Port Botany

PORT BOTANY LAND USE SAFETY STUDY
OVERVIEW REPORT

Department of Urban Affairs and Planning

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Photo courtesy Sydney Ports Corporation

Foreword

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Minister for Urban Affairs and Planning

and Minister for Housing

Port Botany is an area of State and national significance. In addition to a large volume of containerised general cargo, the Port handles a number of chemicals and hydrocarbon products. The storage and transport of these materials have led to increasing community concerns over safety.

A comprehensive cumulative risk assessment study of the Port was completed in 1985. Since then, port facilities have been expanded, community perceptions have continued to evolve and risk assessment techniques have further developed. In view of these changes, the Department of Urban Affairs and Planning (DUAP) has undertaken the Port Botany Land Use Safety Study summarised in this report. The study aims to update the 1985 study and formulate a land use safety strategy for the Port and its surrounding uses. The strategy takes into account the assessment of risks and the level of safety management.

The study approach utilises techniques of hazard analysis and quantitative risk assessment pioneered by DUAP. Land use and technical controls have been used to develop a strategic framework to assist decision-making in the Port and surrounding areas.

The NSW Government is committed to ensuring the highest level of community safety and participation. I commend this strategic study as a tool for improved planning decision-making for the benefit of the community.

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Executive Summary

BACKGROUND

Port Botany is a major infrastructure facility of State and national significance. The Port area handles and accommodates a number of activities involving hazardous materials including: the berthing, loading and unloading of ships carrying dangerous goods; the storage and distribution of bulk liquid chemicals, oil, LP Gas, and other liquefied flammable gases; and the general storage and handling of packed and bulk hazardous materials.

These activities have the potential to impact on public safety and the environment. It is thus important that the community, Government and industry understand the risk associated with the various activities at Port Botany so as to integrate development opportunities and sound land use safety and the protection of the community and the environment.

In 1985, the then Department of Environment and Planning published a comprehensive risk assessment study for the Botany/Randwick industrial complex and Port Botany. The study estimated cumulative risk levels and associated land use safety implications. The strategy established as the result of that study involved extensive and specialised risk assessment procedures, risk reduction and management, and strengthening coordinated operational and organisational mechanisms, including emergency planning and fire protection and prevention. Developments in the Port area have proceeded on the basis of complying with the strategic recommendations of that study.

THE PORT BOTANY LAND USE SAFETY STUDY

This study has been undertaken by the Department of Urban Affairs and Planning with the main objectives of:

- updating the 1985 cumulative risk study for Port Botany, taking into account approved

developments implemented since the publication of that earlier study and the assessment regime that has been applied to them
- developing updated cumulative risk contours for existing and possible future developments in the Port, so as to provide a framework for efficient assessment and decision making for future developments; and
- formulating a strategic land use safety framework for future developments in the Port and surrounding land uses.

The study was undertaken in liaison with the Sydney Ports Corporation (SPC) and in consultation with a Reference Group consisting of representatives of local councils, community groups and industry representatives. The study adopted up-to-date quantified risk assessment techniques, using internationally recognised modelling tools. The study involved: auditing facilities in the Port area; the modelling of possible incident scenarios (more than 5000 events were modelled); the estimation of the effect of major incidents and their likelihood of occurrence; the quantification of cumulative risk; and the development of strategic recommendations arising out of the ensuing analysis.

In addition to existing activities, the assessment included the impacts of postulated future developments, consistent with the Sydney Ports Corporation development strategy.

KEY FINDINGS
The study findings fall into four broad categories:

- adequacy of technical and safety controls and management standards within individual facilities
- cumulative off-site risks and land use safety implications
- infrastructure and safety support facilities; and
- community awareness and consultation.

In relation to the technical safety standards adopted by various facilities, the study found that there are variations in the overall standard of safety management and safety awareness between the various sites. Individual site reports have been submitted to each company with specific recommendations aimed at strengthening the level of their technical and management safety.

While most facilities adopt comprehensive safety practices and have appropriate controls (certainly by comparison to the 1985 study) the safety audits showed that there is a need for general improvement in relation to:

- strengthening the development and implementation of formal safety management systems within the various installations
- strengthening formalised mechanisms for the identification of safety-critical items, and permit to work systems
- consistency in the systems for the reporting and maintenance of information relating to incidents and accidents and adherence to sound incident/accident reporting systems; and
- systematic safety and general competency training.

Figure 1 depicts the overall cumulative risk from existing and approved new port facilities, expressed in the form of individual risk contours. *Figure 2* shows the effect of including postulated new development. *Figure 9* presents societal risk curves. The risk contours shown in *figure 2* represent the cumulative envelope within which risk should not be significantly increased through additional developments.

The study found that the cumulative risk is within tolerable limits, measured against criteria adopted both nationally and internationally and no residential areas are affected. This finding applies only with respect to risks from port operations and does not include risks from the nearby industrial area of Botany/Randwick or Sydney Kingsford Smith Airport. This finding also excludes the transportation, particularly by road, of dangerous goods to and from the Port area.

In planning terms the study also found that further expansions of bulk liquid facilities in the Port area may be accommodated under strengthened safety controls, without significantly increasing the cumulative risk, relative to existing conditions. However, intensification of storage and handling of toxic compressed or liquefied gases is inappropriate. Future developments in the Port area may be constrained by off-site transportation issues unless appropriate infrastructure is provided.

The study found that there is a need to monitor the interaction of risk between adjacent facilities, since relevant criteria may have been exceeded in some cases. Future assessment of new proposals will need to have particular regard to risk interactions between sites. A review of protective measures at the affected facilities may need to be undertaken to ensure risks of interactions from adjoining sites are taken into account and managed.

In relation to support safety infrastructure, the study found that the earlier recommendations made in 1985 for coordinated emergency planning and procedures and for improvements to fire protection and prevention measures, have been implemented. There is, however, a need to strengthen the security arrangements in the Port area in recognition of the specialised nature and vulnerability of the operations being undertaken. There may also be the need for more extended on the ground testing of joint emergency procedures by way of simulated exercises, in liaison with the relevant authorities.

STRATEGIC DIRECTION

The outcomes of this study enable an integrated strategic land use framework to be developed. The elements of the recommended strategy are:

1. Ensuring, through the development control and environmental impact assessment processes, that there is no increase in the cumulative risk from future developments as depicted in *figure 2*. Special consideration will need to be given to ensuring that, consistent with established assessment criteria and guidelines, there is no increase in risks due to interaction between various facilities.

2. Planning strategies and controls for surrounding areas should ensure that there is no increase in the number of people exposed to risk as a result of Port operations. This involves restricting the types of development involving residential, active recreation, large commercial or sporting facilities within the contour lines established in *figure 2*. It also involves consideration of the societal risk implications of significant intensification of people in the vicinity of the Port area.

3. Implementation of risk reduction and advanced best practice risk management at all sites in the Port area. The individual site specific auditing reports highlight the recommended technical, operational and organisational issues to be addressed.

4. Ensuring ongoing updating and testing of emergency procedures and planning, adequate fire protection and prevention and coordinated emergency procedures in the area. The need for strengthening security arrangements in the Port area is a priority area in this regard.

5. Strengthening ongoing community participation, liaison and communication and implementing community-right-to-know principles and concepts.

FIGURE 1. STUDY AREA SHOWING CUMULATIVE INDIVIDUAL RISK CONTOURS — EXISTING AND APPROVED NEW DEVELOPMENT

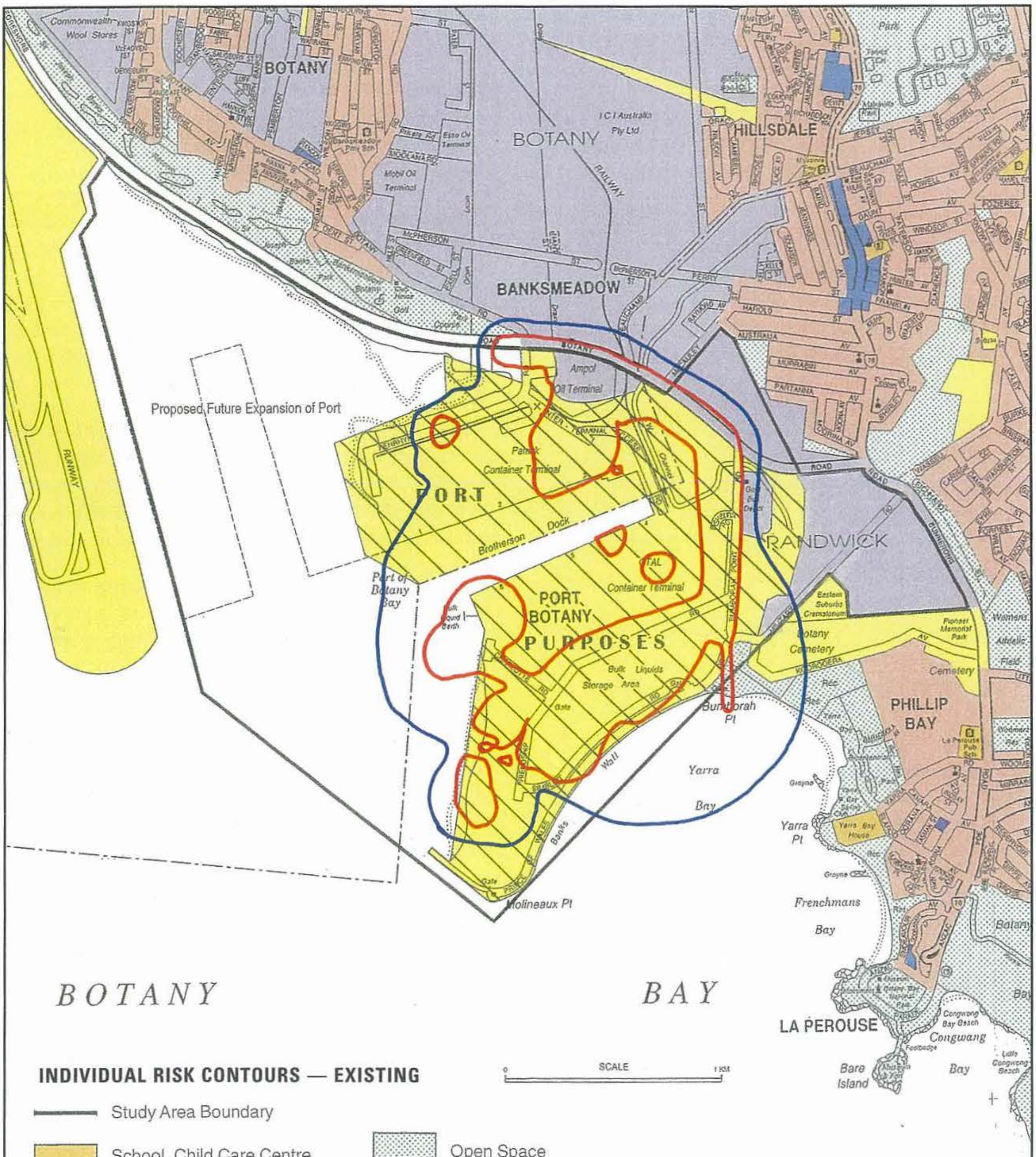
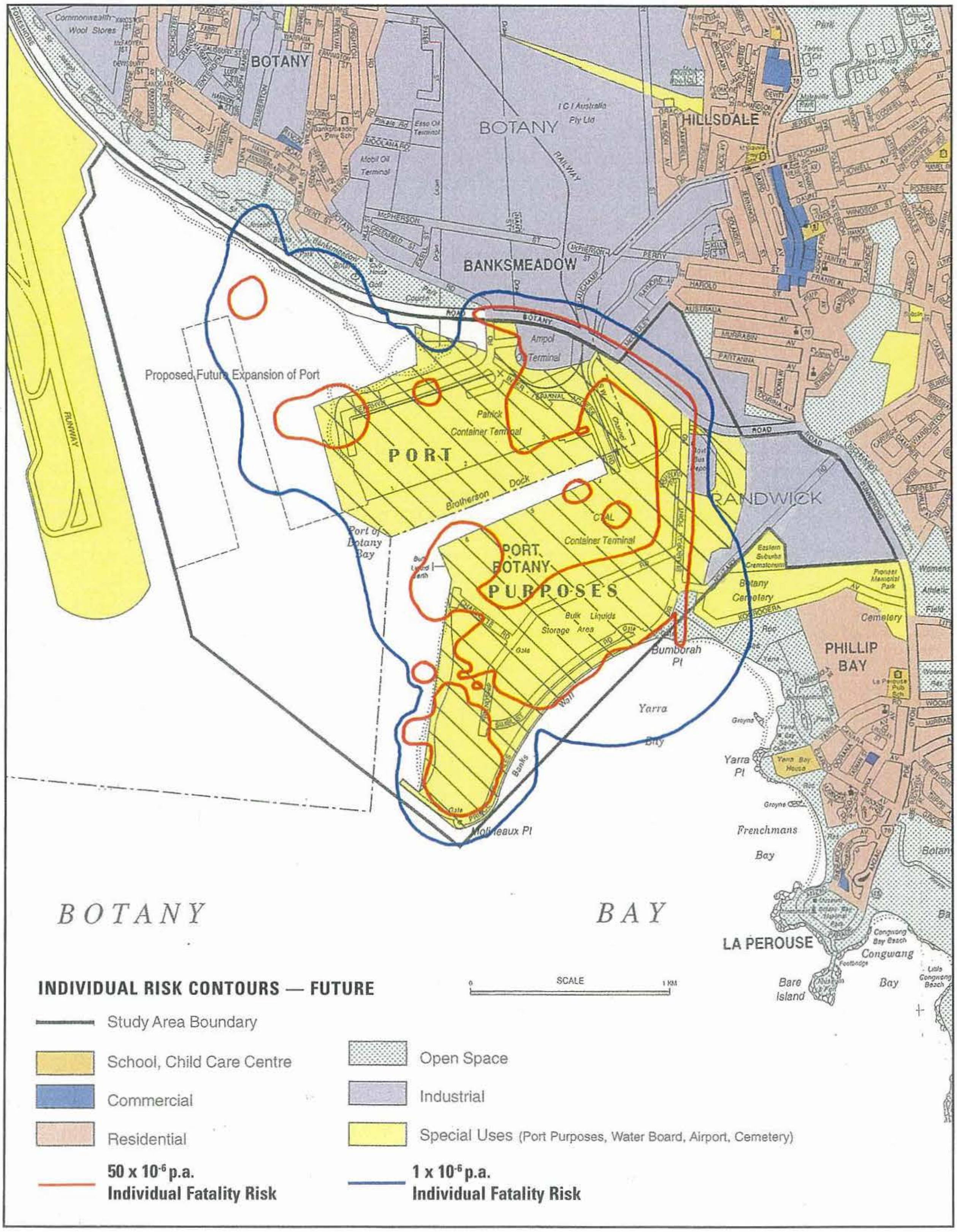


FIGURE 2. CUMULATIVE INDIVIDUAL RISK CONTOURS INCLUDING POSTULATED FUTURE DEVELOPMENT



Recommendations

1. **Future developments in the Port area should undergo early risk assessment and comprehensive environmental impact processes to conclusively demonstrate that they will not contribute to any increase in cumulative risk as shown in *figure 2*. Developments should also conclusively demonstrate that, consistent with the Department of Urban Affairs and Planning risk criteria, there will not be any propagation of risks to neighbouring facilities.**

   1.1 In particular, there should not be any significant increase in toxic compressed or liquefied gases stored or handled at the Port.

   1.2 Proposals for expansion of Port facilities should be subjected to the seven-stage assessment process under the *Environmental Planning and Assessment Act 1979* and demonstrate compliance with relevant risk criteria. There should be no increase in cumulative risk, including both individual and societal risk, beyond that shown in *figure 2* and *figure 9*.

   1.3 The Director-General's requirements for Environmental Impact Statement (EIS) should incorporate the above requirements to ensure appropriate assessment is carried out.

   1.4 An ongoing process of updating the cumulative risk contours, as shown in *figure 1*, should be undertaken in light of decisions on future developments in the Port and changes in external factors, such as aircraft movements.

2. **Development controls should be put in place to ensure there is no significant increase in the number of people exposed to risk inside the residential risk contour shown in *figure 2*.**

2.1 New development in the vicinity of the Port should be consistent with the recommendations of the Department of Planning's (1992) *Botany Bay Regional Policy Guidelines*. Such developments should be generally port-related or associated activities which will form a buffer between the Port and the surrounding residential and commercial areas.

2.2 Proposals for the development or redevelopment of residential, commercial or high density developments outside the Port area, particularly inside the one in a million residential risk contour, identified in *figure 2* should not take place. Residential intensification in the vicinity of the residential risk contour should also be the subject of an assessment of the risk from sources outside the port, such as industry, transport and the nearby airport, together with the societal risk implications.

3. **Risk reduction and safety management measures, identified in the individual site studies, should be implemented in accordance with an agreed program and with particular emphasis on the following:**

3.1 Improved surveillance and monitoring of external transfer pipelines for bulk liquids, to improve leak detection. This should include both technical and operational measures.

3.2 Loading arms rather than flexible hoses should be used for all high volume or high pressure volatile liquid and liquefied gas transfer operations.

3.3 Sites should initiate a systematic program to identify, inspect and maintain safety critical equipment.

3.4 Restrictions on roadside parking and queuing of heavy vehicles in the port area should be strictly enforced to reduce the likelihood of traffic obstructions causing dangerous goods transport accidents.

3.5 All sites transporting LPG by road in bulk should review their driver training, inspection, operating and emergency procedures and safeguards to minimise transport risks.

3.6 All sites should review and strengthen their safety management system (SMS). The effectiveness of the SMS should be monitored by periodic independent compliance audits at intervals of not less than once every two years.

3.7 Safety management systems should include effective measures for management of change.

3.8 Container handling procedures for volatile and toxic dangerous goods should be reviewed by Sydney Ports Corporation and the container terminal operators to minimise the time these materials spend on the port. Procedures should ensure that containers are appropriately marked, segregated and protected from damage during loading, unloading, storage and transport operations.

3.9 All sites should review their training arrangements to ensure that personnel have an appropriate understanding of operational hazards and are fully trained in operating and emergency procedures.

3.10 An overall review of incident/accident recording and reporting systems should be undertaken. A consistent best practice guideline should be developed and adopted by industry in the Port.

4. **Emergency plans and procedures and fire prevention and protection systems should be kept up to date. Security arrangements for the Port area should be strengthened.**

4.1 The Sydney Ports Corporation, in liaison with Port users and occupiers, should review and strengthen/upgrade overall security arrangements in the Port area to prevent unauthorised third party access. Both procedural and physical measures to restrict access should be considered.

4.2 The Port emergency and fire prevention/ protection systems and procedures should be kept up to date as new development proposals progress.

4.3 Consideration should be given to holding periodic coordinated field surprise emergency exercises to validate emergency procedures and practices.

5. **Port users should adopt community-right-to-know principles to ensure the community is adequately informed about port activities, associated risks and the safety management measures that are adopted. The *Responsible Care Program* adopted by the Plastics and Chemicals Industry Association (PACIA) is an appropriate model.**

5.1 A formal mechanism should be established to implement the community-right-to-know program through a consultative committee having representation from Sydney Ports Corporation, port users, councils, community groups and relevant government agencies.

5.2 Priority should be given to regular dissemination to the community of information relating to safety and environmental management and performance through regular annual reporting, newsletters and public forums. Relevant details should include:

- general operational information
- information about safety and emergency management systems
- safety performance statistics
- incident and accident details
- adherence to conditions of consent and licence conditions
- responses to specific community information requests.

Introduction

BACKGROUND

A risk assessment study of Port Botany was carried out in 1985, in recognition of the fact that a number of the storage and handling activities carried out in the area involve hazardous materials with the potential to adversely affect public safety and the built and natural environment.

Since that study was completed, additional facilities have been approved and constructed, there have been modifications and improvements to existing facilities, community attitudes have continued to evolve and risk assessment techniques have been further enhanced. These factors make it timely to carry out a review of the risk from the port and its associated activities.

Relevant issues include:

- whether the existing and approved potentially hazardous facilities pose a significant level of risk to existing or likely future land uses in the vicinity
- what constraints and opportunities there are for future use of the land in the study area for port related industrial development
- whether there are likely to be constraints on the future use of surrounding lands
- whether transportation of hazardous materials within the study area (including by pipeline) poses a significant level of risk to surrounding land uses; and
- whether there are opportunities to clarify planning controls to achieve an efficient approach to risk management throughout the area.

This report outlines the key findings and recommendations that arise from consideration of these issues. A more detailed report, incorporating details of the technical assessment, is being separately prepared.

THE PORT BOTANY AREA

Port Botany and its surrounding area are mainly devoted to industrial or commercial uses. The nearest residential areas are Hillsdale, Matraville, Chifley, Phillip Bay and La Perouse. The closest of these is about 200 m from the Port boundary.

Apart from the industrial facilities, other nearby uses are primarily residential and open space. Special use zones include schools, a government bus depot, Botany Cemetery and the Eastern Suburbs Crematorium. Areas of open space include Yarra Bay Bicentennial Park and Banksmeadow Park. The closest sensitive use is Banksmeadow Public School, which is over 1 km from the port facilities.

Areas of the Botany Bay foreshore are also used for swimming and other water-associated recreation, and the waters off Molineux Point are used for fishing and sailing.

Figure 3 and *figure 4*, respectively, present an aerial view of the port and a land use map of the port and its surroundings. The study area boundary is shown on *figure 4*.

PLANNING CONTEXT

Most of the study area within the Port lies within the City of Randwick and falls under Randwick Interim Development Order (IDO) No. 18, gazetted in 1980. Under the IDO, the land has been set apart for 'the purposes of the establishment and operation of a port providing wharfage, cargo handling and storage facilities.' That part of the Port which falls within the City of Botany Bay is zoned 5(a) Special Uses under Botany LEP 1995. Within these areas the only permissible uses are port related and ancillary activities and all development requires consent.

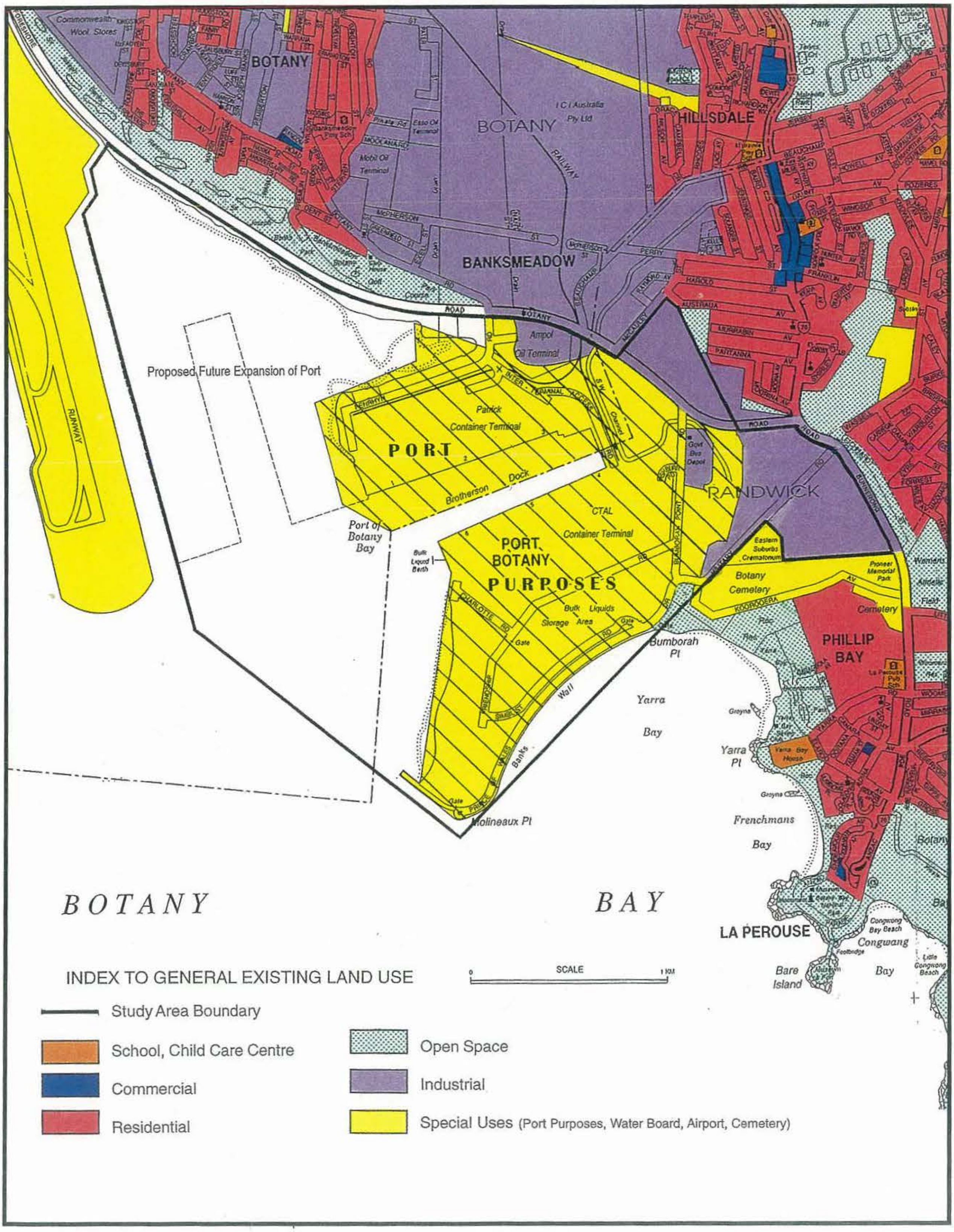
The Department of Planning's (1992) *Botany Bay Regional Policy Guidelines* recognise the strategic importance of Port Botany and the nearby Botany/Randwick industrial complex, together with Sydney Airport and the Ampol Kurnell refinery. The Guidelines note community and planning concerns over levels of land use safety in these areas. They recommend a balanced approach of limiting the residential and working population in and around the areas, while progressively upgrading the environmental performance of the industrial facilities.

In recognition of the State and regional significance of the Port Botany facilities, the Port is subject to a Direction under Section 101 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Direction allows the Minister for Urban Affairs and Planning to determine development applications for potentially hazardous development, together with applications for berths, terminals and other associated facilities and works.

Most development within the Port is of a scale and type which brings it within the definitions of Schedule 3 of the Environmental Planning and Assessment Regulation 1994 and is thus, designated development. Applications for designated development must be supported by an environmental impact statement (EIS). Further, if developments are potentially hazardous within the definitions of State Environmental Planning Policy (SEPP) No. 33 *Hazardous and Offensive Development* they are also subject to a seven-stage approval process, including a requirement for a preliminary hazard analysis (PHA).

FIGURE 3. GENERAL VIEW OF THE PORT BOTANY AREA

FIGURE 4. LAND USE MAP OF PORT BOTANY AND SURROUNDS



Study Description

SCOPE OF THE STUDY

The study covers Port operations and related industry within the area under the management of the Sydney Ports Corporation, together with the immediately adjacent facilities. These include the State Transit Authority, Pioneer Plasterboard, Alcatel TCC, Sydney Haulage Containers, Ampol and Australian Paper sites. In all, the study covered (30) individual facilities and activities.

The scope of the assessment includes existing, approved and possible future operations. It covers ship loading and unloading, terminal and storage operations and those areas of the container terminal handling hazardous materials. The study also includes berths, hazardous materials movements on internal roads and pipelines, together with the Ampol Banksmeadow operations and marine operations involving hazardous materials within Botany Bay.

The study excludes naval ships and risks from incidents involving non hazardous materials (ship collision where there are no dangerous goods). It excludes Occupational Health and Safety matters.

Table 1 (overleaf) gives a breakdown by type of the 30 individual facilities considered.

Appendix 1 gives additional detail. It should be noted that the postulated future sites are included for calculation purposes only. They do not represent a proposed pattern of future development nor does their inclusion imply that such development is desirable or possible. The postulated future developments, consistent with the Sydney Ports Corporation development strategy, were included to estimate the effects of possible expansion on risk. Locations were selected, taking into account logical expansion paths for existing activities.

TABLE 1. TYPES OF FACILITIES STUDIED

Type	Number
Bulk Liquids Storage	3 existing sites; 1 approved new site; 4 postulated future sites
Liquefied Hydrocarbon Gas Storage	3 existing sites; 1 approved new site
Container Terminals	5 existing sites; 1 postulated future site
Manufacturing Sites	3 existing sites
Bulk Liquids Berth Facilities	1 existing berth; 2 postulated future berths
Miscellaneous Facilities	5 existing facilities; 1 approved new facility

STUDY OBJECTIVES

The main objectives of the study were to:

- update the 1985 cumulative risk study for Port Botany, taking into account approved developments implemented since the publication of that earlier study and the assessment regime that has been applied to them
- develop updated cumulative risk contours for existing and possible future developments in the Port, so as to provide a framework for efficient assessment and decision making for future developments; and
- formulate a strategic land use safety framework for future developments in the Port and surrounding land uses.

STUDY ORGANISATION

The project was conducted in three stages:

1. gathering of site information, preliminary site screening and auditing of the safety management systems
2. site by site and cumulative quantified risk assessment (QRA) of existing and possible future facilities; and
3. analysis of findings and technical and policy recommendations.

TABLE 2. REFERENCE GROUP COMPOSITION

Representation	Numbers of members
DUAP	3
Sydney Ports Corporation	2
Councils (Botany/Randwick)	2
Port Industry	2
Community Groups	3

A Reference Group of local and State Government, community and industry representatives was formed, to ensure the study received input from various key stakeholders and to encourage an open and transparent process. Its composition is summarised in *table 2*. The Reference Group was consulted as the study progressed.

STUDY METHODOLOGY

The following paragraphs briefly summarise the techniques used to carry out the study. Appendix 2 provides more detailed information.

The study comprised the following stages:

- screening and auditing
- risk assessment
- development of technical and policy recommendations.

Screening

All sites were visited at the commencement of the study to obtain a general appreciation of the nature and scale of operations and possible risks. A questionnaire was used to obtain basic technical information about each site. This information was evaluated to categorise sites as potentially major, medium or minor risk generators, using a risk classification and prioritisation method developed by the United Nations (UN). This allowed detailed analysis to focus on key areas.

The UN method, which is described in greater detail in Appendix 2, produces a broad estimate of the risks due to major accidents from the manufacture, storage, handling and transport of hazardous materials. The hazardous materials activities are firstly *classified* by such factors as type, location and quantity. This information is then used to generate an approximate estimate of societal risk which forms a basis for *prioritising* the further analysis. Results are expressed as annual potential loss of life (PLL).

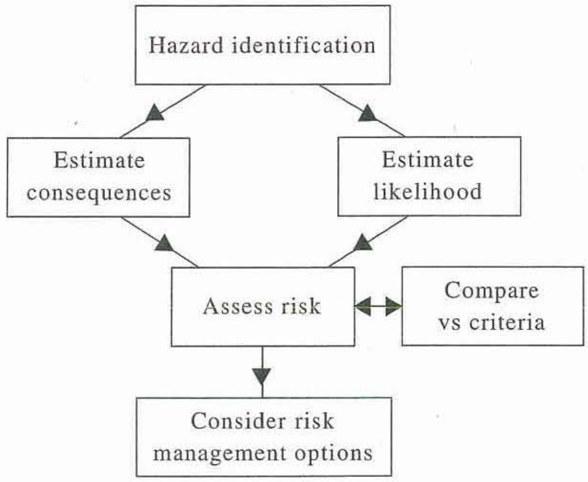
In broad terms, major risk generators were those sites for which the PLL was significant. Medium risk generators were those for which the PLL was low but calculable. The minor sites were those for which PLL was too low to be calculated by the UN method. In some instances, sites were conservatively classified as being potentially medium risk generators on the basis of professional judgement, even though the UN method alone would have suggested a minor classification.

Screening was applied to the fixed sites only. Risks from pipelines and internal road transport were considered separately, rather than being subject to the UN method.

Auditing
Major sites were subjected to a rigorous safety management audit, using a proprietary tool known as *MANAGER* (**MANagement** safety Assessment Guidelines in the Evaluation of **R**isk). *MANAGER* covers ten key areas of safety management:

- safety policy and accountability
- process safety information
- formal safety studies
- management of change
- process and equipment integrity and quality assurance
- human factors
- training and performance
- incident and accident investigation
- auditing process safety
- emergency response and control.

FIGURE 5. RISK ANALYSIS STEPS



MANAGER results were used to generate safety management recommendations and were also taken into account in the detailed quantitative risk assessment.

Risk Assessment
The quantitative risk assessment involved a process of hazard identification, consequence calculation, frequency estimation and risk assessment. The approach is shown diagrammatically in *figure 5*, above. Results are shown as risk contours, societal risk plots and diagrams and tables showing the main risk contributors. The evaluation considered individual sites and operations as well as the Port as a whole.

Development of Technical and Policy Recommendations
Technical and safety management recommendations were developed by considering the results of the audits and the results of the risk analysis. Recommendations were based on best practice, practical technical risk reduction options and the significance of particular risk contributors.

Policy recommendations were developed by DUAP, allowing for possible patterns of development within the Port area and its environs.

Key Study Outcomes

PRELIMINARY SCREENING

A total of 22 sites were screened. As a result, six were classified as potentially major risk sites, five as medium and the remainder as minor. The classification was based on the results of the screening calculations as summarised in *table 3*. Only those sites with negligible off-site risk potential were classified as minor.

TABLE 3. RISK CLASSIFICATION FOR EXISTING PORT BOTANY SITES

Classification	Screening Result (PLL)	Sites
Major	>0.07	Patricks; CTAL; Boral; Powell Duffryn/JORTL; Terminals; ICI Hydrocarbons
Medium	<0.0005	Ampol; Australian Paper; Sydney Buses; Port Botany Container Park; SPC Bulk Liquids Berth
Minor	Negligible	All others

The results demonstrate the substantial difference between the major and medium sites. (There were no sites with PLL between 0.0005 and 0.07.)

Major sites were given a full *MANAGER* audit and the medium sites a modified audit, which covered the same ten areas of safety management as the full audit, but without the numerical scoring. Detailed auditing was not carried out on the minor sites.

SAFETY MANAGEMENT AUDITS

The degree of detail required of a safety management system (SMS) will depend on the nature of the hazards and the size of the facility being studied and the SMS should be tailored accordingly. The expected Management Factor (MF) scores for a well managed facility would be expected to vary as a result of that tailoring. Actual scores also reflect variations in the effectiveness of the management systems being studied.

The MANAGER scores of the major sites ranged from 0.9 to 2.6, compared with a standard of 1.0. The scoring system is described in Appendix 2. While there is clearly room for improvement on individual sites, the results for most sites were considered reasonable in the context of their inherent hazards.

Moreover, it should be noted that a number of sites were still in the process of introducing upgraded Quality Assurance (QA) and Safety Management Systems (SMS) at the time the audit was conducted. The *MANAGER* scores reflected the SMS in place at the time of the audit and did not take into account the proposed improvements. The results are considered, therefore, to be conservative.

The results of the audits, by safety management sub-system, are discussed in the following paragraphs. In addition, more detailed site-specific reports have been submitted to the individual port facilities.

Safety Policy and Accountability

Several sites have been accredited to the quality assurance standard AS 3902 and generally good management systems were found to be in place. The systems were well documented and the management structure was considered appropriate. A number of installations, however, did not have a clearly articulated safety policy, although most companies had senior management support for safety-related activities.

Process Safety Information

All sites had up to date basic safety information such as Material Safety Data Sheets (MSDS), equipment design records, design codes and standards. The bulk liquids terminals and LPG terminals generally scored better in this area. However, few sites had a formal review program to ensure that process safety documentation was comprehensive, accurate and up to date.

Process Hazards Analysis

All sites audited had already carried out at least some form of safety study and, except for the container terminals, had formal procedures for undertaking such studies. While the container terminals had systems for annual internal audits, these focused on Occupational Health and Safety (OH&S) issues, rather than on the hazards from storing and handling dangerous goods.

None of the sites had a system for identifying safety critical equipment in order to focus inspection, testing and maintenance activities.

Management of Change

Some sites had formal documented management of change procedures. Other sites tended to make decisions based on engineering judgment and were judged as being below the benchmark level in this respect.

Process and Equipment Integrity and Quality Assurance (QA)

Maintenance staff on all sites were generally aware of safety critical items, although these items were not usually formally identified. Monitoring of these items generally relied on the experience of the engineer or person responsible for equipment maintenance. Companies that did not utilise a computer maintenance tracking system used engineering judgment or manual systems to identify problem areas requiring particular attention.

The Permit To Work (PTW) system on several sites was rated good and addressed the need for control of third party access to equipment. One site also had verification procedures to ensure contractors adhered to safety procedures. Some sites had a less effective PTW system, in that some activities were exempt from the PTW systems and people working under the system were not always adequately controlled. One site had no PTW system and control of outside contractors at this site was also considered poor.

Human Factors

All sites had written procedures but the extent to which activities were covered by the written procedures varied. The main operations were generally adequately covered but ancillary activities were typically not addressed in detail. One site had checklists to cover all major operations on site to avoid omitted steps. Other sites relied on the operators' vigilance and experience to ensure procedures were properly followed.

Those sites with certification to quality assurance standard AS3902 were judged to have adequate management control and review systems in place. Sites that did not employ QA procedures were less effective.

Bonus and reward schemes for productivity or safe work were not encouraged, except in the container terminals. Although the container terminals did not have specific bonuses or incentives for safe work practices, productivity was encouraged through monetary rewards. This could provide a potential to cut corners in order to achieve better productivity and hence additional financial rewards.

One site had strict overtime load sharing requirements to prevent individuals working excessive hours. All other sites had overtime rates considerably higher than those usually experienced in large scale process companies. Much of the overtime was caused by the nature of those facilities where some activities, such as ship unloading, must take place outside normal work hours.

Control rooms were generally adequate for their purpose. Staffing of most of the sites was considered appropriate. Staffing levels were typically based on site operational requirements as recognised through an enterprise bargaining agreement. Sites generally had good housekeeping. Equipment was regularly painted and entrances and roadways were free from rubbish or obstructions.

Shift handovers at all sites followed general industry practice, in that operators had approximately 30 minutes handover time and log books were kept. Shift patterns for all sites were stable, except for the bulk liquids terminals.

Training and Performance
Training standards varied considerably between sites. One site had a good formal selection and training program. A training matrix was used for all training requirements. Another site with a good program did not use a training matrix but carried out training on an as-needed basis. One site had neither a formal training program nor used training needs analysis. Training was mainly based on regulatory or operational requirements.

Incident and Accident Investigation
All sites had accident and incident reporting systems, but these varied in their amount of detail and there was little consistency between sites. The systems on one site were considered to be ineffective. Investigation results were used to generate site statistics at several of the sites. The reporting forms used at two sites were not conducive to producing accident data. One site undertook root cause analysis in investigations, but this was not well addressed at other sites. Reasonable follow up systems were in place at some sites. At other sites, this aspect still required attention.

Auditing Process Safety
All sites had a range of annual internal audits. Audits ranged from simple housekeeping checks to full scale QA and hazard audits. For the sites with QA accreditation, regular quality audits were also undertaken. The most comprehensive audits were undertaken by some of the bulk liquids terminals. At all sites, necessary resources were allocated for the audits and follow up of the recommendations was undertaken and reviewed by senior management.

Emergency Response and Control
All sites had a site emergency plan integrated with the SPC emergency plan. Generally the manuals were of adequate detail and broadly followed the DUAP Industry Emergency Planning Guidelines.

Regular drills in emergency procedures were held for all sites, but these did not include practical exercises based on the specific hazard scenarios inherent to the sites. Emergency communication resources were found to be adequate but lists of emergency contact telephone numbers were not well maintained.

REVIEW OF PORT INFRASTRUCTURE
A review was also made of the adequacy of the port safety and emergency infrastructure. Key findings are summarised as follows.

Fire Protection

In additional to mains water supplies, each of the major sites has independent fire fighting facilities, including on-site fire water storage. Total water storage is 10 000 000 m^3. There is a total of 74 000 litres of foam spread over three sites but available to all facilities through mutual aid arrangements. The sites have automatic alarm connections to the NSW Fire Brigades. Typical response times to an alarm are 5–7 minutes from either Matraville or Botany Fire Stations. The bulk liquids facilities are encircled by a 450 mm diameter fire main supplied by Sydney Water.

In addition to land based facilities, the Bulk Liquids Berth has the capability to provide sea water from Botany Bay through the product lines to the bulk liquids storage areas. There is also a Class A fire fighting tug on stand by in the port. This has the capability to fight ship and waterside fires or draught sea water at 20 000 litres per minute, delivering water by hose to NSW Fire Brigades pumping units.

Local fire stations have basic HAZMAT response equipment, with backup and more extended HAZMAT support from Marrickville and Chullora.

It is judged that the combination of internal and external fire fighting resources is adequate and this has been confirmed by the NSW Fire Brigades.

Emergency Planning

The basis of port emergency planning is a regularly updated common Port Botany Emergency Plan, initially established in 1984.

TABLE 4. HAZARDS BY INSTALLATION

	Fires					Toxics					
	Involving bulk storage of class3/C1/C2 (flammable liquids/combustible liquids)	Involving bulk storage of class 2.1 (flammable gases)	Involving drums and containers with class 3 and 2.1	Involving pipelines carrying flammable liquids or gases	Involving the transport (road, rail, ship) of flammable liquids or gases	Toxic gas release	Toxic liquid release	Explosions (includes confined and semi-confined vapour explosions)	Toxic Combustion Products excluding hydrocarbon combustion products	Environmental pollution: includes noise and odour	Acid spills
PD Van Ommeren Site A	X		X	X	X		X	X	X	X	X
JORTL		X		X	X			X		X	
Terminals	X		X	X	X		X	X	X	X	X
Boral		X		X	X			X		X	
Container Terminals Aust. Ltd			X		X	X	X	X	X	X	X
Patricks			X		X	X	X	X	X	X	X
ICI Hydrocarbons		X		X	X			X		X	
APM	X	X		X	X	X		X		X	X
SPC BLB/Brotherson Dock	X		X	X	X	X	X	X	X	X	X
Ampol	X			X	X					X	
Sydney Buses	X		X							X	
Port Botany Container Park	X		X				X		X	X	
Sydney Haulage		X	X	X			X	X	X	X	
Smith Bros		X	X				X	X	X	X	
Tug/Marine Plant Industries										X	
Alcatel	X									X	
Pioneer Plasterboard			X							X	
Approved developments											
Elgas		X		X	X			X		X	
PD Van Ommeren Site B	X			X	X					X	

All port facilities are active members of a mutual aid group covered by the plan.

In 1994 the emergency plan was comprehensively reviewed and is now a special sub-plan to the Eastern Suburbs District Emergency Plan.

A Port Botany Emergency Plan Committee meets quarterly. It is chaired by SPC and has representatives from each site and from emergency services organisations. The committee reviews and updates individual site arrangements and communication links and conducts at least one table-top and one 'hands-on' simulated emergency exercise each year involving emergency services personnel and port users. The latter exercises are carried out at a pre-arranged time and do not fully test the system's effectiveness in dealing with completely unexpected events.

Security
All sites have perimeter security systems and security patrols are carried out on a regular basis. A number of the bulk liquids storage facilities and the Bulk Liquids Berth have closed circuit television monitoring of access points and on-site activities.

Because of the size of the Port area and the limited control of access by public roads and by sea, particularly outside of normal working hours, it may be possible to gain unauthorised access to some facilities and there is anecdotal evidence of considerable freedom of movement throughout the Port area.

While the incidence of sabotage is not expected to be high, there is a clear need to review security arrangements, particularly the control of vehicles and people moving into and out of the port through effective fencing, gates, security checks and remote and random monitoring.

RISK ASSESSMENT
Hazard Identification
A summary of the identified hazards, by installation, is shown in *table 4*.

The most significant of these, in terms of their potential effects outside the Port area, are:

- fires arising from LPG pipeline leaks
- fires arising from LPG tanker movements
- toxic gas releases from containers and drums; and
- fires from ruptures of major LPG or flammable liquids storages.

Consequences
Before consequences were modelled, the identified hazards were subjected to a screening procedure in which the various scenarios were examined to eliminate those which could not lead to credible off-site impacts. The purpose of screening was to avoid resource intensive modelling of those events that could clearly be shown to cause no significant off-site effects. Hazards that were modelled in terms of accident propagation and off-site consequences to people included:

- fatality to any offsite population (from exposure to toxic substances, heat radiation or explosion overpressure); and
- propagation within the site.

Over 5000 possible events were ultimately modelled on the basis of the identified hazards. The average number of off-site and residential fatalities per event were calculated in each case. Those with the highest potential consequences at a residential boundary are summarised in *table 5*.

TABLE 5. EVENTS WITH POTENTIAL SIGNIFICANT RESIDENTIAL CONSEQUENCES

Contributor	Severity Index (per event)
Chlorine release from drum failure	100
Propane tank BLEVE (Boiling Liquid Expanding Vapour Explosion)	25
Hydrogen sulphide cylinder rupture	20
Pool fire or flash fire from road tanker (Class 3 and combustibles)	10
Fires from other fixed installations	<5

TABLE 6. SUMMARY OF MODELLED EVENTS

Facility type	Tanks, fittings and containers			Pipeline, pipes and hoses				Pumps			Road transport with loading and unloading				Shipping includes loading and unloading				Drum filling			Rail loading and unloading			
	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Toxic releases	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Toxic releases	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Toxic releases	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Pool fires	Large pool fires	Dispersion leading to possible flash fires, VCE	Toxic releases
Bulk liquids	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X		X	X	X				
Container terminals	X	X	X	X							X	X	X	X	X	X	X	X				X	X	X	X
Pressurised liquefied gases			X				X			X			X				X								
Refrigerated liquefied gases	X	X	X				X			X					X	X	X								

The table uses a relative ranking in the form of a 'severity index' to compare the consequences of individual events. The severity index was calculated by first assigning an index of 100 to the event causing the greatest number of residential fatalities. The relative severity of each of the other events was then calculated against that benchmark.

In considering the events listed in *table 5*, it is important to differentiate between consequences and risk. For example, the chlorine event represents the hot rupture of a full container of chlorine drums, initiated by aircraft impact. While the consequences of a major chlorine drum leak are relatively high, due to possible spread of the gas cloud into the residential area, the risk is relatively low. This is because of the low frequency of handling chlorine through the port combined with a low likelihood of the drums being involved in a fire. Chlorine leaks contribute less than 1% of the total risk to the residential areas from all port related activities. Similarly, while hydrogen sulphide gas is toxic, it is seldom handled through the port and is thus a minor risk contributor.

The propane tank BLEVE represents the effect of a catastrophic failure of an above ground storage tank, accompanied by fire. BLEVE of a major tank could have heat radiation effects beyond the port boundary but the likelihood is again, very low.

Road tanker pool and flash fires have a relatively limited area of effect but because these materials are transported on the port perimeter they can have consequences beyond the boundary. Low ignition probabilities for Class 3 and combustible liquids make this event a minor risk contributor.

Table 5 demonstrates the importance of strictly controlling high consequence events. In particular, it shows that growth in the storage or handling of toxic liquefied or pressurised gases through the port could have significant adverse cumulative risk implications and therefore, should be avoided.

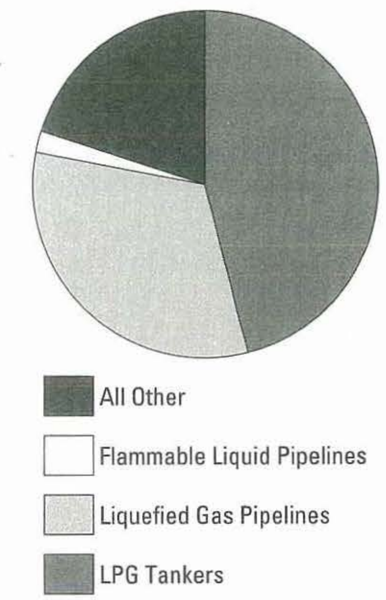
A number of other events, while not impacting on the residential areas, may affect adjacent sites and activities within the port area. They are not discussed in this summary report, which concentrates on the risk from the port as a whole on the surrounding land uses. However, effects on adjacent sites have been taken into account in preparing the findings and recommendations. The details are in the individual site reports.

Consequence distances for a range of possibly fatal events are summarised in Appendix 3. It

TABLE 7. SELECTED BASIC FAILURE DATA

Equipment	Failure Frequency
Chlorine Drum Rupture	6.5×10^{-6} p.a. per drum
Flanges — 5 mm leak	3.6×10^{-4} p.a. per flange
LPG pressurised bullets — 5 mm leak	3.7×10^{-5} p.a. per bullet
Isotainer — 25 mm leak	9.6×10^{-5} p.a. per container
LPG Road tanker — 50 mm leak	2.0×10^{-2} per road accident
Chemical road tanker — 50 mm leak	7.2×10^{-9} per km
Berthed ship striking by passing vessel	4.0×10^{-6} per passing
Ship impact against wharf	2.2×10^{-3} per visit
150 mm pipeline — 25 mm leak	1.2×10^{-6} per m. year
300 mm pipeline — 25 mm link	8.5×10^{-7} per m. year
300 mm pipeline — full bore rupture	5.8×10^{-8} per m. year

FIGURE 6. SOCIETAL RISK CONTRIBUTORS



should be noted that, with few exceptions, the effects do not extend outside the port or industrial areas.

The types of events modelled for the various operations at Port Botany are shown in *table 6* (opposite).

Likelihood
The likelihood of each event was estimated by using a combination of basic failure frequency data and fault or event trees. A consistent set of basic data was provided in support of the study by DNV Technica, covering the failure categories shown in Appendix 2.

The data were thoroughly checked by DUAP against other available reputable sources. Particular care was taken to ensure that the figures used were relevant to the types of facility being studied. In the case of chlorine drum failures, the DNV supplied data were modified slightly on the basis of DUAP experience. Other failure data were considered to be appropriate.

Selected basic failure frequencies used in the study are shown in *table 7*.

Appendix 4 gives typical examples of fault and event trees. These were used to generate frequencies for the main incident scenarios from the basic failure data.

RISK
In order to identify the main contributors to risk to people living outside the study area, the risk results were ranked according to the potential loss of life associated with the various events. The relative contribution to the overall potential loss of life (PLL) by the main risk contributors is shown in *figure 6*.

It should be noted that some high consequence events, such as LPG bulk tank ruptures, do not contribute significantly to residential risk because of the low probability of such events.

The results have also been calculated in terms of individual and societal risk, as discussed below.

Individual Risk
Individual risk is a measure of the likelihood of a given outcome at a particular location (in this case the death of any person who may be at that location). The estimates of the cumulative

FIGURE 7. STUDY AREA SHOWING CUMULATIVE INDIVIDUAL RISK CONTOURS — EXISTING AND APPROVED NEW DEVELOPMENT

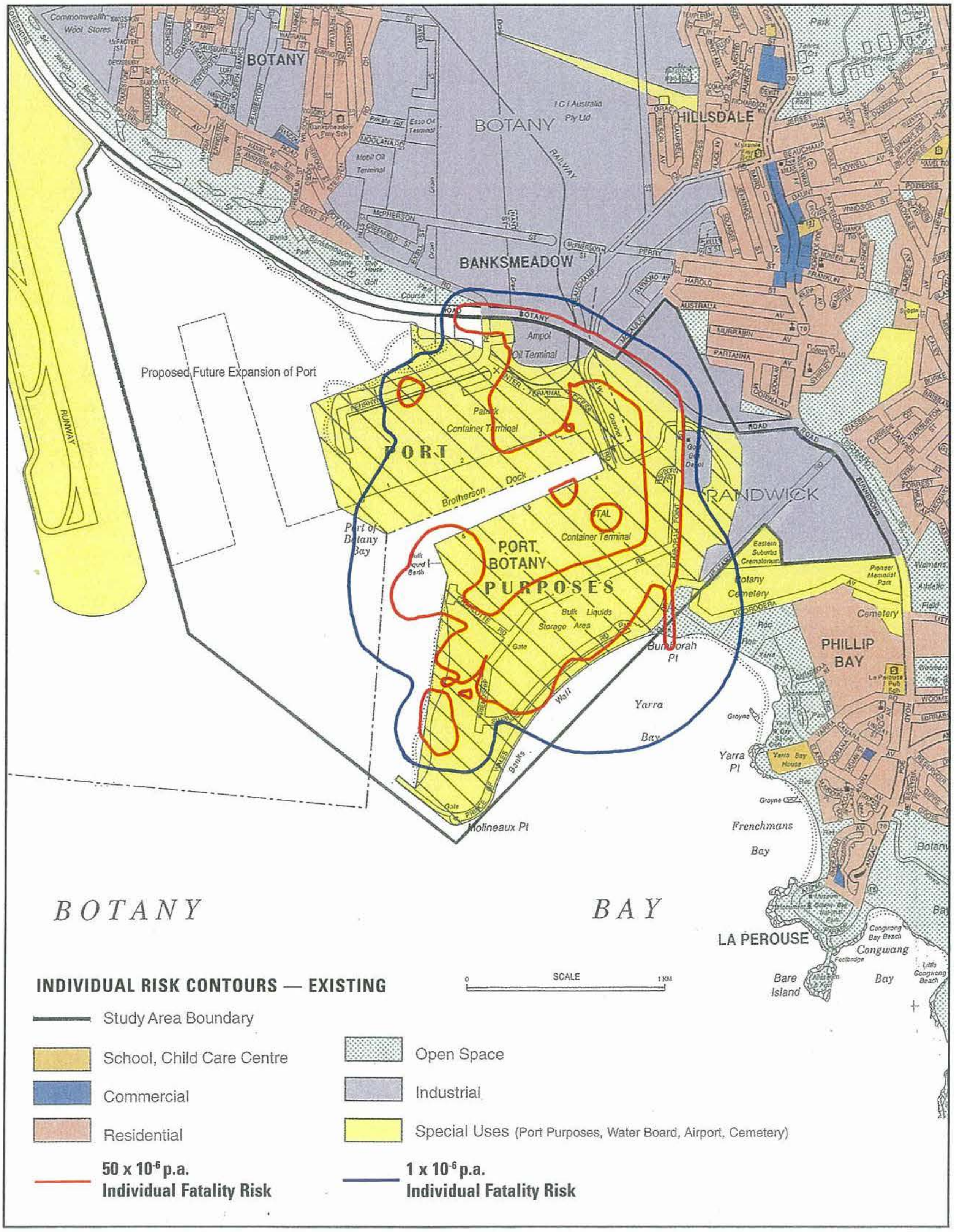
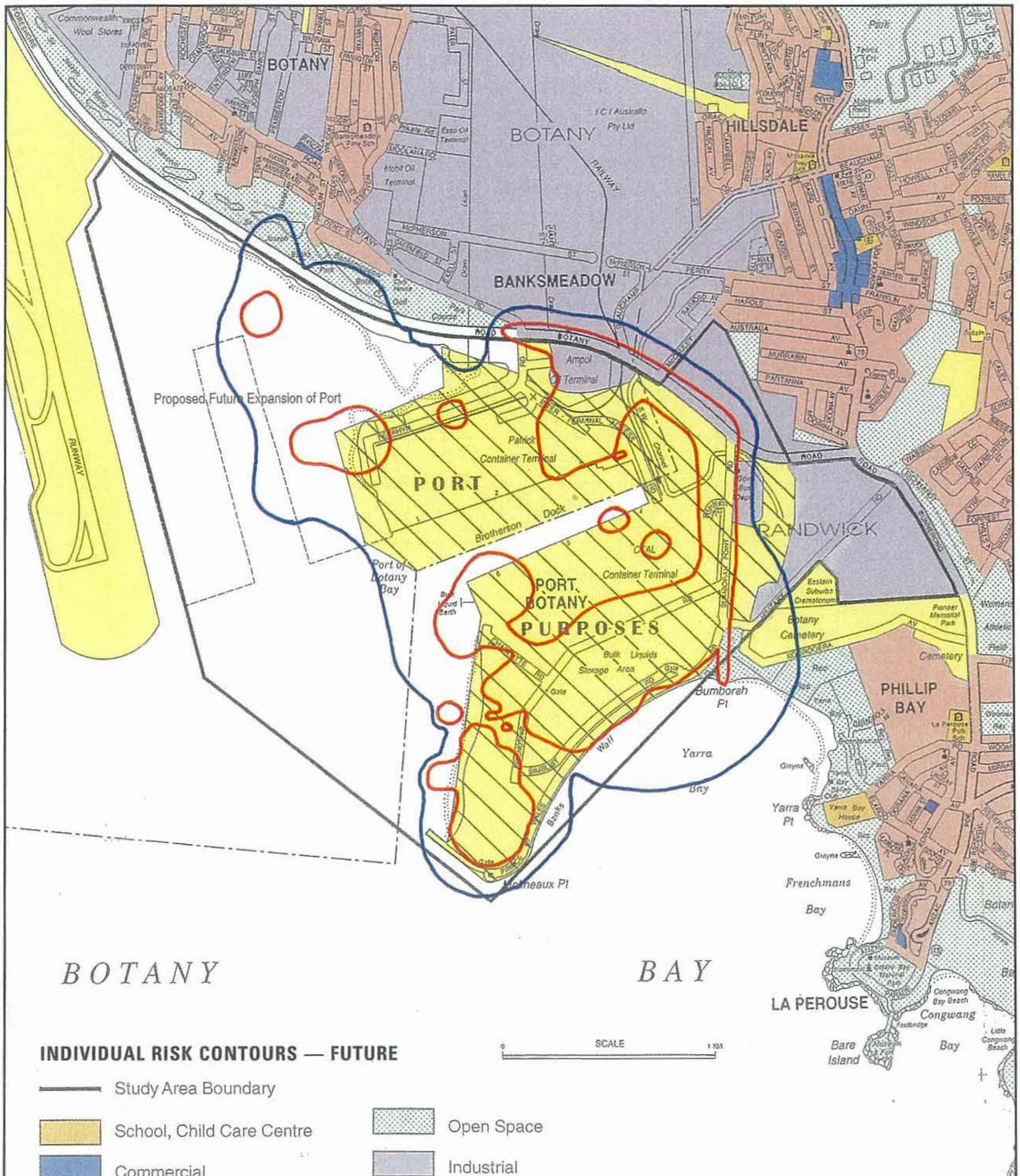


FIGURE 8. CUMULATIVE INDIVIDUAL RISK CONTOURS INCLUDING POSTULATED FUTURE DEVELOPMENT



individual risk from the facilities within the study area are shown in *figure 7* (existing and approved new development) and *figure 8* (including postulated future development). The estimates are shown as risk contours superimposed on a land use map of the study area and its surrounds.

In presenting the risk contours, only those emanating from the SPC controlled areas, Ampol and Sydney Haulage are shown. This allows clear differentiation between risks arising from port related facilities and those from nearby industrial facilities and the airport.

Societal Risk

While individual risk measures the likelihood of a particular location experiencing a specified level of harm, societal risk takes into account the number of people that could be affected by the various events. It is typically presented as an F-N curve, which is a plot of cumulative frequency versus consequences, measured as fatalities.

The estimated societal risk from port activities to residential populations outside the study area is shown in *figure 9* (page 20). Two F-N curves have been calculated, one for existing and approved operations and one that includes postulated future developments.

Evaluation

CRITERIA

General

In assessing the tolerability of risk from port activities, both qualitative and quantitative techniques have been considered. These are discussed in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 *Risk Criteria for Land Use Safety Planning*. Relevant general principles are:

- the avoidance of all *avoidable* risks
- the risk from a major hazard should be reduced wherever practicable, even where the likelihood of exposure is low
- the effects of significant events should, wherever possible be contained within the site boundary; and
- where the risk from an existing installation is already high, further development should not pose any incremental risk.

HIPAP 4 sets out a number of types of quantitative criteria (fatality, injury property and environmental damage). However, to keep the number of risk calculations manageable, this study focuses on individual and societal fatality risk. The most relevant criteria are discussed below.

Individual Risk

It is generally accepted that off-site risk from a facility should be low in relation to the background risk. This has led to the criteria in *table 8* (overleaf) being adopted in New South Wales for individual fatality risk.

These criteria have been developed for new industry and surrounding land use proposals. While, ideally, they should apply to existing situations, it is recognised that this may not be possible in practice. New South Wales has adopted the following principles for existing industry:

- the one in a million per year individual fatality risk level is an appropriate criterion

TABLE 8. NSW INDIVIDUAL FATALITY CRITERIA

Adjacent Land Use	Risk in one million per year
Sensitive — hospitals, aged care, schools, etc.	0.5
Residential	1
Commercial	5
Sporting complexes and active open space	10
Industrial	50

within which no intensification of residential development should take place; and

- safety reviews and risk reduction should be undertaken at facilities where resultant residential risk levels are in excess of the 10 in a million per year individual fatality risk level.

Societal Risk

The setting of societal risk criteria is a complex task on which there is not yet common agreement and New South Wales has not set specific criteria for societal risk. However, an ALARP (As Low As Reasonably Possible) approach is gaining increasing recognition. Such an approach identifies three societal risk bands: negligible, ALARP and intolerable. This is illustrated in *figure 9*, which is a composite of some typical criteria adopted elsewhere.

However, it should be emphasised that the criteria in *figure 9* are illustrative only for the purposes of this study and do not represent a proposed position for NSW. In the figure, the solid line represents societal risk from existing and approved new development, while the dotted line shows the effect of including postulated new facilities.

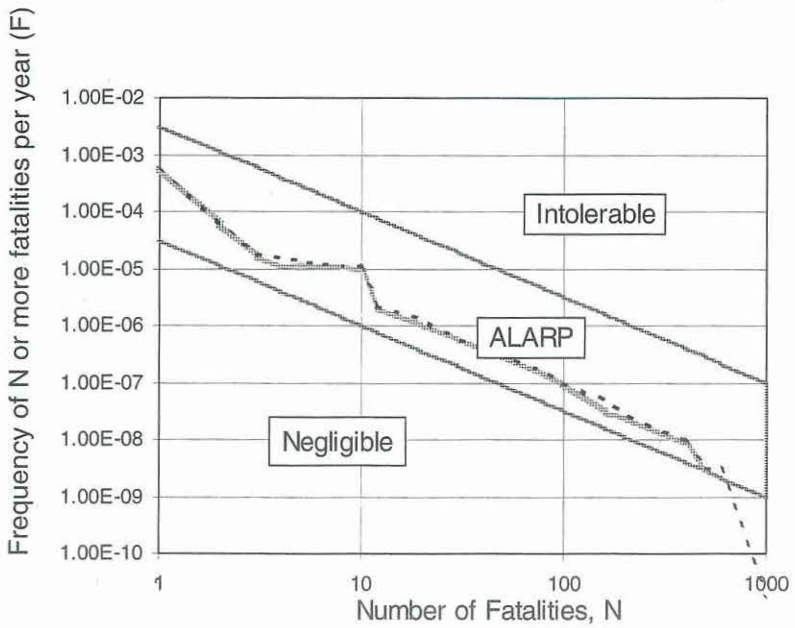
Below the negligible line, provided other individual criteria are met, societal risk is not considered significant. Above the intolerable level, an activity is considered undesirable, even if individual risk criteria are met. Within the ALARP region, the emphasis is on reducing risks as far as possible towards the negligible line. Provided other quantitative and qualitative criteria of HIPAP 4 are met, the risks from the activity would be considered tolerable in the ALARP region.

RISK ASSESSMENT

Individual Risk

The 50 in a million risk contours for existing sites and approved developments, subject to controls, are all contained within the industrial

FIGURE 9. PORT BOTANY SOCIETAL RISK VS INDICATIVE CRITERIA



zone and for the most part are within the SPC controlled port area. Small sections of the 50 in a million contour cross Botany and Bumborah Point Roads. This is primarily due to pipeline and truck movements, particularly of LPG, along these routes.

The 50 in a million risk contours for some individual sites partially encroach onto neighbouring industrial sites within the port area.

There are no residential areas within the one in a million or ten in a million contours.

These findings also apply after the inclusion of appropriately located and managed postulated new development to represent a fully developed port.

Societal Risk

The societal risk from the study area in relation to the surrounding residential population is relatively low, reflecting the good separation distances from the port to the residential areas.

For the most part, societal risk is towards the low end of the ALARP range of the indicative criteria. The increased frequency of small scale accidents is related in the main to pipeline and road movements of LPG, as noted above.

The inclusion of postulated future development has very little effect on societal risk, since possible sites for bulk liquids expansion are well away from residential areas. Further expansion of LPG facilities is unlikely once the Elgas underground storages are commissioned.

Findings

The key findings of the study relate to the interaction between the Port and surrounding land uses. They are summarised below in four categories:

- risk from Port Botany activities
- safety management
- land use safety planning and future development; and
- community awareness and consultation.

RISK FROM PORT BOTANY ACTIVITIES

1. The individual risk of fatality from the operations of the SPC controlled land of Port Botany meets the published NSW risk criteria. The 50 in a million risk contours for existing sites and approved developments are all contained within the industrial zone. There are no residential areas within the one in a million or ten in a million contours. Societal risk results are tolerable but additional risk reduction measures are desirable, particularly in dealing with risks posed to adjacent facilities.

2. Incidents associated with the movement of dangerous goods by road or pipeline represent the highest overall risk contribution beyond the port area boundary. Events initiated by aircraft impacts on some of the fixed installations are also significant.

3. Because of the relatively small quantities of toxic materials handled, risks due to fires involving these products are low. Some toxic products are also formed during combustion of other dangerous goods. However, these are not a significant source of off-site fatality risk as they rise in the thermal plume and disperse to non-fatal concentrations before reaching any residential areas.

4. Nitrogen blanketing in tanks is an effective means for reducing the potential frequency of

tank top fires and the escalation of tank top fires. Automatic foam suppression systems also aid in incident mitigation.

5. The risks from hose transfer at the bulk liquids berth have been effectively minimised by the procedure of nitrogen pressure testing the hoses at the berth before each transfer.

6. Risks due to ship manoeuvring in the vicinity of the port do not contribute significantly to cumulative risk.

7. Leaks of chlorine or hydrogen sulphide, associated with container terminal operations, have the potential for significant off-site consequences. However, the frequency is sufficiently low that risk criteria are satisfied.

8. Since aircraft impact is a significant factor in the predicted overall major incident frequency, risks are sensitive to any significant change in the number or pattern of aircraft movements. In particular, any change in the flight pattern that would increase the frequency of flight over the bulk liquids and container storage areas is likely to increase the overall risk levels.

SAFETY MANAGEMENT

1. The overall standard of safety management and safety awareness varies from site to site and there is significant room for improvement on some sites.

2. Areas where there is a general need for improvement include:

   - development of formal safety management systems
   - consistent incident and accident reporting
   - identification of safety critical items
   - management of change
   - permit to work systems; and
   - training and competency monitoring.

3. Port emergency arrangements, including fire fighting, are adequate and all sites have an up to date emergency plan integrated with the SPC Emergency Plan. The testing of the emergency procedures is not fully effective.

4. There are weaknesses in overall port security, particularly outside of normal working areas, because of the limited controls over the movement of people and vehicles in some areas of the Port.

LAND USE SAFETY PLANNING AND FUTURE DEVELOPMENT

1. Expansion of the Port activities by the addition of the postulated new installations considered in the study, does not significantly affect the public risk from the fixed installations, since areas available for expansion are generally well separated from residential activity. The 50 in a million risk contours for existing sites and approved developments are all contained within the industrial zone.

2. The study shows a slight increase in societal risk after the inclusion of postulated new facilities, which is mainly associated with an increase in road movements of dangerous goods.

3. Specific proposals for new or expanded facilities still need to be thoroughly assessed on their merits and should be able to demonstrate that they will meet relevant environmental and risk criteria and will not significantly add to the cumulative public risk.

4. There may be potential to streamline the risk assessment by applicants of new port related developments which are similar to, and consistent with, those already studied. Development of assessment procedures should involve consultation with key stakeholders, including local councils and the community.

5. The assessment of any proposals for significant further increase in the storage and handling of flammable materials at the port should include a review of the ongoing adequacy of fire protection systems and water supply.

6. New or expanded facilities for the handling of toxic materials, particularly compressed or liquefied gases, are inappropriate since these could significantly increase off-site risk.

7. Although Port Botany activities pose a relatively low risk to the residential area, the adjacent land uses are also potentially subjected to risk from other industrial facilities, airport operation and dangerous

goods traffic. Since these have not been assessed in this study, the study results should not be used to endorse residential intensification.

8. The results of the study reinforce earlier conclusions that development in the vicinity of the port should reflect land uses which provide a buffer between the port and its surrounding residential and commercial areas.

COMMUNITY AWARENESS AND CONSULTATION

1. There is a high degree of community concern over the level of public risk associated with port operations.
2. Feedback from the Reference Group indicates that such concern arises, at least in part, from limited awareness of the nature of port activities, the level of risk, safety performance and the effectiveness of safety management measures.
3. There is a need to strengthen ongoing community participation, liaison and communication, associated with the implementation of community-right-to-know principles.

Appendices

APPENDIX 1. FACILITIES STUDIED

It should be noted that the postulated future installations do not represent a proposed expansion plan. They have been included to allow the effects of various options to be assessed.

TYPE	EXISTING	APPROVED	POSTULATED FUTURE
Bulk Liquids Storage	• Ampol (formerly Caltex) Banksmeadow • Terminals Australia • PD Van Ommeren Site A	• PD Van Ommeren Site B	4
Liquefied Hydrocarbon Gases	• Boral Gas • JORTL • ICI Hydrocarbons	• Elgas	
Container Terminals	• CTAL • Patricks • Port Botany Container Park • Sydney Haulage Containers • Smith Bros		1
Manufacturing Sites	• APM • Pioneer Plasterboard • Alcatel TCC		
Bulk Liquids Berth Facilities	• Sydney Ports Corporation — Bulk Liquids Berth		2
Miscellanous Facilities	• Stannard Bros • State Transit Authority • Wallace Tugs • Waratah Towage • J Fenwicks	• Collex	
TOTAL	20	3	7

APPENDIX 2. STUDY TECHNIQUES

As indicated in the body of the report, the project was conducted in three stages:

1. gathering of site information, preliminary site screening and auditing of the safety management systems
2. site by site and cumulative quantified risk assessment (QRA) of existing and possible future facilities; and
3. consideration of findings and technical and policy recommendations.

First Stage Study Techniques

There were five main elements in the first stage of the project.

Review of Previous Risk Studies

A number of hazard audits and risk assessment studies have previously been carried out on individual sites. These were reviewed to obtain initial information on the hazards specific to the sites, the range of accidents that could arise out of these hazards and the safety management measures already in place.

Site Familiarisation

Following review of the previous risk studies, familiarisation visits were made to each of the facilities to obtain additional relevant background information and to explain to the site operators the purpose of the study.

Questionnaires

A detailed site questionnaire was developed covering technical information required for the detailed QRA. Results were used to confirm and amplify data collected in the initial site visits. The questionnaire covered:

- site background information
- materials handled and quantities
- details of site operation
- transportation
- fire protection
- emergency planning
- incident history
- previous safety studies; and
- equipment data sheets for all major items.

Screening

Once the initial familiarisation was completed, the information was used in a risk classification and prioritisation process developed by the United Nations (*Manual for the Classification and Prioritisation of Risks from Major Industrial Facilities*).

The UN method produces a broad estimate of the risks due to major accidents from the manufacture, storage, handling and transport of hazardous materials. The hazardous materials activities are firstly *classified* by such factors as type, location and quantity. This information is then used to generate an approximate estimate of societal risk which forms a basis for *prioritising* the further analysis.

The procedural steps are outlined in *figure 10.*

FIGURE 10. RISK SCREENING STEPS

Classification of activities and inventories

↓

Estimation of consequences

↓

Estimation of probabilities

↓

Estimation of societal risk

↓

Risk prioritisation

Sites were then ranked as potentially minor, medium or major risk generators, based on their estimated risk potential, expressed as annual potential loss of life (PLL). This allowed the study team to focus detailed analysis on the most significant sites.

In broad terms, major risk generators were those sites for which the PLL was significant. Medium risk generators were those for which the PLL was low (less than one hundredth of any major risk site), but measurable. The minor sites were those for which PLL was negligible because quantities of hazardous materials were below the minimum for which the UN method gives meaningful results. In some instances, sites were conservatively classified as being potentially medium risk generators on the basis of professional judgement, even though the UN method alone would have suggested a minor classification.

Screening was applied to the fixed sites only. Risks from pipelines and internal road transport were considered separately.

Auditing
Those sites ranked as potentially major risk generators were subjected to a rigorous safety management audit, using a proprietary technique known as *MANAGER* (**MAN**agement safety **A**ssessment **G**uidelines in the **E**valuation of **R**isk). The potentially medium risk sites were given a simplified audit. Potentially minor risk generators were not audited.

The *MANAGER* technique covered ten key elements of safety management:

- safety policy and accountability
- process safety information
- formal safety studies
- management of change
- process and equipment integrity and quality assurance
- human factors
- training and performance
- incident and accident investigation
- auditing process safety
- emergency response and control.

MANAGER uses a scoring system, standardised against a typical well-run world-scale petrochemical complex. The scoring places the greatest weight on worse than standard results. Scores can range from 0.1 (best) to 100 (worst), with 1.0 representing performance equivalent to the benchmark. The simplified audit covers the same 10 categories but does not incorporate formal scoring.

Approach to the QRA
The quantitative risk assessment involved a process of hazard identification, consequence calculation, frequency estimation and risk assessment. The approach is explained in Hazardous Industry Planning Advisory Paper (HIPAP) No. 6: *Guidelines for Hazard Analysis* and is shown diagrammatically in *figure 5* in the body of the report.

In summary, the steps were:

Hazard Identification
For each activity, the possible initiation, development and consequences of incidents, as well as mitigating factors, were systematically considered. Hazard identification techniques included drawing on past experience, hazard and operability studies, fault tree analysis and event tree analysis. For this study, hazard identification was carried out using hazard identification sheets. These were completed for all sites, each significant type of hazard and all classes of materials.

Consequence Calculation
Consequence calculations were carried out on each of the incidents considered during hazard identification. This involved estimating the effects of explosions, fires and toxic releases. Analysis of the results provided a further refinement of the hazard identification process and assisted in directing detailed analysis toward those events with significant risk potential.

Frequency Estimation
Risk requires consideration of how often an event will occur as well as the size of the consequences. Frequency estimation involved consideration of historical accident and failure rate data from various sources and the use of logic models such as fault and event trees.

Basic data was provided in support of the study by DNV Technica. The failure data covered:

- compressors
- heat exchangers (various)
- condensers
- pumps (various)
- chlorine evaporators and drums
- flanges
- tanks (various)
- LPG storage vessels (mounded and non-mounded) and process vessels
- isotainers
- road tankers (LPG and general)
- piping (process and underground)
- flexible hoses and loading arms
- PVC piping
- valves; and
- pigtails.

Historical failure rate data were checked to ensure that their sources were consistent with the operations being studied. In accordance with the audit methodology, some adjustment of failure rates was made to take account of the *MANAGER* results. The adjusted failure data were then used, together with the consequence calculations, to estimate the risks.

Risk Analysis
Risk may be defined as the likelihood of any defined adverse outcome, such as death or injury to people or damage to property or the environment.

Individual risk measures the likelihood of a particular location experiencing a specified level of harm. It is typically presented as a series of contour lines that connect points of the same level of risk.

The individual risk may be compared with acceptability criteria such as those set out in HIPAP 4 *Risk Criteria for Land Use Safety Planning.*

Societal risk takes into account the number of people that could be affected by the various events. It is typically presented as an F-N curve, which is a plot of cumulative frequency versus consequences, measured as fatalities.

Risk calculations were carried out using a set of computer programs known as *SAFETI.* The programs calculate consequences of all identified failures and combine these with their likelihood to produce detailed estimates of the overall risk.

Calculations were carried out on a site by site basis, as well as for the study area as a whole. Calculations covered two cases: existing installations plus approved developments; and existing, approved and postulated future development. In assessing the future case it was assumed that vacant land under SPC control would be occupied by a mix of installations similar to the current pattern.

From the QRA, the key risk contributors were identified and cumulative risk contours and societal risk results plotted.

EVALUATION
The results of the safety management audits and the QRA were then compared with criteria and used as a basis for developing the findings and recommendations summarised in the body of the report.

APPENDIX 3. TYPICAL CONSEQUENCE DISTANCES FOR FATALITY

The types of outcome from a major incident depend on the material involved. *Table 9* summarises the most significant types of events modelled during the course of the study.

TABLE 9. TYPES OF EVENT MODELLED

Material	Outcome
Toxic gas	Gas cloud dispersion
Flammable liquefied gases	VCE Flash fire Fireball Jet fire
Flammable liquids	Pool fire Vapour explosion
Bulk solids	Explosion Fire
Explosives	Explosion

Typical examples of the modeling results are given in the following paragraphs.

Liquefied Toxic Gases

There is no bulk toxic gas storage at Port Botany. The only toxic gases held within the Port boundary are the result of container movements through the container terminals. Chlorine is contained in special purpose drums and cylinders. For a significant leak to occur, the most likely initiating event would be a dropped container during handling. Damage to a connection was modelled as a 6 mm liquid leak. For a meteorological condition of F1.5 — considered the most conservative for toxic dispersion — the estimated fatal consequence distance was about 200 m. This compares with the closest handling point to the port boundary of 500m.

Liquefied Flammable Gases

Propane and butane, commonly referred to as LPG, together with ethylene, represent the major storage of liquefied flammable gases at the Port. Of the various events, modelled, a BLEVE (Boiling Liquid Expanding Vapour Explosion) represents the potentially most destructive.

In the case of an 18 tonne LPG road tanker at one of the loading points, it was assumed that half the contents would be lost prior to the BLEVE occurring — through pressure relief valves and leaks. Therefore only 9000 kg would be available for the BLEVE. With this flammable mass the radius of the fireball was calculated as 60 m with a duration of some 9 seconds.

It is conservatively assumed that at a heat radiation of 12.6kW/m^2 there is a significant chance of fatality for extended exposure. The 12.6kW/m^2 contour extended 200 m from the BLEVE, well within the port boundary.

Liquid Fires

The likelihood of fatality as a result of a fire is dependent on both the intensity of the heat radiation and the duration of the exposure. It is typically assumed that fatality will occur at a heat intensity of 12.6 kW/m^2. *Table 10* shows the calculated consequence distances for a relatively large spill (100 m^2) of various flammable liquids.

Flash fires can be expected for class 3PGI and some 3PGII material. The table shows screening results for some representative 3PGI and 3PGII materials held at Port Botany. The table shows both area fires and flash fires. Flash fire distances are shown for two typical meteorological conditions (D5 and F1.5).

TABLE 10. AREA AND FLASH FIRE HAZARD RANGE CLASS 3 LIQUIDS

Fatality Distances (from edge of pool to 12.6 kW/m^2), 100 m^2 spill, pool evaporation and fire			
Material Spilled	*D5 Flash fire (m)*	*F1.5 Flash fire (m)*	*Area fire (m)*
Benzene	40	130	30
Propylene oxide	90	340	30
Methyl ethyl ketone	70	60	30
Ethyl acetate	60	40	20
Vinyl acetate	60	40	20
Hexene	100	200	40

For early ignition, area fires were modelled. For late ignition, fires were conservatively modelled as flash fires.

In the case of Classes 3PGIII, C1 and C2 only pool fires were modelled.

Bulk Solids and Explosives
The majority of bulk solids pose limited risks under fire conditions, since they do not give rise to flammable pools or vapour clouds. The exception is those solids which are explosive as well as being combustible.

For the materials with explosive potential handled through the port, explosions were assumed to occur only in the event of a major fire. These explosions were treated as TNT equivalent mass and modelled in *SAFETI* as a BLEVE. Butane was chosen as the equivalent material and the computer program *PHAST* was used to calculate the necessary parameters (i.e. the equivalent mass to be used in *SAFETI* modelling).

The most significant possibly explosive material handled through the port is ammonium nitrate.

Table 11 indicates the distances to peak overpressure levels of 0.21 and 0.42 bar for the TNT equivalent masses used for the study. A peak overpressure of 0.21 bar typically equates to 10% fatalities while a peak overpressure of 0.42 bar would result in 50% fatalities. The two equivalent masses in the table represent minimum and maximum quantities of ammonium nitrate handled through the port in any one day. The distances shown in the table are all contained within the Port perimeter.

TABLE 11. EFFECTS OF EXPLOSIONS

Mass equivalent TNT (te)	0.21 bar peak overpressure distance (m)	0.42 bar peak overpressure distance (m)
1.6	88	58
27.3	225	150

APPENDIX 4. TYPICAL FAULT AND EVENT TREES

Figure 11 **and** ***figure 12*****, respectively give a typical event tree for a pipeline liquid leak and a fault tree for an ammonium nitrate container rupture. The resulting frequencies, in combination with the consequence calculations, were used in generating risk estimates. For ease of presentation, the numerical results are not shown.**

FIGURE 11. TYPICAL EVENT TREE FOR LIQUID LEAK

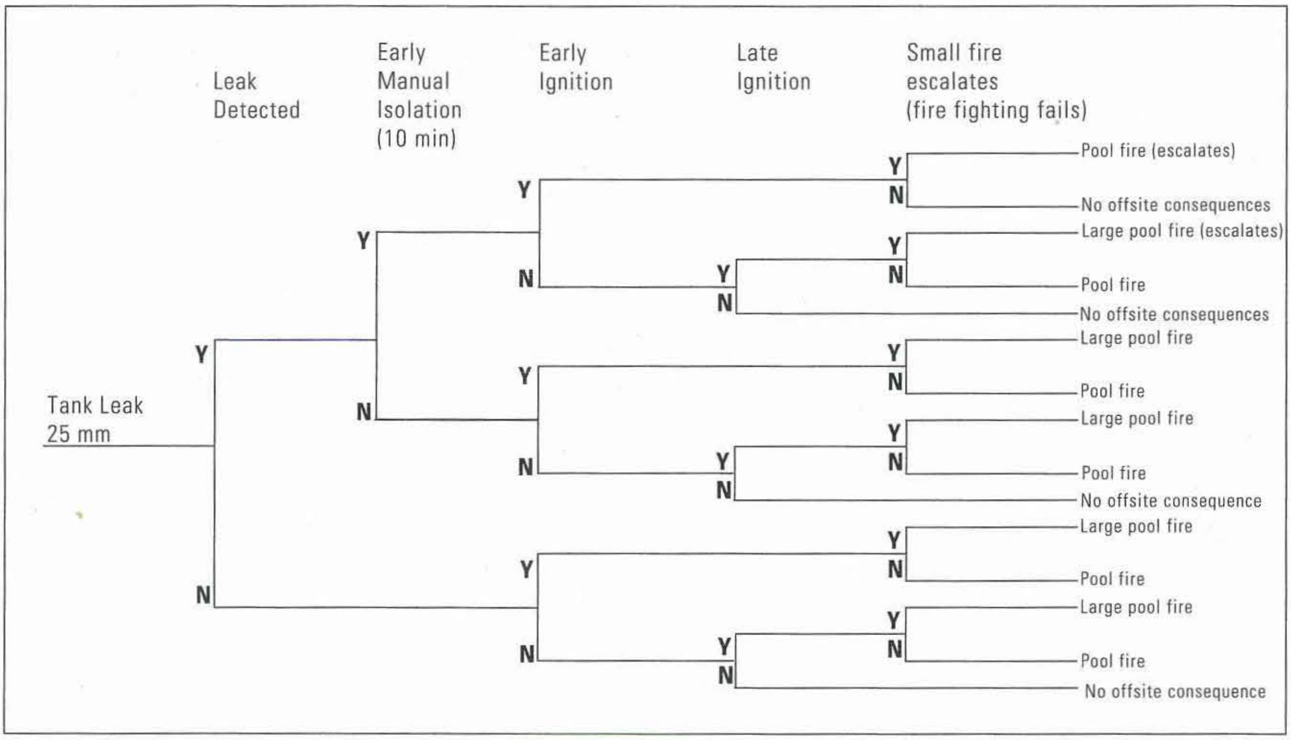


FIGURE 12. FAULT TREE — CONTAINER HOT RUPTURE