1.1E-9	-	1.1E-10	4.4E-06	-	4.4E-07
		octane	20 te		2.8E-9	7.2E-9	1.1E-9	6.4E-07	1.6E-06	2.5E-07

III.7. REFERENCES

ACDS 1991, *Major Hazard Aspects of the Transport of Dangerous Substances, Advisory Committee on Dangerous Substances*, Health & Safety Commission, HMSO.

Davenport, T.J. (1991), "*A Further Survey of Pressure Vessel Failures in the UK*", Reliability 91, London, June 1991.

DNV RiskNet, 2001, Offshore QRA Methods.

DNV Technica c1996, *Quantitative Risk Assessment of the Transport of LPG and Naphtha in Hong Kong - Methodology Report, Electrical & Mechanical Services Department*, Hong Kong Government, Project C6124.

DNV Technica, 1980, *Risk Assessment of Liquid Chlorine Transport, Water Supplies Department*, Government of Hong Kong, June 1980, Project C1918.

DNV, 1993, *Port Safety Study QRA*, Fremantle Port Authority, September 1993 Project A1020.

DNV, 1996, *Comparative QRA of road tunnels*, Civil & Civic, October 1996, Project 2216.

HSE (1997): "*Railway Safety - HM Chief Inspector of Railways' Annual Report for 1996/97 1995*", HSE Books.

HSE (2000), "*Offshore Hydrocarbon Release Statistics 1999*", Offshore Technology Report OTO 1999 079.

RTA, 1996, *Working Papers, Supplement to M5 East Motorway Environmental Impact Statement.*

TNO Purple Book, Guidelines for quantitative risk assessment, Part 2 Transport

Appendix IV

Fire and Smoke Analysis

TABLE OF CONTENTS

IV.1. INTRODUCTION

There is the potential for a fire to occur in a container or, more likely, in a vehicle (crane, forklift, reach stacker, truck). This section assesses the likelihood, consequences and risk of a fire involving one or more shipping containers emitting toxic smoke that could cause fatalities, injuries or irritation to people off-site.

The effects due to heat radiation levels and emission of material vapours have been considered earlier in the main body of the report.

As there is the possibility of a fire evolving toxic fumes, a separate consideration was included to fully assess the risks.

In this appendix, the likelihood of a fire involving one or more containers on the intermodal site is considered first. This is followed by a discussion on the consequences of such a fire. Finally, the risk of such fires is considered.

IV.2. FIRE LIKELIHOOD

The likelihood of fires involving one or more containers on the site is rare. Thus it is necessary to estimate the likelihood of fires using data from a number of sources. The likelihood of warehouse fires and vehicle fires is considered, followed by an assessment of the historical data from Port Botany.

IV.2.1. Warehouse Fires

The likelihood of warehouse fires is estimated by various authors to range from 10^{-3} to 10^{-2} p.a.. Some brief details are given below.

Table IV.2.1 Warehouse Fire Frequency Estimates

Source	Fire Estimate
Health and Safety Executive (HSE) in the United Kingdom [Hymes & Flynn, UKAEA - SRD/HSE R578, 1002]	Major warehouse fire frequency is 2.5×10^{-3} p.a.
Baldwin, Accident Analysis and Prevention (Vol.6)	Serious fire frequency in warehouses to be in the order of 1×10^{-3} pa;
Environmental Impact Assessment Report for the Commission of Inquiry into Proposed Manufacturing Plant by WR Grace Australia Ltd., Kurnell, Sydney, October 1987	Fire frequency of 4.6×10^{-3} per warehouse year
Various studies in the UK and US	Approximately 10^{-2} p.a. for the fire frequency in a warehouse - averaged across all industry sectors.

The above three publications indicate a fire frequency in the order of 1×10^{-3} to 1×10^{-2} p.a. is common for warehouses. However, these warehouses are general storage facilities and do not have the stringent control of a DG warehouse (e.g. ignition source control, leak monitoring, fire fighting facilities, etc. Previous reports have estimated that the fire frequency in a DG store could be considered to be 1 order of magnitude less – 1×10^{-4} to 1×10^{-3} p.a.

This is not directly applicable to goods in a shipping container as warehouses are open, with easy access for forklift trucks and thus air circulation is good. Within a container, that will be passing through the intermodal, there is likely to be limited space not occupied by packages or dunnage. In addition, air ingress is limited due to the sealing of the containers against dust, saltwater spray, etc.

IV.2.2. Vehicle Fires on the Intermodal Terminal

Within the intermodal terminal, there will be no opening of containers. The containers are simply moved from one mode of transport to another, possibly with some on-site storage (maximum 5 days) as well. Because the containers are not opened at all, the likelihood of a fire commencing within a container is very low. A much more likely fire would involve a vehicle. Electrical faults and overheating brakes can cause fires, as can vehicle accidents causing fuel spills.

The likelihood of a vehicle fire on the intermodal terminal was estimated using the number of fires attended by the NSW Fire Brigade associated with freight transportation and the number of heavy vehicles that are registered in NSW.

There were 332 freight road vehicle fires in NSW in 2001/02[1], 13 rail transport vehicle fires, 35 heavy equipment fires and 8 special vehicles, container fires. This is a total of 388 fires across all of NSW that could occur at the intermodal terminal. As there were 1 350 000 vehicles of this type registered in NSW in 2001/02[2], the average fire risk per vehicle was 2.9 x 10^{-4} per vehicle p.a.

On the intermodal terminal terminal there will be a number of vehicles. The total estimated number of vehicles including forklifts and trucks awaiting loading/unloading is assumed to be an average of 50 at all times. Thus the vehicle fire frequency is estimated to be 0.014 p.a.

However a vehicle fire at the intermodal will not cause any off-site fatalities. It is only if the fire escalates to involve toxic materials in a shipping container that there is the potential for significant off-site effects.

For a vehicle fire to escalate to involve a shipping container in the fire, the vehicle fire must be adjacent to a container, continue burning for a significant period and be of a significant size. Most vehicle fires would be relatively small fires, easily extinguished. There is also the ability for the emergency services to fight such a fire or cool nearby containers. As a fire will not spread to a container immediately it commences, the presence of people on site, communication with the emergency services and the short response period of the fire brigade will in most cases enable effective fire fighting before a container is involved. It has been assumed that one in every 100-vehicle fires will escalate to involve a container, becoming a container fire.

The likelihood of a fire involving a shipping container is thus estimated to be 1.4 x 10^{-4} p.a. As only 0.1% of containers moved through the intermodal contain toxic materials, the overall likelihood of a fire involving a shipping container with toxic materials is estimated to be 1.4 x 10^{-7} p.a.

IV.2.3. Historical Data

Long-service personnel at Sydney Ports can only recall a single fire incident over the last decade. This fire involved a container of xanthates, which are used in mining. The xanthates had become contaminated with some water during the shipping and a reaction had commenced. This reaction was exothermic and produced small quantities of carbon disulphide. This is a very smelly compound at low concentrations and is flammable at higher concentrations. This incident was a minor fire and was managed by the port authorities in cooperation with the fire brigade by removing the container to an isolated section of the yard and then fighting the fire. This incident involved a Class 4.3 material (Dangerous When Wet)

[1] http://www.nswfb.nsw.gov.au/education/publications/statisticsreport_0102.pdf
[2] RTA Annual Report 2002.

which has a higher fire hazard compared to a Class 6.1 toxic material. No fires involving vehicles or cranes could be recalled by Sydney Ports personnel over the last decade.

Thus there was only one fire over the last 10 years when greater than 6 million containers have been traded. If it is assumed that there could be 1 fire involving a container in every 6 million containers moved, the likelihood of a fire involving a container on the intermodal is estimated to be 1.7×10^{-7} per container movement. The estimate of the likelihood of a fire involving a container carrying Class 6.1 toxic materials is thus 1×10^{-4} p.a.[3]

IV.2.4. Summary of Likelihood

Dangerous goods warehouse fires are estimated to occur with a likelihood of 1×10^{-4} to 1×10^{-3} p.a.

The vehicle fire frequency escalating to involve a container carrying toxic materials is estimated to be 1.4×10^{-7} p.a. and the historical recollections of fires on Port Botany corresponds to a toxic material fire likelihood of 1×10^{-4} p.a.

For this study, the historical based likelihood (1.7×10^{-7} per container movement p.a. which is equivalent to 1×10^{-4} p.a. for the Class 6.1 materials) has been considered to be the most appropriate.

[3] 2609 containers p.a. through Port Botany in 2004, scaled by 22.3% for the proposed intermodal terminal at Enfield

IV.3. CONSEQUENCE MODELLING

The consequence modelling of fires involving Class 6.1 toxic materials has been undertaken for the materials listed in Table IV.3.1. This was based on the propensity of the material to emit toxic smoke when involved in a fire and the quantities that are transported through Port Botany and thus are likely to be transported through the intermodal terminal at Enfield.

The modelling of fires involving containers of toxic materials was undertaken using the following frequencies, based on the conservative estimates of historical data. The number of movements of the more hazardous materials that is forecast for the intermodal terminal when at capacity is given below along with the fire likelihood estimates.

The more likely scenario (90% of the likelihood) is a fire involving only a small proportion of the contents of the container (assumed to be 1 tonne). The more serious incident, involving 20 tonnes of the material, is estimated to occur at 10% of the likelihoods given above.

The speed of the fire also depends on the availability of air into the container. Two rates of air ingress to the fire have been modelled: free access of air and 1 air change per hour (ACH). These have been assumed to be equally likely.

Table IV.3.1 Modelling of Smoke from Fires

Material	Common Package	Total Movements at Capacity	Likelihood of Fire Involving Part of the Container Load	Likelihood of Fire Involving All of the Container Load
Carbamate Pesticides	IBC	22	3.4E-06	3.7E-07
Acrylamide	bags	25	3.8E-06	4.3E-07
Organophosphorous Pesticides	drums	19	2.9E-06	3.2E-07
Toluene Diisocyanate	drums & tanks	73	1.1E-05	1.2E-06
Total		139	2.1E-05	2.4E-06

These scenarios are modelled as occurring at any of the various lifting locations on the site or in the storage areas of the site[4]. These accidents are included in the fatality, injury and irritation risk modelling undertaken in Section 9.2.

[4] For each lifting location on the site, four scenarios are modelled associated with smoke modelling: Part container load with free access of air, part container with 1 ACH, all the container with free access of air, and all the container with 1 ACH.

The modelling of the smoke from fires was undertaken using the breakdown of the materials in a fire, coupled with a emission of a gaseous form of the original molecule.

Table IV.3.2 Modelling of Smoke from Fires

Material	Common Package	Total Transport Quantity (2004) [tonnes]	Active Ingredient (A.I.) [5]	Molecular Formula (A.I.)	No. of Atoms per Molecule							LD50 [mg/kg]	Flash Point	Large Fire Scenario		Small Fire Scenario	
					C	H	O	N	S	Cl	P			Total Mass in Fire [kg]	Area of Fire [m^2]	Total Mass in Fire [kg]	Area of Fire [m^2]
Carbamate Pesticides	IBC	1004	Methomyl	$C_5H_{10}N_2O_2S$	5	10	2	2	1	0	0	<25	<100C	20000	14.884	1000	0.7442
Acrylamide	bags	1127	Acrylamide	C_3H_5NO	3	5	1	1	0	0	0	>25	>100C	20000	14.884	1000	0.7442
Organophosphorous Pesticides	drums	851	Chlorpyrifos	$C_9H_{11}Cl_3NO_3PS$	9	11	3	1	1	3	1	>25	<100C	20000	14.884	1000	0.7442
Toluene Diisocyanate	drums & tanks	3255	Toluene Diisocyanate	$C_9H_6N_2O_2$	9	6	2	2	0	0	0	>25	>100C	20000	14.884	1000	0.7442

5 Data is not available on the specific pesticides handled - Methomyl and Chloropyrifos were selected as representative pesticides (as these materials contain a relatively high proportion of Cl, N and S atoms).