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SITE B PROPOSED THROUGHPUT INCREASE

S75W APPLICATION FOR EXPANSION

QUANTITATIVE RISK ASSESSMENT

PORT BOTANY

VOPAK TERMINALS AUSTRALIA

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Title: **Site B Proposed Throughput Increase** **S75W Application for Expansion** **Quantitative Risk Assessment** **Port Botany**	**QA Verified:** J. POLICH **Date: 11 June 2015**

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ABBREVIATIONS

ACFS	Australian Container Freight Services
AS	Australian Standard
CR	Cone Roof
DPE	NSW Department of Planning and Environment
EP&A	Environmental Planning and Assessment
HIPAP	NSW Hazardous Industry Planning Advisory Paper
IFR	Internal Floating Roof
IP	Institute of Petroleum
JSEA	Job Safety Environment Analysis
LEL / LFL	Lower Explosive Limit / Lower Flammability Limit
MOC	Management of Change
OGP	Oil & Gas Producers
P&ID	Piping & Instrumentation Diagram
PFD	Probability of Failure on Demand
PLC	Programmable Logic Controller
QRA	Quantitative Risk Assessment
SCADA	Supervisory Control and Data Acquisition
SFARP	So Far As Reasonably Practicable
SPC	Sydney Ports Corporation (now NSW Ports)
UFL	Upper Flammability Limit
ULP	Unleaded Petrol
VRU	Vapour Recovery Unit
WHS	Work Health and Safety

TERMINOLOGY

Term	Definition
Combustible liquid	Any liquid, other than a flammable liquid, that has a flash point, and has a fire point that is less than its boiling point (AS 1940–2004).
Consequence	Outcome or impact of a hazardous incident, including the potential for escalation.
Flammable liquid	Liquids [...] which give off a flammable vapour at temperatures of not more than 60.5°C, closed cup test, or not more than 65.6°C, open cup test, normally referred to as the flash point (AS 1940–2004).
Flash fire	The combustion of a flammable vapour and air mixture in which flame passes through that mixture at less than sonic velocity, such that negligible damaging overpressure is generated.
Flash point	The lowest temperature, corrected to a barometric pressure of 101.3 kPa, at which application of a test flame causes the vapour of the test portion to ignite under the specified conditions of test (AS 1940–2004).
Gasoline	Synonymous with petrol, the common used term in the refining industry.
Heat radiation	The propagation of energy in the infra-red region of the radiation electromagnetic spectrum, commonly ‘heat'.
Individual risk	The frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards.
Jet/spray fire	The combustion of material emerging with significant momentum from an orifice.
Lower flammability limit (LFL)	That concentration in air of a flammable material below which combustion will not propagate.
Offsite	Areas extending beyond the plant boundary. This includes both public and private holdings.
Onsite	Site B terminal area, defined within the plant boundary.
Pool fire	The combustion of material evaporating from a layer of liquid at the base of the fire.
Risk	The likelihood of a specified undesired event occurring within a specified period or in specified circumstances, It may be either a frequency (the number of specified events occurring in unit time) or a probability (the probability of a specified event following a prior event), depending on the circumstances.

Societal risk The relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realization of specified hazards.

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1. SUMMARY

1.1. Background

Vopak Terminals Australia Pty Ltd (Vopak) operates the Sydney Site B hydrocarbon fuel terminal located within the NSW Ports Port Botany precinct. The site is a Major Hazard Facility (MHF), with the first site Safety Case prepared in 2012.

The site was initially developed in 1995 and has expanded in stages, with the last major expansion (the “B3 expansion project”) completed in 2010. Quantitative Risk Assessment studies (QRAs) have been prepared for the various expansions on the site. Vopak is now proposing to increase the hydrocarbon throughput at Site B from 3,950 ML/year to 7,900 ML/year, and the associated road tanker export capacity from 1,897ML/year to 3,700 ML/year, with the balance exported via ship or pipeline.

Vopak was advised by NSW Ports that as part of the Environmental Assessment (EA) required for the increase in throughput, a risk assessment study should be undertaken. This is as per Section 75W of the Environmental Planning and Assessment (EP&A) Act for any modifications to current/approved development consents.

Sherpa Consulting Pty Ltd (Sherpa) was retained by Vopak to prepare a QRA for the Site B operations covering the proposed increase in throughput in order to show that the relevant land use planning risk criteria will be met. The QRA covers both the current and projected future operation (Mid Case 2030) and supersedes previous QRA studies for Site B.

The QRA was carried out in accordance with the NSW Department of Planning and Environment (DPE) HIPAP 6 *Hazard Analysis* guidelines.

1.2. QRA Scope

The QRA covered hydrocarbon loss of containment scenarios for operations within the Site B boundary, and also for Vopak ship import and export activities within NSW Ports Bulk Liquids Berth (BLB) areas as follows:

- NSW Ports area (Vopak operations only) at BLB1 and BLB2/Wharf Areas and associated pipelines from BLB1 and BLB2 to Site B
- Storage tanks, manifolds, pumps and piping, and road tanker export/import activities within Vopak Site B.

Import and export pipelines (Jet Fuel Line and Caltex Transfer Pipeline) once outside the boundary of Site B, were not included in the QRA.

The QRA included consequence and frequency analysis. Scenarios considered were:

- Pool fires (spills into bunded areas, manifold areas, tanker loading bay)
- Tank top fires
- Spray fires (pumped liquid systems)

- Flashfires resulting from large overfills of gasoline from storage tanks ("the Buncefield scenario").

TNO Riskcurves was used to generate risk contours for both the current and future increased throughput cases. Individual fatality and property damage risk were then assessed against the land use planning risk criteria outlined in the HIPAP 4 *Risk Criteria for Land Use Planning* guidelines.

Injury risks from heat radiation and/or explosion overpressure were not evaluated in this study as injury risk criteria are applicable only for residential and sensitive uses which are not present in the Port Botany precinct. These areas are well outside the worst case consequence impact area identified in the QRA.

1.3. QRA Basis

The QRA is based on the maximum throughput and storage capacities for Site B and accounts for the highest hazard product (gasoline).

As part of this QRA, checklists have been developed to allow an evaluation of future changes that may arise to determine whether they would already be covered by the existing QRA basis. Checklists are provided in APPENDIX E Section E1.3.

If the criteria in the checklists are met, the Site B QRA and fire safety study already cover the change and no update to the studies would be required. If checklist criteria are not met, review and potential update to the studies would be required.

Changes such as hydrocarbon fuel product reallocation between existing tanks, minor changes in manifolds or piping within the site (which already occur as part of Site B operations) do not require an update to the QRA as it has already been based on the highest hazard product (gasoline) in any tank, road tanker bay or manifold, hence these types of changes have minimal effect on offsite risk. An update to the QRA would typically relate to significant changes such as introduction of an entirely new product to the site (ie not a fuel hydrocarbon) or a major engineering or equipment change, for example replacement of an existing tank with a larger tank.

1.4. Findings

1.4.1. Individual Fatality Risk

Comparison of the risk against the HIPAP 4 risk criteria is given in Table 1.1. The risk contours for the existing and future increased throughput operations are shown in Figure 1.1 and Figure 1.2, respectively. These show that:

- The risk criteria for all offsite land uses are met for both current and the future increased throughput operations.
- The site boundary target risk level (50 x 10^{-6} per year) is met for both current and the future increased throughput operations.

- In general, there is an increase in risk for all risk contour levels for the increased throughput case. This is due to:
  - The addition of several new facilities around the Site B terminal which introduces more leak sources around the terminal. These include addition of BLB2 and additional pipelines for hydrocarbon import to Site B, as well as provision of four new road tanker bays (product export and ethanol/biodiesel unloading).
  - Increase in the overall terminal throughput, which increases the frequency at which hydrocarbon can be released from terminal equipment and operation.
- The main risk contributors to the individual fatality risk (future case) are as follows:
  - At the 50 x 10^{-6} per year contour (within the Site B boundary):

    Gasoline jet fire from the new proposed road tanker loading gantry bay 8-9, pool/bund fires from T-624 and T-625 are the major risk contributors to the offsite risk at the 50 x 10^{-6} per year contour on the eastern limit of Site B (near Friendship Road). However, the risk contour at this level remains within the site boundary for the projected future case operation.
  - At the1 x 10^{-6} per year contour

    Flash fires due to the gasoline tank overfill incidents ('Buncefield' scenario) are the major risk contributors to the offsite risk at the 1 x 10^{-6} per year contour. The same contributors apply for the 0.5 x 10^{-6} per year contour.
  - Southern limit of 5 x 10^{-6} per year contour

    Pool fires (including bund fires) are the major risk contributors to the offsite risk at the 5 x 10^{-6} per year contour. This contour

1.4.2. Damage and Propagation Risk

The risk criterion for damage and propagation risk is complied with for both current and future increase throughput operations. Incident heat flux radiation (23 kW/m^2) at neighbouring potentially hazardous installations or at land zoned to accommodate such installations does not exceed 50 x 10^{-6} per year.

1.4.3. Risk Contours Comparison with the Vopak Site B Stage 3 FHA

Prior to this QRA study, the Final Hazard Analysis (FHA, 2007) report for the previous Site B expansion ("B3 expansion"), presented the most recent cumulative risk contours for the Site B operations. Comparison with the previous FHA, both the 50 x 10^{-6} and 1 x 10^{-6} per year risk contours generated for this updated QRA study (current case which is representative of the same case as the FHA, ie B3 expansion) are larger than the contours produced in the FHA. This is due to:

- Differences in study scope

The updated QRA included release scenarios from the BLB and the import pipeline to site, as well as releases from manifolds, pumps and pipework on site, whereas the FHA included equipment within the Site B boundary only.

- Level of detail assessed

  The FHA mainly assessed large tank terminal fire scenarios (eg tank fires and road gantry releases). The QRA assessed in detail the potential leak sources (ie parts count) for all equipment with hydrocarbon inventories.

- Inclusion of gasoline tank overfill ('Buncefield') scenario

  The QRA included the Buncefield scenario tank overfill scenarios and associated flammable vapour clouds which may ignite. In the past prior to Buncefield, the industry has previously considered these scenarios to be extremely unlikely and they were not included in hydrocarbon tank farm consequence assessments (such as the 2007 FHA).

1.4.4. Risk Contours (Future Case) Comparison with the Port Botany Land Use Study

Based on visual comparisons only:

- The 1 x 10^{-6} per year risk contour for Site B future case operation will be within the projected future case use overall risk contour (1 x 10^{-6} per year as shown on Figure 2/Figure 8, *Port Botany Land Use Safety Study Overview Report 1996*).
- The 50 x 10^{-6} per year risk contour for Site B future case operation is contained within the Site B boundary and hence, it will be within the projected Port Botany future case use overall risk contour (50 x 10^{-6} per year).

Hence, there will be no significant effect on the cumulative risk as shown in the Port Botany Land Use Safety Study future use case.

1.5. Study Recommendations

The QRA is intended primarily as a risk profile comparing the current and proposed future expansion cases against HIPAP 4 criteria. The QRA shows that the risk criteria are met hence no specific recommendations relating to improved risk reduction measures have been made.

While the QRA identifies existing risk control measures and safeguards, it does not provide a detailed demonstration of the adequacy of the control measures in place to control risks to levels considered So Far As Reasonably Practicable (SFARP). The proposed modification will require update to Vopak's MHF Safety Case as per the requirements of the NSW Work Health and Safety (WHS) Regulation 2011 (Section 9.3, Division 4). Review and demonstration of SFARP will also be done as part of the Safety Case update.

It is recognised that in the increased throughput case, the risk contours extend further to the south and east into the ACFS site in comparison to the current case. It is therefore recommended that:

- As part of the review of the emergency response plan (ERP) that will be required[1] for the proposed Site B throughput increase, Vopak with input from ACFS undertake a review of access/egress form the ACFS site to determine if any additional emergency access or exit provisions are required in the event of an incident in the southern or eastern parts of the Vopak site.

[1] The ERP will require review for a number of reasons including as part of Vopak's internal change management process and as a requirement of the WHS MHF regulations. It is also expected the DPE will set a condition of consent relating to provision of an updated ERP as this is a standard condition as per HIPAP12 *Hazards-Related Conditions of Consent* for a change of this nature.

TABLE 1.1: COMPARISON WITH INDIVIDUAL FATALITY RISK CRITERIA

Description	Risk criteria (per year)	Compliance with criteria?		Comments
		Current operations	Future operations	
Hospitals, child-care facilities and old age housing (sensitive land uses).	0.5×10^{-7}	Yes	Yes	The risk contours extend up to approximately (current case) 300m and (future case) 350m from the west and south eastern site boundary. However, there are no sensitive land uses in this area.
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use).	1×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current case) 235m and (future case) 285m from the eastern site boundary. However, there are no residential land uses in this area.
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).	5×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current and future case) 94m from the eastern site boundary but do not extend into any commercial land uses. However, there are no commercial land uses in this area. The ACFS container warehouses to the south of Site B are industrial facilities with small numbers of people in ancillary offices rather than commercial offices with high populations or access by the general public. Hence this criterion is not applicable within the port area. Refer to the notes to Table 5.5 for further information).
Sporting complexes and active open space areas.	10×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current and future case) 80m from the eastern site boundary. However, there are no recreational land uses in this area.
Target for site boundary.	50×10^{-6}	Yes	Yes	Wharf For both the existing and future case operations, the contour is retained at the wharf area. Site The site boundary target is met for existing and future operations, where the contour is kept on site.

FIGURE 1.1: INDIVIDUAL RISK CONTOUR (CURRENT OPERATION)

FIGURE 1.2: INDIVIDUAL RISK CONTOUR (PROJECTED FUTURE OPERATION)

2. INTRODUCTION

2.1. Background

Vopak Terminals Australia Pty Ltd (Vopak) operates the Sydney – Site B ('Site B') hydrocarbon fuel terminal located within the NSW Ports Port Botany precinct (formerly known as Sydney Ports Corporation (SPC)). The site is a Major Hazard Facility (MHF), with the first Safety Case prepared in 2012.

The majority of products are imported from the Port Botany Bulk Liquid Berth (BLB), stored at Site B, then exported offsite by road tanker or pipeline. Site B is a Major Hazard Facility (MHF) located in the same precinct as nearby MHFs operated by Elgas, Qenos and Origin.

Vopak is proposing to increase the throughput at Site B as follows:

- Increase the Site B total throughput from 3,950 ML/year to 7,900 ML/year.
- Increase the Pipelines throughput from 1867.5 ML/year to 2,160 ML/year.
- Increase the Road Tanker loading throughput from 1,897ML/year to 3,700 ML/year.
- Increase the Ship export throughput to 2,000 ML/year.

This will be achieved by implementation of various related projects, including:

- Construction and operation of three new road tanker loading bays (loading bays 7,8 and 9) and additional transfer pumps and product supply pipelines, plus one unloading bay for biofuels, additives and other ancillary products together with road tanker unloading pumps).
- Implementation of west entry path for road tankers entry to site and link road around the North and West of Site B, including a new driver amenities building.
- Connection of Site B CTP (Caltex Transfer Pipeline) within Site B to include other gasoline grades.
- Upgrade of the jet fuel pumping arrangements and jet fuel export line.
- Vapour Recovery Unit (VRU) Upgrade - this would be required when the current VRU reaches capacity.
- Ship import debottlenecking of inlet manifolds, tank import pipelines and tank inlets, inclusive of tank-to-tank and tank recirculation piping and pump facilities as well as instrumentation for quantity and quality control to increase flowrates
- Ship export debottlenecking of tank outlets, tank export pipelines and transfer pumps as well as instrumentation for quantity and quality control to increase flowrates.

- Commencement of operation of a second Bulk Liquids Berth 2 (BLB2) and associated Marine Loading Arm, pipelines (constructed in 2013) adjacent to the existing Bulk Liquid Berth (BLB1) at Port Botany and associated manifold extensions.

A number of other works not directly related to the hydrocarbon facilities will also be undertaken including

- Civil, Structural, Piping, Electrical and Instrumentation Works for the above.
- Increase in the size of the approved warehouse near the Fire Pump House.
- Ongoing maintenance and enabling works will be undertaken, as required, throughout the life of the project for the entire site. This includes the construction, installation, and the ongoing maintenance, repair, replacement and / or removal of:
    - Fittings, fixtures and infrastructure
    - Parking areas, and other paving works
    - Landscaping
    - Lighting, utilities and service facilities, security cameras and devices.

2.2. Requirement for Study

NSW Ports advised Vopak that as part of the Environmental Assessment (EA) required for the increase in throughput, a risk assessment study should be undertaken. This is as per Section 75W of the Environmental Planning and Assessment (EP&A) Act for any modifications to be done under current/approved development consents.

The most recent risk assessments for Site B are the Site B Final Hazard Analysis (Ref.1, prepared in 2007 as part of the Site B3 expansion project, which was largely completed by 2010) and the Site B MHF Safety Case (2012, Ref.2). The Site B 2007 FHA is in the form of a high level quantitative risk assessment (QRA) and the Safety Case uses bowtie analysis.

To confirm whether the offsite risk from the proposed increase in throughput meets the relevant land use planning risk criteria, Vopak has retained Sherpa Consulting Pty Ltd (Sherpa) to undertake a QRA for the Site B operations for both current and projected future case.

2.3. Study Objectives

The main objectives of this study were to:

- Develop a comprehensive understanding of the hazards, risks and the safeguards associated with the existing Site B and proposed modifications required to achieve the expansion.

- Prepare a QRA in accordance with NSW Department of Planning and Environment (DPE) guidelines HIPAP 6 'Hazard Analysis' (Ref.3).
- Establish whether the offsite risk levels comply with the risk criteria in the NSW DPE HIPAP 4 'Risk Criteria' (Ref.4), which covers:
  - Fatality risk to offsite land uses, expressed as individual risk
  - Risk of property damage to neighbouring hazardous installations.

  Note: Injury risks from heat radiation and/or explosion overpressure were not evaluated in this study as this criterion is applicable for residential and sensitive use areas only. No such developments are present in the Port Botany precinct.
- Establish whether the updated risk contours fall within the NSW DPE Port Botany Land Use Safety Study (Ref.5) findings. In particular the QRA will seek to demonstrate that there is:
  - No increase in cumulative risk as shown in Figure 2 of the *Port Botany Land Use Safety Study Overview Report 1996* (Overview Report)
  - No propagation of risks to neighbouring facilities.
- The updated QRA supersedes the QRA in the 2007 FHA, and will be included in the EA for the Section 75W expansion application.
- The QRA is also intended to provide technical input to update the Vopak Site B's Safety Case to cover the proposed expansion which will be required as per NSW Work Health and Safety (WHS) Regulation 2011 (Section 9.3, Division 4).

2.4. Study Scope

The scope of this study includes:

- Current Site B operations

  This reflects the 'current' Site B operations, based on 2013-2014 operational data.
- Projected future Site B operations

  This case included the proposed increased throughput and modifications based on Mid Case 2030 Projection (Ref.6).

2.5. Study Exclusions and Limitations

The exclusions and limitations of this study are summarised in Table 2.1.

TABLE 2.1: STUDY EXCLUSIONS AND LIMITATIONS

No.	Exclusions and Limitations	Remarks
1.	Offsite Risk only was assessed	This assessment focuses on the major accident events with the potential to cause offsite impacts (ie outside the property boundary). Onsite risk to employees and contractors was not assessed, however the QRA contains sufficient detail (frequency and consequence for all scenarios are provided) to provide input to the MHF Safety Case if needed. Risk to onsite occupied buildings was not assessed. This study assessed risk related to the operational phase only. Construction activity risks are covered by other assessment processes such as construction safety studies, work permits and associated Job Safety Environment Analysis (JSEA).
2.	Scope – VRU, slops and additives	Vapour Recovery Unit (VRU), slops tanks and additives storage were not included in the QRA due the relatively small inventories and consequence heat radiation footprints.
3.	Scope – Export pipelines	The QRA only included the booster pumps and the discharge piping on site within the Vopak site boundary. The export pipelines which are outside the Site B boundary are managed as per relevant Australian Standards such as AS2885. The export pipelines outside the Site B boundary are excluded from the QRA. Assessment was undertaken only up to the site boundary limits.
4.	Scope – Societal Risk	Societal risk profiles have not been quantified as the surrounding land use is largely low density industrial.
5.	Scope – Transport Risk Assessment	Transport risk assessment outside Site B boundaries was not included in this assessment.
6.	Update of Safety Case (Ref.2) for Site B modifications	The QRA used the 2012 Site B Safety Case to prepare the Hazard Identification section. SFARP demonstration and acceptability of onsite risk based on Vopak's corporate risk criteria was not addressed. The MHF Safety Case will be updated by Vopak prior to commencement of operations with the proposed additional activities as part of the site MHF licence requirements as per NSW WHS Regulation 2011 (Section 9.3, Division 4)

No.	Exclusions and Limitations	Remarks
7.	Utilisation of Vopak Site B Final Hazard Analysis (Ref 1)	The QRA drew on FHA to prepare the Hazard Identification section. Quantitative data contained in the 2007 FHA was reviewed and was generally updated with consequence and frequency data using current publicly available sources. The QRA now supersedes the 2007 FHA.

3. FACILITY DESCRIPTION

3.1. Location and Surroundings

The Vopak Site B terminal is located at 20 Friendship Street, Port Botany and is contained within the NSW Ports precinct (formerly known as Sydney Ports Corporation (SPC)). Site B is located in the same precinct as the nearby Major Hazard Facilities (MHF) operated by Elgas, Qenos and Origin.

An aerial photo showing the location of the Site B terminal is provided in Figure 3.1

The surrounding area is primarily characterised by industrial activity neighbours. There are no significant commercial spaces, no retail centres or similar developments that routinely have a large number of people occupying them (eg commercial office space, retail centres)[2]. Table 3.1 summarises the industrial facilities land near to the Site B terminal.

TABLE 3.1: INDUSTRIAL LAND USES NEAR TO TERMINAL

Location	Neighbouring Facility
North	Elgas
East	Qenos
South	Australian Container Freight Services (ACFS)
West	NSW Ports Pipeline Corridor

The nearest residential area is located at Phillip Bay approximately 1500 metres to the east of the site across Yarra Bay. Other residential areas, slightly further away (~2 kilometres), are Matraville/Chifley to the north-east, Little Bay to the east, La Perouse to the south-east and Botany to the north-west. Botany cemetery is located 800 metres to the east.

[2] State Environment Planning Policy (SEPP) – Port Botany, Port Kembla and Port of Newcastle (2014) (the Three Ports SEPP) clause 21 specifically prohibits business premises or office premises unless the consent authority is satisfied that the development is associated with, and ancillary to, port facilities or industrial uses of land.

FIGURE 3.1: VOPAK SITE B - AERIAL PHOTO

3.2. Site B Terminal Description and Operations

The Vopak Site B terminal occupies approximately 9 hectares of land in total and is divided into three main areas, B1, B2 and B3. Areas B1 and B2 were completed and commissioned in 1996 and 2007, respectively. Area B3 was completed and commissioned during 2009 and 2010.

The majority of the terminal comprises storage tanks (26 internal floating roof tanks, 7 additive tanks and 6 slop tanks) which store gasoline, jet fuel, fuel grade ethanol and diesel. The rest of the terminal is divided into smaller areas that include road tanker loading/unloading bays, main road tanker vehicle access ways and operations control building.

The current Site B total storage capacity is approximately 345,570 m^3 (including slops and additives tanks). Currently based on the average from 2013-2014 operation, the average Site B throughput is approximately 2,693,000 m^3/year.

Site B terminal is operational 24 hours per day, 7 days per week manned by Operations personnel onsite. All Site B activities (controlling tank movements, product transfers, road tanker loading, VRU monitoring, fire system control and alarms) are coordinated by the Control Room Operator via the SCADA system.

A site layout of the Site B terminal is shown in Figure 3.2.

Hazardous materials stored onsite mainly comprise of bulk petroleum fuel products (gasoline, diesel and jet fuel), ethanol, petrol additives and smaller quantities of chemicals (eg cleaning fluids and lubricants) for site maintenance. Product allocation within the Site B area is illustrated in Figure 3.2.

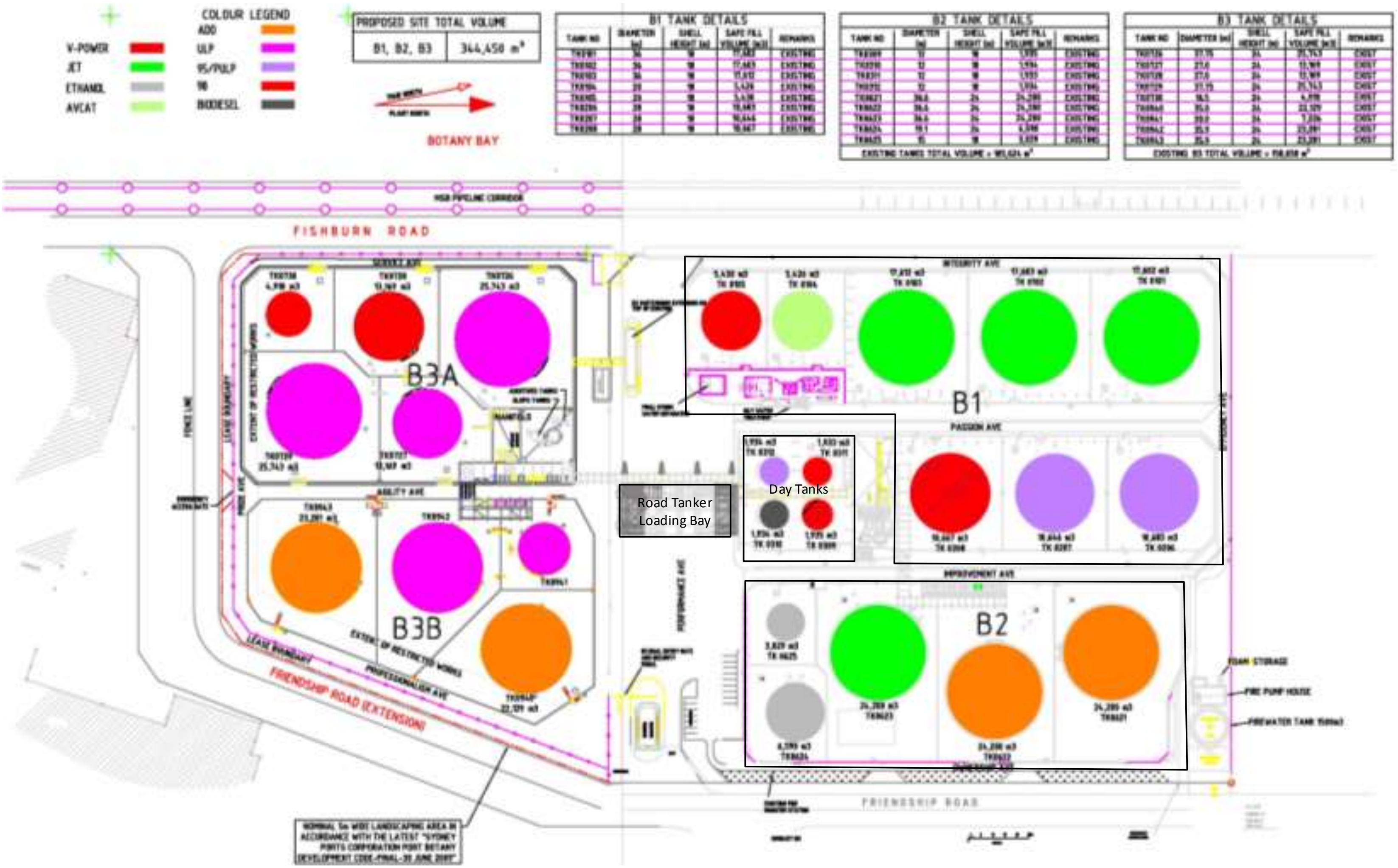

FIGURE 3.2: SITE LAYOUT AND PRODUCT ALLOCATION

3.3. Site B Terminal Operations

Vopak Terminal Sydney - Site B is integrated into a wider network of petroleum and liquid fuels transport infrastructure including Caltex Banksmeadow, Caltex Kurnell, Mobil Silverwater, NSW Ports and Sydney Airport (JUHI).

Vopak Site B terminal receives, stores and transfers a variety of liquid petroleum products owned by its various customers. These products include gasoline, jet fuel, automotive diesel fuel (ADO), biodiesel and fuel grade ethanol. The products are mainly received in bulk from petroleum parcel tanker ships via the Bulk Liquids Berth (BLB1 and BLB2), pipelines (eg CTP), as well as road tankers. Product despatch is mainly by road tankers. A significant proportion of the product is also transferred by pipeline from Site B to Sydney Airport (Jet Fuel) and Silverwater terminal (via the CTP).

The nature of these operations remains the same with the increased throughput changing quantities only.

The terminal product transfer utilisation is provided in Table 3.2.

TABLE 3.2: TERMINAL PRODUCT TRANSFER UTILISATION

Product Transfers	Transfer Utilisation	Products
Import	Petroleum parcel tanker ships (BLB1 and BLB2)	Various
	Caltex Transfer Pipeline (CTP)	Various
	Road Tanker	Ethanol
Export	Road Tanker	Various
	Caltex-JUHI Pipeline	Jet Fuel
	Caltex Transfer Pipeline (CTP)	Various
	Petroleum parcel tanker ships (BLB1 and BLB2)	Various

Products can be directed to selected tanks by interconnections made at the transfer manifold. Depending on the nature of the products, they can be stored in various tanks of different capacities, in localities suited to product type and flash point. Details around the Site B storage tanks are provided on Table 3.3. Tank product allocation is subject to change and will be carried forward under the Vopak management of change process. Refer to Section 3.4 for additional details of typical operational changes.

Jet fuel is transported to JUHI (Joint User Hydrant Installations) at Sydney Airport (Mascot) by tapping into the Caltex/JUHI pipeline at Bumborah Point Road. Transfers to JUHI are monitored and controlled by Caltex. Ground fuels, diesel and gasoline are transported via the Caltex Transfer Pipeline (CTP), used as a bi-directional fuel transfer pipeline joining Site B to Caltex Banksmeadow Terminal allowing export to Sydney Metropolitan Pipeline (A pipeline connecting Caltex Banksmeadow Terminal to Mobil Silverwater, Shell Clyde and Newcastle Terminals) and import from Caltex Kurnell refinery.

There are a total of 9 road tanker loading bays (6 existing & 3 proposed) used to load tankers with products and 1 (proposed) unloading bay to import ethanol and biodiesel into Site B.

The process flow diagram for Site B is shown in Figure 5. There is no process interaction between Site B operations with nearby MHFs operated by Elgas, Qenos and Origin other than in the coordinated response to an emergency.

3.4. Operational Changes

A key feature of the Site B operational capability has been to maximise flexibility of storage tanks and pipeline distribution systems for both import and export transfers to cater for (future) client requirements. The critical areas for such operations are the storage tanks, transfer manifolds and the road tanker loading facilities. Inlet, outlet and pump manifolds are designed for this future flexibility including flowrate changes (by increasing the number of duty pumps). As Vopak respond to commercial drivers, changes to the terminal operation are a fairly frequent occurrence. Site B terminal design caters for this as follows:

1. Storage tanks:

- All of the bulk storage tanks have been designed, constructed and operated in accordance with AS1940 on the basis that each can store Class 3 Flammable (highest hazard product is gasoline). Hence, any petroleum product can be stored in any tank (except for T-621 which is currently reserved for Diesel storage only, and ethanol in only some tanks).
- All tanks are fitted with identical:
    - High Level, High-High Level and ESD systems
    - Separate Inlet and Outlet Manifolds complete with Remotely Actuated Tank Valves
    - Dewatering facilities (for removing free water settling out from product at the tank bottoms)
    - Dedicated Transfer Pump.

This means it is a relatively routine task to convert the tank to another product service. Generally, manifold changes, road tanker facility changes and computer control systems (PLC/SCADA) updates are all that are required in the field.

Safety Management systems (emergency plans, logistics and signage) are also updated prior to refilling the storage tank with the new product.

2. Piping and Manifolds

There are also occasions when minor modifications to existing pipework systems or additional pipework is required to effect the change of product service. Terminal manifold systems are designed such that removable spool pieces allow a variety of cross-connections to enable product to be delivered to the nominated storage tank(s). A change of product/tank, can be realised relatively simply by re-arrangement, additions or modifications (to pipework).

This is a standard Vopak operation and any proposed change to the infrastructure is managed safely by the Vopak Management of Change (MOC) Procedure. These changes can be relatively frequent, i.e., several times per year.

3. Road Tanker Gantry Facilities

The road tanker gantry facility (which includes filling arms, additive injections systems, blending systems, computer controls, loading pumps) is designed for maximum flexibility in being able to change product/loading arms via removable spool pieces on the product header pipelines which travel overhead of each loading bay. A change can be realised relatively simply by re-arrangement, additions or modifications (to pipework).

Similarly, for blending of fuel additives or biofuels such as ethanol and biodiesel using standardised minor additions to the existing loading arm skids.

TABLE 3.3: STORAGE TANK CAPACITIES AND PRODUCTS

Tank	Site	Product	Diameter (m)	Height (m)	Safe Fill Level (m3)	Full Bund Area (m^2)	Intermediate Bund Area (m^2)
TK101	B1	Jet A1	36	18	17,602	11,189	2853.6
TK102	B1	Jet A1	36	18	17,603	11,189	2834.5
TK103	B1	Jet A1	36	18	17,612	11,189	2816.2
TK104	B1	Avcat	20	18	5,426	11,189	1333.6
TK105	B1	ULP98	20	18	5,430	11,189	1350.9
TK206	B1	95/PULP	28	18	10,683	6,217	2046.1
TK207	B1	95/PULP	28	18	10,646	6,217	2071.3
TK208	B1	V-Power	28	18	10,667	6,217	2099.7
TK309	B2	V-Power	12	18	1,935	2,321	628.9
TK310	B2	Biodiesel	12	18	1,934	2,321	537.3
TK311	B2	ULP98	12	18	1,933	2,321	578.1
TK312	B2	95/PULP	12	18	1,934	2,321	576.7
TK621	B2	ADO	36.6	24	24,200	13,354	3736.7
TK622	B2	ADO	36.6	24	24,200	13,354	3688.9
TK623	B2	Jet A1	36.6	24	24,200	13,354	3596.8
TK624	B2	Ethanol	19.1	24	6,590	13,354	1340.2
TK625	B2	Ethanol	15	18	3,029	13,354	991.1
TK726	B3A	ULP	37.75	24	25,743	11,018	3020.0
TK727	B3A	ULP	27	24	13,169	11,018	1877.5
TK728	B3A	ULP98	27	24	13,169	11,018	1865.1
TK729	B3A	ULP	37.75	24	25,743	11,018	2959.4
TK730	B3A	ULP98	16.5	24	4,918	11,018	1296.4
TK940	B3B	ADO	35	24	22,129	10,115	2877.8
TK941	B3B	ULP	20	24	7,226	10,115	1243.3
TK942	B3B	ULP	35.9	24	23,281	10,115	3025.8
TK943	B3B	ADO	35.9	24	23,281	10,115	2968.1

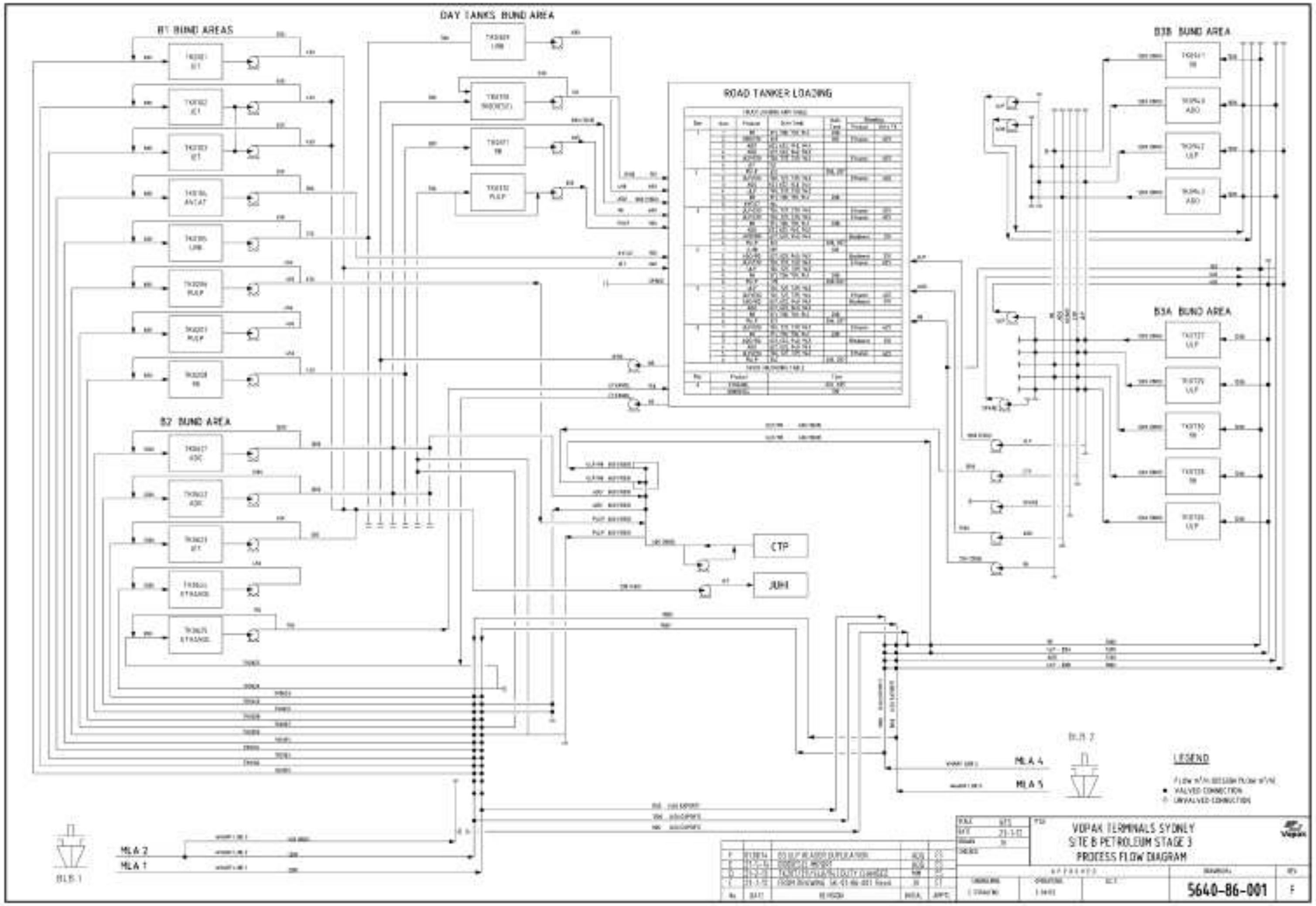

FIGURE 3.3: SITE B - PROCESS FLOW DIAGRAM

3.5. Emergency Response Equipment

The following emergency response equipment is available on the Site B terminal:

- Emergency / fire alarm system
- Fire extinguishers
- Firewater system (including firewater storage, fire pumps, foam concentrate storage, ring main etc.)
- Fire Hydrants, monitors and hose reels
- Spray cooling on tank shells/roofs (remotely operated)
- Bulk storage tank fixed in-tank top foam injection systems designed for full tank surface fires (remotely operated)
- Truck loading bay fixed foam/water deluge system (initiated by fire detection and can also be remotely operated)
- Main pump bays provided with fixed foam/water deluge system (initiated by fire detection and can also be remotely operated)
- Medium expansion foam portable trailer (2 sets available on site).

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4. QRA BASIS

4.1. Overview

A number of simplifying assumptions need to be made to prepare a QRA and the results are therefore dependent on the assumptions made in defining the input scenarios. This is particularly true of bulk terminal sites due to the potential variety of products and throughputs. It is therefore important to understand any limiting assumptions in conjunction with the QRA results.

The QRA has utilised information including site operational data, license conditions, throughput information and typical products handled over preceding years to arrive at a product allocation basis and throughput.

The QRA basis, including site operational data and throughputs for both current and projected future case operation were provided by the operator (appropriate for use) and is summarised in APPENDIX A.

To cater for the terminal flexibility as described in Section 3.4, the QRA has been prepared on the basis of various upper limit assumptions regarding presence of the highest hazard product (gasoline) and throughputs.

This means that the QRA already covers typical operational changes at Site B such as changes in manifolds and piping, change in tank product allocation and use of the pipelines for any fuel hydrocarbon as long as they are within the fuel types already handled at Site B.

A series of checklists have been prepared that summarise the constraints of the QRA and to allow an evaluation of any future changes that may arise to determine whether they would already be covered by the existing QRA basis. The checklists are given in APPENDIX E.

4.2. Current vs Projected Future Case Operation

The main changes between the current and the projected future case operation are as follows:

- Increase in total throughput from 3,950 ML/year to 7,900 ML/year, including:
    - Increase in frequency of ship import and transfer rate to Site B
    - Increase in frequency of import from Caltex Banksmeadow Terminal (via CTP pipeline) to Site B
    - Increase in road tanker export throughput
    - Increase in pipeline export throughput (via the CTP and JUHI pipelines)
    - Increase in ship export throughput and transfer rate (via BLB1 and BLB2).
- Provision of additional facilities, including:

- BLB2 and associated pipelines.
- Four new road tanker bays (Bay 7-9 for product export and Bay 10 for ethanol and biodiesel unloading).

- Upgrade of existing facilities, including:
  - Modifications to internal site pipework to allow filling of tank up to 1,750m^3/hr.
  - Connection of Site B CTP (Caltex Transfer Pipeline) within Site B to include other gasoline grades.
  - Upgrade of the jet fuel pumping arrangements and jet fuel export line.

It should also be noted that there are no changes to the number of storage tanks, terminal layout, capacity and products handled on the Site B terminal, between the current and future case operation.

4.3. Future Site B Traffic Plan and Locations of New Road Tanker Loading Bays

The proposed future Site B traffic plan (and layout) is shown in Figure 4.1.

The proposed site traffic plan is referred to as the West Entry plan (northern approach) where the road tankers would enter the Site B terminal via Fishburn Road and exits from Friendship Road, post loading.

This is different to the existing site traffic plan where the road tankers enter and exit the Site B terminal via Friendship Road (turning paths inside the terminal, East Entry).

There is no onsite full truck/road tanker parking facility. Trucks/road tankers fill up and leave the site.

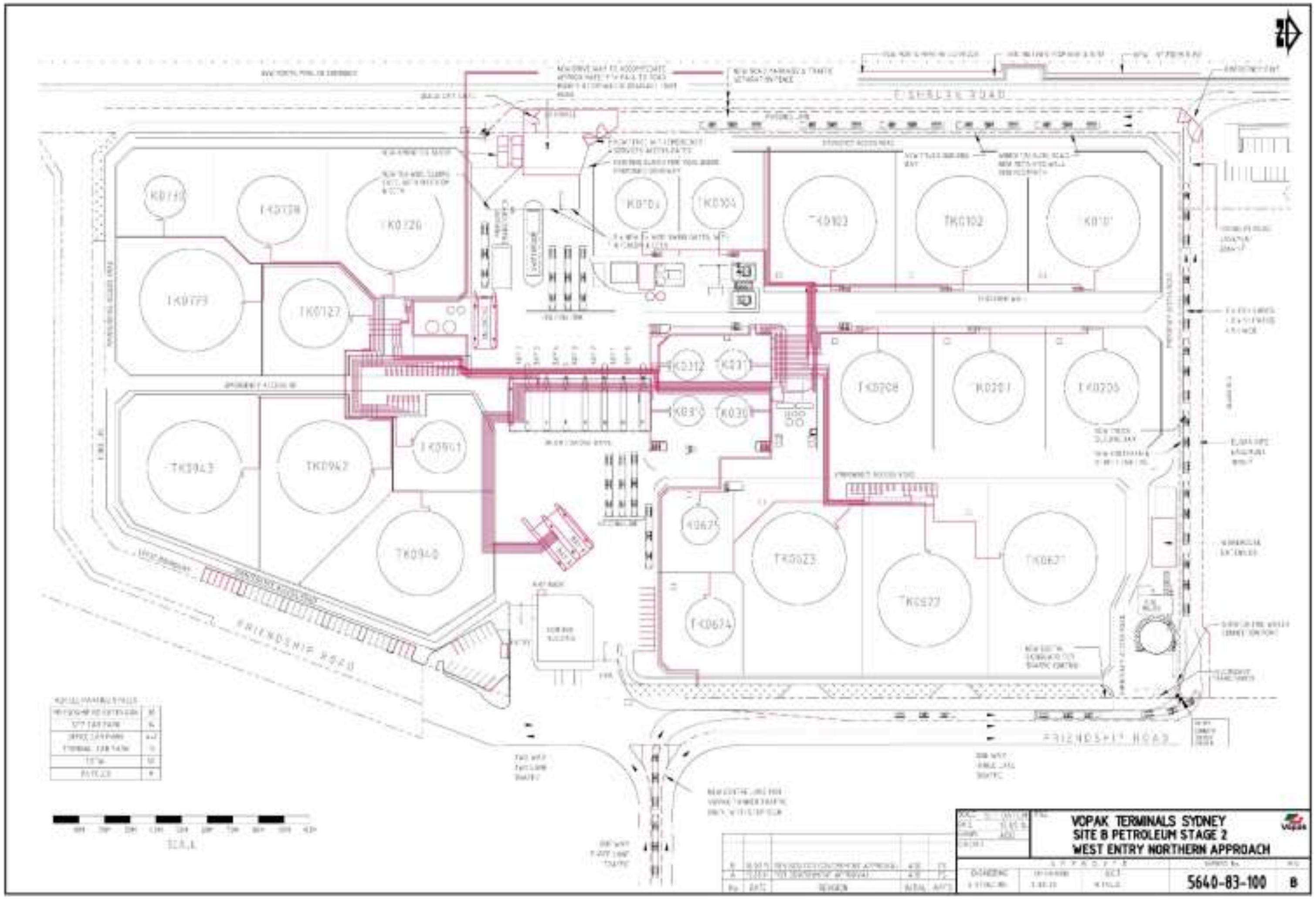

FIGURE 4.1: PROPOSED FUTURE SITE B TRAFFIC PLAN – WEST ENTRY

5. METHODOLOGY

5.1. Overview

An overview of the QRA process, including the steps and inputs for this study is shown in Figure 5.1. This study approach is consistent with the approach outlined in the HIPAP 6 Hazard Analysis Guidelines (Ref. 3). The subsequent sections provide further information.

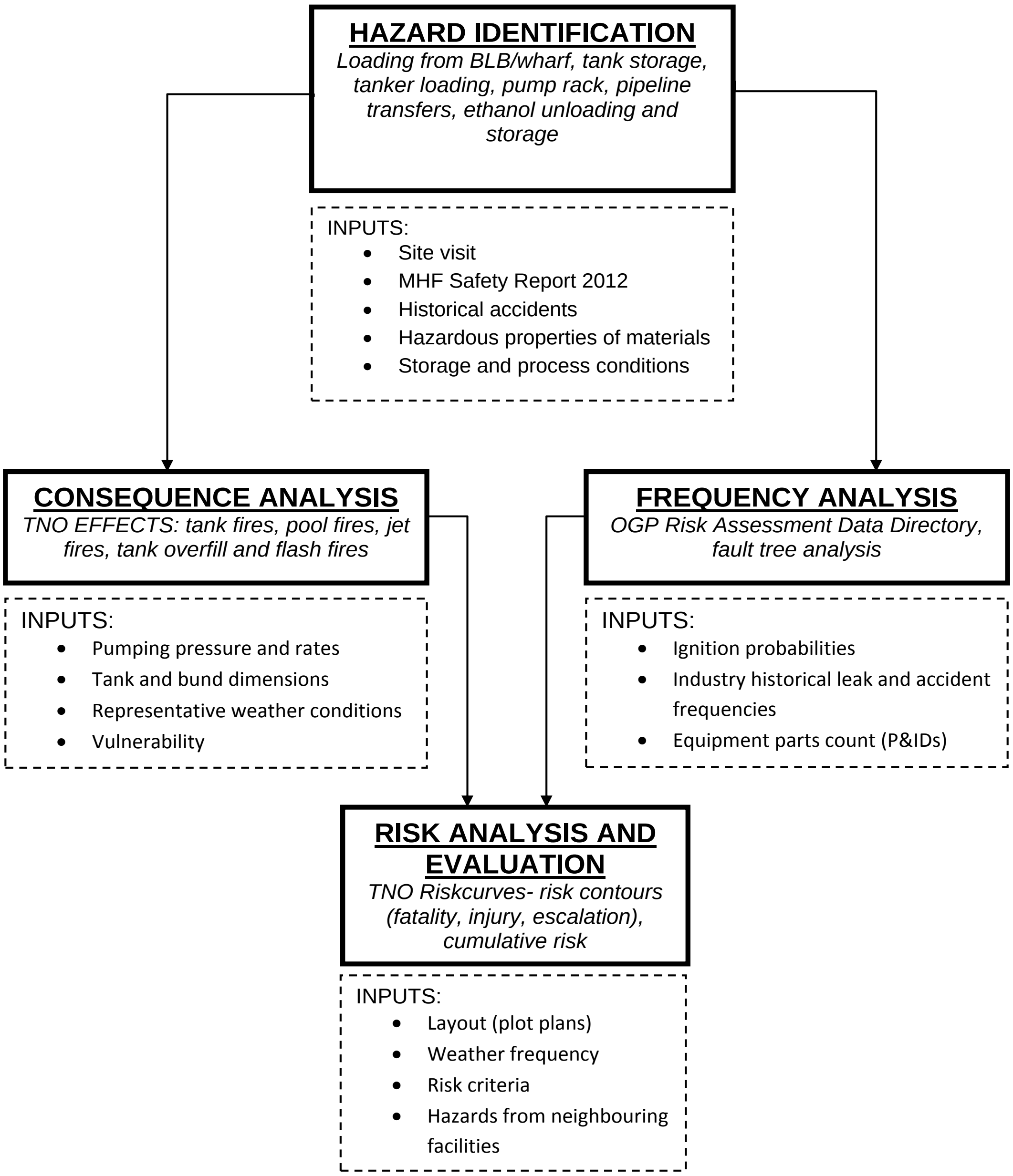

FIGURE 5.1: OVERVIEW OF QRA PROCESS

5.2. Hazard Identification

Hazard identification is the process of establishing the scenarios that could result in an adverse impact, together with their causes, consequences and existing safeguards. The main aims are to:

- Show an understanding of the underlying causes of the hazards
- Demonstrate that there are adequate safeguards in place
- Identify the hazards that have the potential for offsite impact.

As part of the hazard identification process, the following were reviewed:

1. The properties of petroleum products and their hazards
2. Major Accident Risk Register (Appendix M of the 2012 Safety Case).

A hazard identification table was then developed to list all potentially hazardous scenarios and identify the ones with the potential for offsite impact requiring quantification. The majority of hazardous scenarios involve loss of containment of hydrocarbon from equipment.

5.3. Consequence Analysis

Consequence modelling of identified scenarios were undertaken to determine the impact area (as heat radiation or are within a flammable cloud) and the resulting extent of injury or fatality effects. Consequence assessment was undertaken using TNO EFFECTS software (an update the previous consequence analysis in the FHA).

5.3.1. Software and Models

Consequence modelling of identified hazardous events was undertaken using TNO EFFECTS v9.0.23. TNO EFFECTS is a commercial software package that uses the models in TNO's Yellow and Green Books (Ref.7 and Ref.8) for calculating the physical effects and consequences of the loss of containment of hazardous materials.

5.3.2. Releases

Loss of containment from equipment was modelled for the representative range of hole sizes in Table 5.1 which are consistent with the historical leak frequency data used for the study.

The hole size selected for the ranges in Table 5.1 are the geometric means, which give a weighting towards the lower band, since smaller sized leaks tend to occur more frequently.

TABLE 5.1: REPRESENTATIVE HOLE SIZES FOR MODELLING LOSS OF CONTAINMENT

Hole size (mm)	Range (mm)
2	1 to 3
6	3 to 10
22	10 to 50
85	50 to 150
Full bore	> 150

For loss of containment downstream of a pump, the maximum release rate was limited to the normal pumping rate or the process flow rate.

During tank filling, the pump rate is slowed when the high level is approaching. In a worst case scenario for overfill, the fill rate would not be slowed and pumping to a tank would continue at the maximum filling/ship import rate.

For leaks from piping connected to a tank, the leak is driven by the head of liquid in the tank and therefore, the tallest tank height was used for modelling.

5.3.3. Scenarios

Figure 5.2 shows the general event tree showing the possible outcomes following loss of containment of a flammable or combustible liquid.

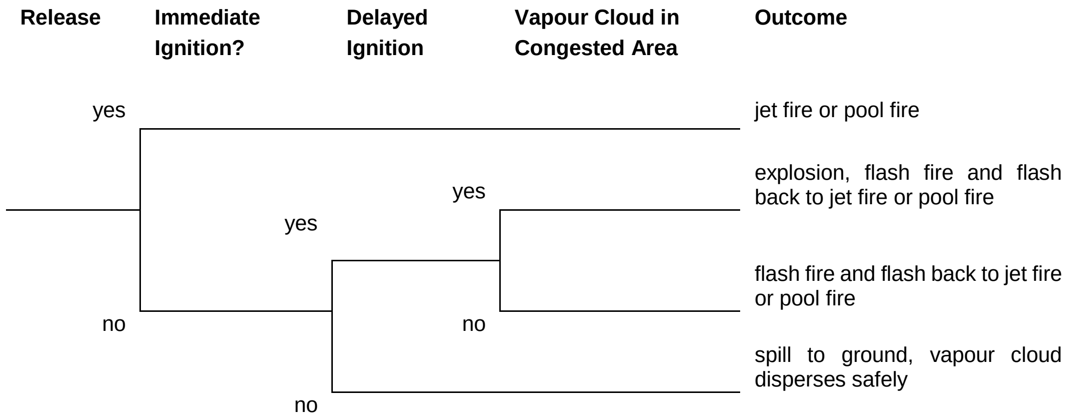

FIGURE 5.2: EVENT TREE FOR LOSS OF CONTAINMENT

When released at pressure, a liquid may form an airborne aerosol and/or fall to the ground. The pressure, hole size and fluid properties including vapour pressure all are factors in whether an aerosol, pool or combination of the two will form. Only the light components from gasoline such as C4s and C5s will tend to form a vapour cloud from evaporation or an aerosol release. The formation of a vapour cloud depends on the release characteristics and weather.

The rule set used for the outcome given ignition is shown in Table 5.2.

TABLE 5.2: SCENARIO RULE SET FOR PRESSURISED LIQUID RELEASES

Fluid	Ignition Timing	Hole Size	Outcome
Gasoline	Immediate	≤ 25 mm	Jet fire
		> 25 mm	Pool fire
	Delayed	≤ 25 mm	Rainout and evaporating pool Flash fire
		> 25 mm	Rainout and evaporating pool Flash fire
Diesel	Immediate	≤ 25 mm	Jet fire
		> 25 mm	Pool fire
	Delayed	≤ 25 mm	Pool fire
		> 25 mm	Pool fire

For liquid releases at low pressure, such as from a tank leak, an evaporating pool and pool fire (given ignition) were modelled.

For loss of containment within a bund, the size of the pool (whether a pool fire or evaporating pool) is limited by the bund size.

Loss of containment of gasoline due to tank overfill ("the Buncefield scenario") and the extent of the flammable cloud envelope was modelled following the UK HSE's Vapour Cloud Assessment (VCA) method (Ref.9), which provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident, hence predicting the distance to the LEL of the cloud.

5.3.4. Explosions

Vapour cloud explosion due to ignition of flammable clouds in the event of a gasoline tank overfill was not modelled in this study.

Based on Sherpa's experience on similar tank terminal facilities, the extent of the overpressures footprint that could result in a fatality (i.e. distance to 21 kPa to outdoor populations) is similar to the flash fire's lower flammability limit (LFL) envelope.

For this study, all delayed ignition events have been modelled as flash fires.

5.3.5. Weather Conditions

Historical meteorological weather data for the Vopak Site B terminal was obtained from the Bureau of Meteorology (BoM). The acquired data sets were based on readings from the Automatic Weather Station (AWS) at Sydney Airport (AWS 066037) and Kurnell (AWS 066043) over the period of July 2000 – June 2008 (Ref.10).

From the acquired data sets, representative weather conditions were consolidated for consequence modelling, as outlined in in Table 5.3. Since evaporation and dispersion are significantly dependent on prevailing weather conditions, a wide range of conditions with significant likelihood of occurrence was selected. The analysis of the data, which is an input to the risk model is included in APPENDIX F.

Jet and pool fires were only modelled under a high wind speed case, D6, since they are less influenced by the prevailing wind and weather conditions and higher windspeeds are more conservative as they result in slightly larger effect distances.

TABLE 5.3: WEATHER CONDITIONS FOR CONSEQUENCE MODELLING

Name	Pasquill Stability Class	Wind speed (m/s)	Description
D6	D	6	Cloudy or high wind condition
E4	E	3	Night time and moderate wind
F2	F	2	Night time/early morning, low wind speed

5.4. Vulnerability

The assessment criteria for exposure to hazardous scenarios (eg fires) are given by vulnerability relationships. These are summarised in Table 5.4.

These criteria are based on the probit equation for fires, consistent with the HIPAP. 4 guidance and the default criteria in the risk model Riskcurves for outdoor populations. For lethality from heat radiation exposure, the default exposure time in Riskcurves is 20 seconds. The table includes the exposure levels for injury and property damage from fires given in HIPAP 4 (Ref.4).

TABLE 5.4: VULNERABILITY CRITERIA FOR FIRE SCENARIOS

Event	Level	Probability of fatality assumed in QRA	Other effects
Jet fire Pool fire	Within fire envelope	100%	Escalation due to direct impingement
	4.7 kW/m^2	Injury	Injury only
	10 kW/m^2	1%	Fatality
	14 kW/m^2	10%	Fatality
	20 kW/m^2	50%	Fatality
	23 kW/m^2	70%	Escalation due to heat radiation
Flash fire	Within LEL (assumed to be flash fire envelope)	100 %	No escalation – very short duration event

5.5. Frequency Analysis

Hazardous scenarios involve loss of containment of hydrocarbon fuels and subsequent ignition. The likelihood of these scenarios was estimated using historical data for each of loss of containment and for ignition. Loss of containment frequencies were estimated by counting equipment items ('parts count') and combining with historical leak frequency data for each equipment type. The main source of historical leak frequencies was OGP's Risk Assessment Data Directory *Process release frequencies* (Ref.11). The full set of data and sources is included in APPENDIX D.

Full surface tank roof fire frequencies were estimated from the most recent LASTFIRE project (Ref.12) based on the storage tank type.

The frequency of tank overfill was estimated using fault tree analysis since this is dependent on instrument failures. The derivation and full set of data and sources is included in APPENDIX D.

5.6. Probability of Ignition

The ignition probability values used in this study were based on the assessment done by Cox, Lees and Ang (Ref.13). The probabilities are based on the release rate and the phase of the fluid assessed. The ignition probability values used in the QRA are provided in APPENDIX D.

Releases for combustible liquids such as diesel are more difficult to ignite due to their high flash point.

In this study, diesel is stored in common bunds with flammable liquids and tank product allocations may also be changed from time to time. Hence to ensure a fire scenario was included for all tanks and to take into account possible escalation from a flammable liquid fire, the ignition probability for diesel was assumed to be one-tenth that of flammable liquids such as gasoline. Likewise, for jet fuel which possess higher flash point compared to gasoline, a factor of 0.3 was applied to the ignition probabilities used for gasoline.

5.7. Risk Analysis

Risk analysis was performed using TNO Riskcurves v9.0.21, which combines the consequences and frequencies to produce contours of equal risk values.

The following risk contours were developed:

- Individual fatality risk
- Risk of property damage and accident - heat radiation of 23 kW/m^2.

Injury risks from heat radiation and/or explosion overpressure were not evaluated in this study as this criterion is applicable only for residential and sensitive use areas only. No such developments are present in the NSW Ports Port Botany precinct.

5.8. Risk Criteria and Evaluation

Table 5.5 summarises the risk criteria against which the hazards from the facility were assessed. These criteria are taken from HIPAP 4 *Risk Criteria for Land Use Planning* (Ref.4).

Additionally, the risk contours generated for the Site B facility were also compared against the 2007 Site B FHA (Ref.1) and Port Botany Land Use Safety Study (Ref. 5) as sensitivity analyses.

TABLE 5.5: RISK ASSESSMENT CRITERIA

Description and land use	Criteria (Note 3) (per year)
Individual fatality risk	
Hospitals, child-care facilities and old age housing (sensitive land uses).	0.5×10^{-6}
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use).	1×10^{-6}
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).Note 1,2	5×10^{-6}
Sporting complexes and active open space areas.	1×10^{-5}
Target for site boundary.	50×10^{-6}
Injury risk – heat radiation exceeding 4.7 kW/m^2	
Residential and sensitive use.	50×10^{-6}
Injury risk – explosion overpressure exceeding 7 kPa	
Residential and sensitive use.	50×10^{-6}
Risk of property damage and accident propagation – 23 kW/m^2 heat flux	
Neighbouring potentially hazardous installations or at land zoned to accommodate such installations.	50×10^{-6}
Risk of property damage and accident propagation – 14 kPa explosion overpressure	
Neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings.	50×10^{-6}

Notes:

1. The commercial risk criterion is applicable to land uses that may have a public access component (eg some sort of retail showrooms or warehouses such as car-yards, Bunnings, Costco etc) or a large population density (commercial offices, call centres, retail centres etc). It is not applied to offices that are directly associated with industrial facilities (examples at Port Botany would be control rooms or offices on an adjacent MHF site, offices associated with Port Security, offices associated with container terminals, a café for people in the Port area) which have low numbers of people and no routine public access. The Three Ports SEPP (Ref 14) specifically prohibits business premises or office premises unless the consent authority is satisfied that the development is associated with, and ancillary to, port facilities or industrial uses of land hence the land around Site B is not zoned for commercial development.

2. The interpretation and applicability of the commercial risk criterion has been confirmed and agreed with the NSW DPE by Sherpa.

3. Criteria specific to toxic injury and irritation are also provided in HIPAP4. These are not included as there are no significant acute toxicity impacts from Site B operations.

6. HAZARD IDENTIFICATION

6.1. Properties of Fuels

Materials handled at the bulk liquids site are all petroleum based hydrocarbons and small quantities of additives with similar properties to fuels. These have a range of properties with regards to flammability. Representative hazardous materials are summarised in Table 6.1.

Gasoline is the only material with a significant fraction of 'light' components hence the only material where a loss of containment has potential to generate a large vapour cloud. Gasoline is a very complex mixture of hundreds of chemicals. The typical composition of gasoline in Australia is given in Table 6.2. For the purposes of considering the potential for formation of large flammable vapour clouds, the fraction of C4/C5s is of interest. The properties of the two different grades of gasoline (ULP 91 and ULP 95) are very similar.

Whilst ethanol has a lower heat of combustion than gasoline, large pool fires produce less soot than gasoline pool fires. Soot tends to block the visible parts of flames thereby, reducing the heat radiation. Experiments show that ethanol pool fire heat radiation impacts are around 30% to 100% higher than from an equivalent gasoline fire.

Gasoline additives are classified as Class 3 dangerous goods. These and other chemicals onsite are not included in Table 6.1 since they are stored in small quantities.

TABLE 6.1: HAZARDOUS MATERIAL PROPERTIES

Characteristic	Gasoline	Diesel	Jet Fuel	Ethanol
Initial Boiling Point (atm.) (ºC)	30-210	260	150-300	78
Density (kg/m^3 at 15-20ºC)	750	830	775-840	789
Autoignition temperature (ºC)	>350	340	>220	363
Flash Point (ºC)	<-40	>60	>38	13
Vapour Pressure (kPag)	30-99.7	<0.1	<0.1	8
Lower Flammability Limit (LFL) (%)	1.4	N/A	1	3.3
Upper Flammability Limit (UFL) (%)	7.6	N/A	6	19.05
Pool burn rates (kg/m^2.s)	0.055	0.039	0.039	0.015
Dangerous Goods Class	3 PGII Flammable	C1 Combustible	3 PGIII Flammable	3 PGII Flammable
Note: 1. Pool burn rates obtained from Lees (Ref.15).				

TABLE 6.2: TYPICAL GASOLINE COMPOSITION

Group	Typical Composition	Typical Materials	Boiling Point (ºC)
C4	3-5%	n-butane iso-butane cis-butene	-0.5 -12 0.8
C5	14 - 20%	n-pentane iso-pentane 3-methyl 1-butene 1,4-pentadiene	35 28 20 26
C6	22%	n-hexane 2-methylpentane	69 62
C7	20%	n-heptane toluene	98 111
C8	18%	n-octane ethylbenzene	126 136
C9	9%	n-nonane	151
>C10	4-8	n-decane dicyclopentadiene	174 170

6.2. Hazard Identification Table

The hazard identification table for the site is included in APPENDIX B. The table contains the following information:

- Scenario
- Cause
- Possible consequences
- Safeguards
- Whether the scenario was carried forward for quantification.

6.3. Summary of QRA Scenarios

From the hazard identification table in APPENDIX B, Table 6.3 lists the scenarios which were carried forward for quantification for inclusion in the QRA.

TABLE 6.3: SCENARIOS CARRIED FORWARD FOR QUANTITATIVE ASSESSMENT

No.	Initial event	Potential scenarios	Comment
1.	Bulk Liquids Berth (BLB)/Wharf Area	Jet fire Pool fire Flash fire	Pressurised release from loading arm and piping. Covers both BLB1 and BLB2. Applicable to all fuels. Jet or pool fire depending on mist and rainout release. Flash fire applicable to gasoline only from pool evaporation after rainout from release. Different ignition probabilities used depending on flash point.
2.	Pipeline – BLB to Site	Jet fire Pool fire Flash fire	Pressurised release from the BLB import pipeline. Covers both BLB1 and BLB2 (for future case). Applicable to all fuels. Jet or pool fire depending on mist and rainout release. Flash fire applicable to gasoline only from pool evaporation after rainout from release. Liquid pool growth resulting from release/rainout is limited to physical restriction (eg road width along the pipeline corridor, adjacent to Botany Bay). Different ignition probabilities used depending on flash point.
3.	Manifold and Pipework to tanks	Jet fire Pool fire Flash fire	Pressurised release from the manifold and pipework to/from tanks. Covers both B1-B2 and B3 manifolds. Applicable to all fuels. Jet or pool fire depending on mist and rainout release. Flash fire applicable to gasoline only from pool evaporation after rainout from release. Liquid pool growth resulting from release/rainout is limited to physical restriction (eg kerbing around the manifold). Different ignition probabilities used depending on flash point.
4.	Storage Tank	Tank full surface fire	Applicable to all tanks and fuels. This scenario represents consequence event following rim seal fires (leading to roof collapse) and/or internal tank explosion. Different ignition probabilities used depending on flash point. Note: all storage tanks on Site B are internal floating roof (IFR) type with external dome.

No.	Initial event	Potential scenarios	Comment
5.	Storage Tank Spill to tank compound bund	Tank bund fire Flash fire	Applicable to all tanks and fuels. This scenario represents the ignited event of liquid spill to tank compound bund. Intermediate and full bund fires were assessed. Different ignition probabilities used depending on flash point. Pool evaporation of liquid in bund may produce a flammable cloud.
6.	Tank overfill	Pool fire Flash fire/explosion	Pool fire resulting from tank overfill is applicable to all fuels. Tank overfill leading to formation of flammable vapour cloud ('Buncefield' scenario) which may result in flash fire and/or explosion is applicable to gasoline tanks only based on the volatility of the 'light' ends. Vapour cloud explosion due to tank overfill was not modelled in this study. Based on Sherpa's experience on similar tank terminal facilities, the extent of the overpressures footprint that could result in a fatality (ie distance to 21 kPa) is similar to the flash fire's lower flammability limit (LFL) envelope. Hence, only flash fire modelling was undertaken in this assessment.
7.	Pump Manifold (including Booster Pumps)	Jet fire Pool fire Flash fire	Pressurised release from pump & discharge piping. Applicable to all fuels. Jet or pool fire depending on mist and rainout release. Flash fire applicable to gasoline only from pool evaporation after rainout from release. Liquid pool growth resulting from release/rainout is limited to physical restriction (eg bunding around the pump manifold). Different ignition probabilities used depending on flash point. Note: The QRA only included the booster pumps and the discharge pipe on site within the Vopak site boundary. The export pipelines which are outside the site boundary are excluded from the QRA. Assessment was undertaken only up to the site boundary limits.

No.	Initial event	Potential scenarios	Comment
8.	Tanker loading release	Jet fire Pool fire Flash fire	Pressurised release from loading line or arm, limited to the load-out pumping rate. Applicable to all fuels. Jet or pool fire depending on mist and rainout release. Flash fire applicable to gasoline only from pool evaporation after rainout from release. Different ignition probabilities used depending on flash point.
9.	Ethanol unloading release	Jet fire Pool fire	Pressurised release (~5 barg) from loading line or arm, limited to the import rate. Jet or pool fire depending on mist and rainout release. Flash fires envelope are usually small, will instantaneously flash back to the pool, resulting in a pool fire.
10.	Biodiesel unloading release	Jet fire Pool fire	Pressurised release (~5 barg) from loading line or arm, limited to the import rate. Jet or pool fire depending on mist and rainout release.

7. CONSEQUENCE ANALYSIS

7.1. Overview

Consequence analysis involves qualitative and/or quantitative review of the identified hazardous incidents to estimate the potential to cause injury, fatalities or damage to property or damage to the environment. In this study, the materials are flammable with minimal acute toxicity issues. Hence, only fire scenarios, including dispersion of flammable vapours were modelled.

The consequences of the following types of events were evaluated to determine the extent of impact from ignited hydrocarbon releases on Site B (as per Table 6.3):

- Jet fires
- Pool fires
- Flash Fires
- Tank full surface roof fires
- Tank bund fires
- Tank overfill ('Buncefield' scenario) resulting in flashfires.

For scenarios where the calculated release rate exceeds the process flow rate, the consequences were modelled using the process flow rate (eg pump discharge rate).

The inputs to the models and the results from the consequence analysis are provided in APPENDIX C with respect to the specified impairment criteria described in Section 5.4.

In addition to the bund and tank roof fires historically accounted for hydrocarbon storage tank consequence assessment, formation of a large vapour cloud due to gasoline tank overfill (such as those that have occurred in Buncefield and Jaipur in recent years) have been included. In the past, the industry considered these scenarios to be unlikely and they were not included in QRAs, for example the 2007 FHA (Ref.1) did not include this scenario.

7.2. Largest Impact Distance

The maximum extent of the worst case vapour cloud scenario from a gasoline tank overfill is approximately 540m (as per results in APPENDIX C Section C6). This does not extend outside the port area, ie the worst case consequences do not extend to any sensitive, residential or commercial land uses as defined in the HIPAP4 risk criteria.

7.3. Inclusion in QRA

All scenarios were included in the frequency assessment and QRA model, ie even if the consequence assessment showed that there was no significant impact outside the Site B boundary (eg small leak sizes). This to allow flexibility to provide input for onsite risk assessment in the updated MHF Safety Case, if required by Vopak.

8. FREQUENCY ANALYSIS

8.1. Overview

The frequency of an event is defined as the number of occurrences of the event over a specified time period; with the period in risk analysis generally taken as one year. Frequency analysis involves estimating the likelihood of occurrence of each of the identified hazardous scenarios considered in this study, using historical equipment failure frequencies and populating the Event Trees developed to characterise the accident pathways.

The overview methodology to estimate scenario frequencies is described in Section 5.5.

The following supporting data is included in APPENDIX D:

- Historical equipment leak frequencies
- Parts count
- Online time probability
- Probability of ignition
- Event Tree Analysis
- Outcome frequencies.
- Storage tank fire frequencies (including tank overfill).

8.2. Effect of Safeguards

APPENDIX D describes how safeguards have been accounted for in the QRA. In summary:

- The frequencies of tank overfill takes into account failure of the independent high level shutdown (SIL 2 equivalent failure rate), which initiates Terminal ESD.
- Operator initiated ESD for loss of containment has been assumed to occur at:
  - BLB1/BLB2 (maximum event contained within wharf bunded area)
  - Road tanker gantries. (maximum event contained within gantry area)
  - Tank overfill during ship import (ie additional to the high level shutdown).
- Activation by operator (10% probability of failure assumed) of the tank top foam pourers has been included on detection of a rim seal fire to prevent progression to a full surface tank top fire. Other types of fire protection have not been explicitly included as safeguard since these are after-event mitigation to reduce escalation effects rather than a preventative safeguard.

9. RISK ASSESSMENT

The risk results are presented as risk contours for both the current and future case operations. Risk contours for individual fatality and property damage and propagation were assessed and presented in the following sections.

Injury risks from heat radiation and/or explosion overpressure were not evaluated in this study as this criterion is applicable only for residential and sensitive use areas only. No such developments are present in the NSW Ports Port Botany precinct.

9.1. Individual Fatality Risk

The risk contours for the existing and future increased throughput operations are shown in Figure 9.1 and Figure 9.2, respectively.

In general, there is a noticeable increase in risk for all risk contour levels for the future case operation. This impact is due to:

- The addition of several new facilities around the Site B terminal, including:
  - Bulk Loading Berth 2 (BLB2) and additional dedicated pipeline(s) to site
  - Four new road tanker bays (Bay 7-9 for product export and Bay 10 for ethanol and biodiesel unloading).

  The addition of these new facilities introduces more leak sources around the terminal, hence increases the overall risk of the terminal operations.

- Increase in ship import rate

  This is mainly applicable for import from BLB2. The ship import rate forms an input to model the tank overfill consequence. In general, the higher the tank fill rate, the larger the potential flammable vapour cloud and the resulting ignited event. Consequently, this will contribute to higher risk levels.

- Increase in overall terminal throughput

  The total throughput for the future case operation was projected to be double of the current throughput (APPENDIX A). This increase in throughput implies that there is also an increase in frequency at which hydrocarbon can be released from terminal equipment and operation. Consequently, this will contribute to higher risk levels.

Comparison of the risk against the risk criteria is presented in Table 9.2. It shows that the risk criteria for offsite land uses are complied with for both current and future operations. The site boundary target is met for both existing and future operations.

TABLE 9.1: COMPARISON WITH INDIVIDUAL FATALITY RISK CRITERIA

Description	Risk criteria (per year)	Compliance with criteria?		Comments
		Current operations	Future operations	
Hospitals, child-care facilities and old age housing (sensitive land uses).	0.5×10^{-7}	Yes	Yes	The risk contours extend up to approximately (current case) 300m and (future case) 350m from the west and south eastern site boundary. However, there are no sensitive land uses in this area.
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use).	1×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current case) 235m and (future case) 285m from the eastern site boundary. However, there are no residential land uses in this area.
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).	5×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current and future case) 94m from the eastern site boundary. However, there are no commercial land uses in this area. The ACFS container warehouses to the south of Site B are industrial facilities with small numbers of people in ancillary offices rather than commercial offices with high populations or access by the general public. Hence this criterion is not applicable within the port area. Refer to the notes to Table 5.5 for further information).
Sporting complexes and active open space areas.	10×10^{-6}	Yes	Yes	The risk contours extend up to approximately (current and future case) 80m from the eastern site boundary. However, there are no recreational land uses in this area.
Target for site boundary.	50×10^{-6}	Yes	Yes	Wharf For both the existing and future case operations, the contour is retained at the wharf area. Site The site boundary target is met for existing and future operations, where the contour is kept on site.

FIGURE 9.1: INDIVIDUAL RISK CONTOUR (CURRENT OPERATION)

FIGURE 9.2: INDIVIDUAL RISK CONTOUR (PROJECTED FUTURE OPERATION)

9.2. Property Damage and Propagation Risk

Damage and propagation risk due to heat radiation impacts were assessed for both current and future case operations. Escalation risk models were prepared only for the heat radiation impacts, as explosion overpressure was not modelled in this QRA (refer to Section 5.3.4).

The damage and propagation risk contours (23 kW/m^2 heat radiation level) for the current and future case operations are presented in Figure 9.3 and Figure 9.4, respectively.

When comparing between the current and future case operation, there is a noticeable increase in risk level around the:

- Wharf/BLB2 area. This was expected as introduction of BLB2 to site operation contributes to higher risk arising from higher ship import and export activities.
- Proposed location of new road gantry bays (Bay 8-9 product export and Bay 10 ethanol/biodiesel unloading). This impact was expected since more leak sources are introduced to the terminal.
- B2 bund (near T-621 and T-622). This impact was observed due to the increased ship import rate leading to larger equilibrium pool fire diameter (still within the bunded area) due to tank overfill from the adjacent gasoline tanks (T-206/T-207/T-208).

Comparison of the risk against the risk criteria is presented in Table 9.2.

TABLE 9.2: COMPARISON WITH DAMAGE AND PROPAGATION RISK CRITERIA

Description	Risk criteria (per year)	Meets criteria?		Comments
		Current operations	Future operations	
Heat radiation of 23 kW/m^2 at neighbouring potentially hazardous installations or at land zoned to accommodate such installations.	50×10^{-6}	Yes	Yes	<u>Wharf</u> For both the existing and future case operations, the contour is retained at the wharf area. <u>Site</u> The site boundary target is met for existing and future operations, where the contour is kept on site.

FIGURE 9.3: DAMAGE AND PROPAGATION RISK CONTOUR (CURRENT OPERATION)

FIGURE 9.4: DAMAGE AND PROPAGATION RISK CONTOUR (PROJECTED FUTURE OPERATION)

9.3. Major Risk Contributors

For the future operations, the major risk contributors at three points were extracted from the individual fatality risk model (future case) and summarised in Table 9.3. The location of these analyses points are shown in Figure 9.5.

Risk analyses of major risk contributors at these selected points indicate that:

- Analysis Point 1: Eastern limit of 50 x 10^{-6} per year contour

  Gasoline jet fire from the new proposed road tanker loading gantry bay 8-9, pool/bund fires from T-624 and T-625 are the major risk contributors to the offsite risk at the 50 x 10^{-6} per year contour on the eastern limit of Site B (near Friendship Road). However, the risk contour at this level remains within the site boundary for the projected future case operation.

- Analysis Point 2: North-eastern limit of 1 x 10^{-6} per year contour

  Flash fires due to the gasoline tank overfill incidents ('Buncefield' scenario) are the major risk contributors to the offsite risk at the 1 x 10^{-6} per year contour. The same contributors apply for the 0.5 x 10^{-6} per year contour.

- Analysis Point 3: Southern limit of 5 x 10^{-6} per year contour

  Pool fires (including bund fires) are the major risk contributors to the offsite risk at the 5 x 10^{-6} per year contour. These events are generally close to the site in regards to the consequence distance.

FIGURE 9.5: LOCATION FOR ANALYSIS OF SIGNIFICANT RISK CONTRIBUTORS

TABLE 9.3: MAJOR RISK CONTRIBUTORS AT SELECTED POINTS (FUTURE CASE)

Location	Main risk contributors	
Eastern limit of 50 x 10^{-6} per year contour (Analysis Point 1)	**Scenario**	**Contribution at location**
	Jet Fire (Medium) – Road Tanker Bay 8-9 (Gasoline)	15%
	Tank Bund Fire T-624 (Ethanol)	11%
	Tank Bund Fire T-625 (Ethanol)	11%
	Pool fire - overfill of T-624 (Ethanol)	11%
	Pool fire - overfill of T-625 (Ethanol)	11%
North-eastern limit of 1 x 10^{-6} per year contour (Analysis Point 2)	**Scenario**	**Contribution at location**
	Flash Fire – overfill of T-206 (Gasoline)	24%
	Flash Fire – overfill of T-207 (Gasoline)	22%
	Flash Fire – overfill of T-208 (Gasoline)	19%
	Flash Fire – overfill of T-726 (Gasoline)	10%
	Flash Fire – overfill of T-942 (Gasoline)	9%
Southern limit of 5 x 10^{-6} per year contour (Analysis Point 3)	**Scenario**	**Contribution at location**
	Pool fire - overfill of T-730 (Gasoline)	51%
	Flash Fire – overfill of T-730 (Gasoline)	5%
	Flash Fire – overfill of T-728 (Gasoline)	5%
	Flash Fire – overfill of T-729 (Gasoline)	5%
	Flash Fire – (Large Pool) Bund 3A (Gasoline)	5%

9.4. Comparison with the Vopak Site B Stage 3 FHA

In 2007, Vopak proposed to install an additional nine storage tanks, three offsite pipelines and associated on-site facilities necessary for the increase storage and handling requirements. This development is known as the B3 area on the Site B terminal.

As part of the project requirements, a Final Hazard Analysis (FHA, Ref.1) was undertaken in accordance to NSW Department of Planning HIPAP 6. The FHA study assessed the then cumulative risk from the Site B operations with respect to the proposed changes, with risk contours generated to illustrate the risk levels.

Prior to this QRA study, the FHA report presented the latest cumulative risk contours for the Site B operations, as shown in Figure 9.6. A comparison with the FHA results was undertaken.

Both the 50 x 10^{-6} and 1 x 10^{-6} per year risk contours generated for this updated QRA study (current case which is representative of the B3 expansion) are larger than the contours produced in the FHA. This is due to:

- Differences in study scope

  The QRA included release scenarios from the BLB and the import pipeline to site, as well as releases from manifolds, pumps and pipework on site, whereas the FHA included equipment within the Site B boundary only.

- Level of details assessed

  The FHA mainly assessed large tank terminal fire scenarios (eg tank fires and road gantry releases). The QRA assessed in details the potential leak sources (ie parts count) for all equipment with significant hydrocarbon inventories.

- Inclusion of tank overfill (‘Buncefield’) scenario

  The QRA included the Buncefield scenario tank overfill scenarios and associated flammable clouds. In the past, the industry has previously considered these scenarios to be unlikely and have been excluded from hydrocarbon tank farm consequence assessment (the 2007 FHA did not include these scenarios).

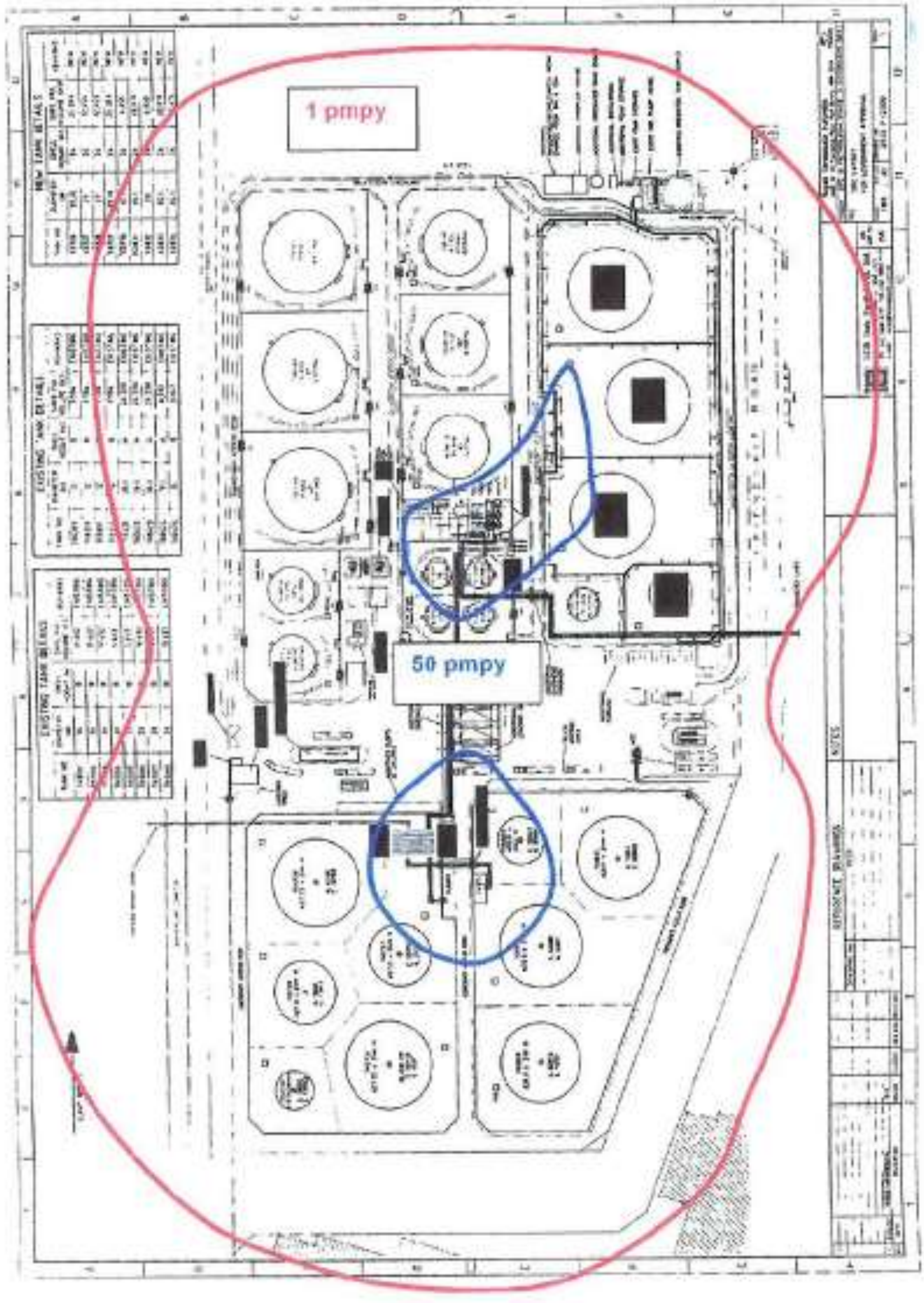

FIGURE 9.6: VOPAK SITE B STAGE 3 FHA – RISK CONTOURS (2007)

9.5. Comparison with Port Botany Land Use Study (Future Case Use)

To determine the potential impact on the Port Botany area, the risk contours reported in the Port Botany Land Use Safety Study (1996, Ref.5) have been reviewed. Figure 2 (which is the same as Figure 8) of the Land Use Safety Study shows risk contours for residential (1 x 10^{-6} per year) and industrial land use criteria (50 x 10^{-6} per year) and is shown in Figure 9.7.

The 1996 contours took into account various future developments, some that have now been implemented including the:

- BLB2 (developed in 2013)
- The then proposed (now constructed and operating) Vopak Stage B1 site
- Additional proposed storage towards Molineux Point to the south (which was not developed and has since been developed into container handing facilities, ie no hazardous materials).

Vopak Site B2 and B3 do not appear to be included.

Visual comparison of the Port Botany Land Use Safety Study (Figure 9.7) against the QRA results (projected future operation case):

- The 1 x 10^{-6} per year risk contour for Site B future case operation will be within the projected Port Botany future case use overall risk contour (1 x 10^{-6} per year).
- The 50 x 10^{-6} per year risk contour for Site B future case operation is contained within the Site B boundary and hence, it will be within the projected Port Botany future case use overall risk contour (50 x 10^{-6} per year).

Hence, there will be no significant effect on the cumulative risk as shown in the Port Botany Land Use Safety Study future use case.

9.6. Conclusions

Overall both the current and increased throughput case meet the applicable risk criteria. However it is recognised that in the increased throughput case, the risk contours extend further to the south and east into the ACFS site than in the current case. It is therefore recommended that:

- As part of the review of the emergency response plan (ERP) that will be required[3] for the proposed Site B throughput increase, Vopak with input from ACFS undertake a review of access/egress form the ACFS site to determine if any

[3] The ERP will require review for a number of reasons including as part of Vopak's internal change management process, also as a requirement of the WHS MHF regulations, and it is also expected the DPE will set a condition of consent relating to provision of an updated ERP as this is a standard condition as per HIPAP12 *Hazards-Related Conditions of Consent* for a change of this nature.

additional emergency access or exit provisions are required in the event of an incident in the southern or eastern parts of the Vopak site.

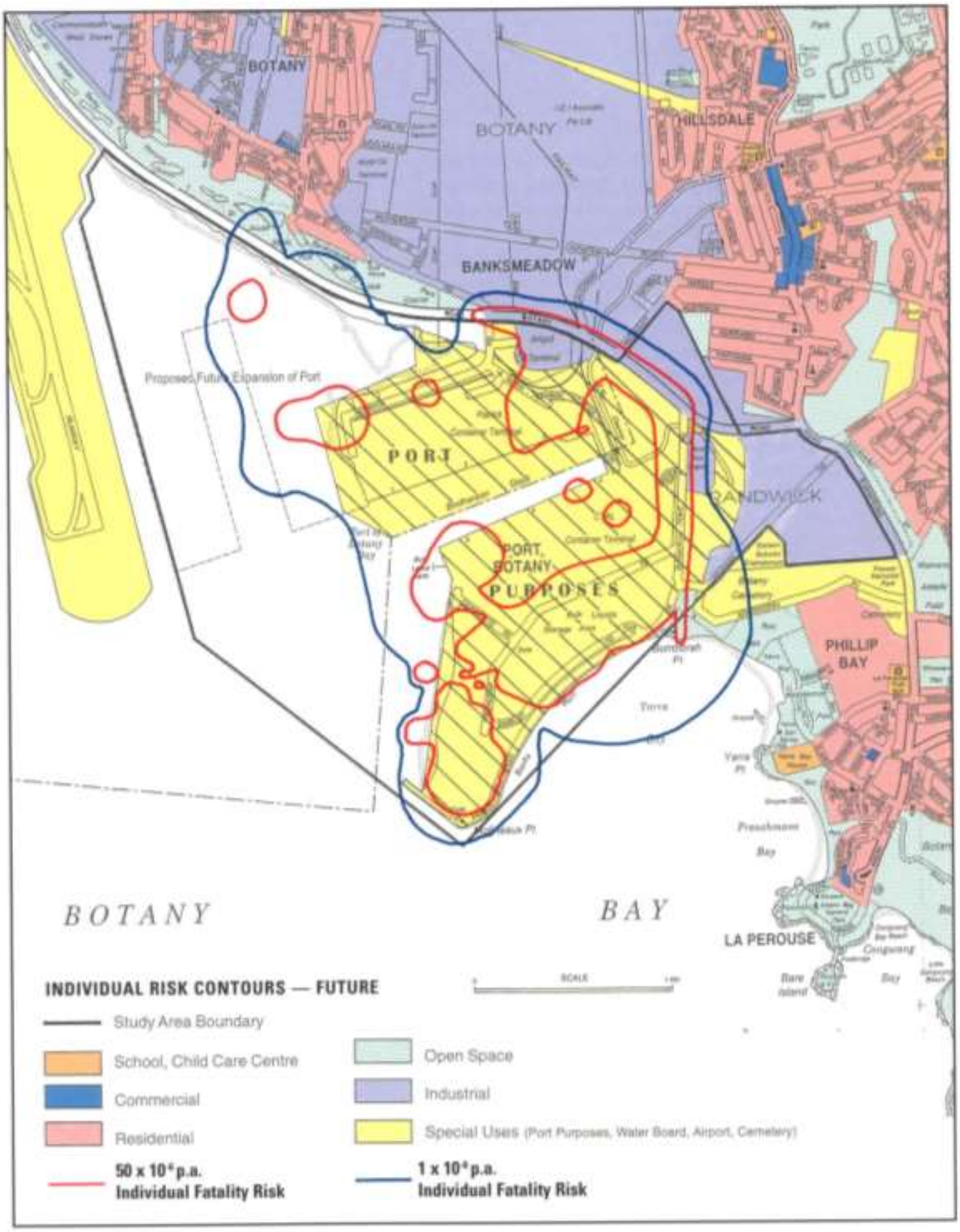

FIGURE 9.7: PORT BOTANY LAND USE STUDY – CUMULATIVE INDIVIDUAL RISK CONTOURS INCLUDING POSTULATED FUTURE DEVELOPMENT (1996)

APPENDIX A. OVERVIEW OF SITE B OPERATIONS AND QRA BASIS

The summary of terminal throughputs (ie product import and export) and QRA operational basis are presented in the following tables:

- Table A.1 – Product Throughput Current Case
- Table A.2 – Product Throughput Future Case
- Table A.3 – QRA Operational Basis.

The terminal throughputs were calculated based on the QRA operational basis data which were provided by Vopak. Operational throughputs in various sections of the terminal were estimated by Sherpa as appropriate for QRA input using the base data provided (and pro-rata calculation was applied for the proposed future operation where appropriate).

For the overall product throughput, it should be noted that the total product import did not exactly equal the product export, with the remaining amount reflecting the stock held in tanks.

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TABLE A.1: SUMMARY OF PRODUCT THROUGHPUT – CURRENT CASE

Summary of IMPORT Product Quantity (m^3/year)						
Product	**Gasoline**	**Diesel**	**Jet Fuel**	**Ethanol**	**Total by Mode**	**% by Mode**
Ship (BLB1)	1,218,700	606,600	520,300	29,500	2,375,100	95.6%
Road Tanker	-	-	-	1,594	1,594	0.02%
CTP	72,170	36,085	-	-	108,254	4.4%
Total by Product	1,290,870	642,685	520,300	31,094	**2,484,948**	
% by Product	49%	24%	21%	1%		

Summary of EXPORT Product Quantity (m^3/year)						
Product	**Gasoline**	**Diesel**	**Jet Fuel**	**Ethanol**	**Total by Mode**	**% by Mode**
CTP	109,152	54,576	-	-	163,728	6%
JUHI	-	-	555,241	-	555,241	19%
Road Gantry	1,365,706	682,853	150,000	-	2,198,559	75%
Total by Product	1,474,858	737428.95	705,241	0	**2,917,528**	
% by Product	51%	25%	24%	0%		

TABLE A.2: SUMMARY OF PRODUCT THROUGHPUT – FUTURE CASE (PROJECTED)

Summary of IMPORT Product Quantity (m^3/year)							
Product	**Gasoline**	**Diesel**	**Biodiesel**	**Jet Fuel**	**Ethanol**	**Total by Mode**	**% by Mode**
Ship (BLB1)	1,365,000	655,200	7,000	655,200	14,000	2,696,400	34%
Ship (BLB2)	2,535,000	1,216,800	13,000	1,216,800	26,000	5,007,600	63%
Road Tanker	-	-	22,000	-	100,000	122,000	2%
CTP	67,715	33,857	-	-	-	101,572	1%
Total by Product	3,967,715	1,905,857	42,000	1,872,000	140,000	**7,927,572**	
% by Product	50.0%	24.0%	0.5%	23.6%	1.8%		
Summary of EXPORT Product Quantity (m^3/year)							
Product	**Gasoline**	**Diesel**	**Biodiesel**	**Jet Fuel**	**Ethanol**	**Total by Mode**	**% by Mode**
Ship (BLB1)	302,400	185,400	6,000	101,400	12,000	607,200	8%
Ship (BLB2)	705,600	432,600	14,000	236,600	28,000	1,600,000	20%
CTP	560,000	280,000	-	-	-	840,000	11%
JUHI	-	-	-	1,320,000	-	1,320,000	17%
Road Gantry	2,344,230	1,112,767	-	259,646	-	3,716,643	47%
Total by Product	3,912,230	2,010,767	20,000	1,917,646	40,000	**7,900,643**	
% by Product	49.5%	25.5%	0.3%	24.3%	0.5%		

TABLE A.3: QRA OPERATIONAL BASIS

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
Vopak Site B Overview						
Site (Export) Throughput Total	2,693,000	m^3/year	2013 Budget Throughput	7,900,000	m^3/year	Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case Upper limit: 7,900,000 m3/year, to account for projected export of Biodiesel and Ethanol by Ship
Incoming Product Transfer						
Overview - Import	SHIP IMPORT (~2,375,000m3/year) Gasoline (51%) + Diesel (26%) + Jetfuel (22%), Ethanol (1%) Total no of ships: 145 Pumping time: 16.5 hours per transfer ROAD TANKER IMPORT (~1,600m3/year) Ethanol CTP PIPELINE (~100,000m3/year) Gasoline (67%) + Diesel (33%)			<u>SHIP IMPORT</u> (~7,700,000m3/year) Gasoline (50%) + Diesel (24%) + Jetfuel (24%), Ethanol and Biodiesel (2%) Total no of ships: 214 Cargo size: 1. 25,000 m3 (64 ships, 30%) - Berth time: 24 hours - Pump time: 16 hours 2. 35,000 m3 (54 ships, 25%) - Berth time: 30 hours - Pump time: 22 hours 3. 45,000 m3 (96 ships, 45%) - Berth time: 36 hours - Pump time: 28 hours <u>ROAD TANKER IMPORT</u> (~120,000m3/year) Biodiesel + Ethanol <u>CTP PIPELINE (~100,000m3/year)</u> Gasoline (67%) + Diesel (33%)		Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Import) Note: Dead time for ship operations ~8 hours Defined in accordance to Pilot-to-Pilot by Port Definition. QRA to use the pumping time only.
(BLB 1) Import Transfer Rate	820	m^3/hr	Calculated: - Shipping frequency for the whole year - Shipping pattern (type of ships/year) - Total import volume across all products - Average no of cargos/ship: 2 - Average pumping time: 16.5 hrs	1,250	m^3/hr	<u>Capacity:</u> BLB1 - 2,500 m3/hr (2x1,250 m3/hr) BLB2 - 3,500 m3/hr (2x1,750 m3/hr) each berth have 2 arms and 2 wharf lines. <u>Note:</u> 1. Individual tank inlets is to be designed to achieve 1,750 m3/hr. 2. At the moment, fill into tank is procedurally limited to 1,250 m3/hr such that it does not exceed the 7m/s velocity to prevent static accumulation. 3. For assessment: 1,250 m3/hr (BLB1 average)
(BLB1) Import Transfer Pressure	7	barg	As provided by Vopak (Shipping Pattern)	10	barg	As advised by Vopak Transfer Pressure for BLB1: 5-10 barg Upper limit taken at 10 barg for assessment.

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(BLB1) Online Time - Import Berth Time	-	-	-	2,314	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Import) Total no of ships: 214 Cargo size: - 25,000 m3 (64 ships, 24hrs berth time) - 35,000 m3 (54 ships, 30hrs berth time) - 45,000 m3 (96 ships, 36hrs berth time) Import Philosophy: BLB1:35% and BLB2: 65%
(BLB1) Online Time - Import Pumping Time	2,393	hours/year	Calculated, based on: - 145 ships per year (2012-2013) - 16.5 hrs pumping time	1,715	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Import) Total no of ships: 214 Cargo size: - 25,000 m3 (64 ships, 16hrs pumping time) - 35,000 m3 (54 ships, 22hrs pumping time) - 45,000 m3 (96 ships, 28hrs pumping time) Import Philosophy: BLB1:35% and BLB2: 65%
(BLB1) % Wharf Online - Import Berth Time	-	-	-	26%	per year	Pumping Time + Dead Time
(BLB1) % Wharf Online - Import Pumping Time	27%	per year	-	20%	per year	Pumping Time only
(BLB 2) Import Transfer Rate	-	-	Not Operational (July 2013)	1,750	m^3/hr	Capacity: BLB1 - 2,500 m3/hr (2x1,250 m3/hr) BLB2 - 3,500 m3/hr (2x1,750 m3/hr) each berth have 2 arms and 2 wharf lines. Note: 1. Individual tank inlets is to be designed to achieve 1,750 m3/hr. 2. At the moment, fill into tank is procedurally limited to 1,250 m3/hr such that it does not exceed the 7m/s velocity to prevent static accumulation. 3. For assessment: 1,750 m3/hr (BLB2 average)
(BLB2) Import Transfer Pressure	-	-	Not Operational (2013)	10	barg	As advised by Vopak Transfer Pressure for BLB2: 5-10 barg Upper limit taken at 10 barg for assessment.

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(BLB2) Online Time - Import Berth Time	-	-	Not Operational (July 2013)	4,298	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Import) Total no of ships: 214 Cargo size: - 25,000 m3 (64 ships, 24hrs berth time) - 35,000 m3 (54 ships, 30hrs berth time) - 45,000 m3 (96 ships, 36hrs berth time) Import Philosophy: BLB1:35% and BLB2: 65%
(BLB2) Online Time - Import Pumping Time	-	-	Not Operational (July 2013)	3,185	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Import) Total no of ships: 214 Cargo size: - 25,000 m3 (64 ships, 16hrs pumping time) - 35,000 m3 (54 ships, 22hrs pumping time) - 45,000 m3 (96 ships, 28hrs pumping time) Import Philosophy: BLB1:35% and BLB2: 65%
(BLB2) % Wharf Online - Import Berth Time	-	-	Not Operational (July 2013)	49%	per year	Pumping Time + Dead Time
(BLB2) % Wharf Online - Import Pumping Time	-	-	Not Operational (July 2013)	36%	per year	Pumping Time only
(CTP) Average no of transfers/month	2	transfer/mth	As provided ("Throughput Summary")	1	transfer/mth	As advised by Vopak
(CTP) Average quantity/per transfer	8,972	m^3/transfer	Calculated based on transfer quantity (Jan 2013 - May 2013)	8,333	m^3/transfer	As advised by Vopak
(CTP) Transfer Rate	553	m^3/hr	Calculated based on transfer rate (Jan 2013 - May 2013)	1,000	m^3/hr	As advised by Vopak
(CTP) Transfer Pressure	7	barg	As advised by Vopak	7	barg	As advised by Vopak
(CTP) Import Online Time	428	hours/year	Calculated, based on: - 2 transfer/month - 8.972 m3/transfer - 12 months/year - 553 m3/hr average transfer rate	100	hours/year	Calculated, based on: - 1 transfer/month - 8,333 m3/transfer - 12 months/year - 1,000 m3/hr average transfer rate
(CTP) % Import Online Time	5%	per year	-	1%	per year	-
(RT - Ethanol) Average no of transfers/month	4	transfer/mth	Assumed 1/week, 1 hr per operation	251	transfer/mth	Calculated, based on: - 100ML annual import throughput by Road Tanker - Average road tanker: 33,210L - 12 months/year
(RT - Ethanol) Average quantity per transfer	33,210	litre/transfer		33,210	litre/transfer	As advised by Vopak
(RT - Ethanol) Transfer Rate	60	m^3/hr	As advised by Vopak	60	m^3/hr	As advised by Vopak

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(RT - Ethanol) Transfer Pressure	5	barg	As advised by Vopak	5	barg	As advised by Vopak
(RT - Ethanol) Online Time	52	hours/year	-	1,667	hours/year	Calculated, based on: - Number of transfer per month - 12 months/year - Average quantity per transfer - Transfer rate
(RT - Ethanol) % Gantry Online Time	1%	per year	-	19%	per year	-
(RT - Biodiesel) Average no of transfers/month	-	-	Not part of operations (2013)	55	transfer/mth	Calculated, based on: - 22ML annual import throughput by Road Tanker - Average road tanker: 33,210L - 12 months/year (~663 trucks)
(RT - Biodiesel) Average quantity per transfer	-	-	Not part of operations (2013)	33,210	litre/transfer	As advised by Vopak
(RT - Biodiesel) Transfer Rate	-	-	Not part of operations (2013)	60	m^3/hr	As advised by Vopak
(RT - Biodiesel) Transfer Pressure	-	-	Not part of operations (2013)	5	barg	As advised by Vopak
(RT - Biodiesel) Online Time	-	-	Not part of operations (2013)	367	hours/year	Calculated, based on: - Number of transfer per month - 12 months/year - Average quantity per transfer - Transfer rate
(RT - Biodiesel) % Gantry Online Time	-	-	Not part of operations (2013)	4%	per year	-
Outgoing Product Transfer						
Overview - Export	ROAD TANKER EXPORT (~2,200,000 m3/year) Majority of product export Gasoline (62%) + Diesel (31%) + Jetfuel (7%) CTP PIPELINE (~164,000 m3/year) Gasoline (67%) + Diesel (33%) JUHI PIPELINE (~555,000 m3/year) Jet Fuel only			SHIP EXPORT (~2,000,000 m3/year) Gasoline (50%) + Diesel (31%) + Jetfuel (17%), Ethanol and Biodiesel (2%) Total no of ships: 82 Cargo size: 1. 10,000 m3 (12 ships 15%) - Berth time: 16 hours - Pump time: 8 hours 2. 20,000 m3 (21 ships, 25%) - Berth time: 25 hours - Pump time: 17 hours 3. 30,000 m3 (49 ships, 60%) - Berth time: 33 hours - Pump time: 25 hours ROAD TANKER EXPORT (~3,700,000 m3/year) Majority of product export Gasoline (63%) + Diesel (30%) + Jetfuel (7%) CTP PIPELINE (~850,000 m3/year) Gasoline (67%) + Diesel (33%) JUHI PIPELINE (~1,320,000 m3/year) Jet Fuel only		Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Note: Dead time for ship operations ~8 hours Defined in accordance to Pilot-to-Pilot by Port Definition. QRA to use the pumping time only.

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(BLB1) Export Transfer Rate	-	-	Not part of operations (Jan 2014)	1,250	m^3/hr	Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Note: For assessment: 1,250 m3/hr (BLB1 average - upper limit) Calculated based on: - Cargo size (m3) - Pumping time (hrs)
(BLB1) Export Transfer Pressure	-	-	Not part of operations (Jan 2014)	10	barg	As advised by Vopak Transfer Pressure for BLB1: 5-10 barg Upper limit taken at 10 barg for assessment.
(BLB1) Online Time - Export Berth Time	-	-	Not part of operations (Jan 2014)	700	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Total no of ships: 82 Cargo size: - 10,000 m3 (12 ships, 16hrs berth time) - 20,000 m3 (21 ships, 25hrs berth time) - 30,000 m3 (49 ships, 33hrs berth time) Export Philosophy: BLB1: 30% and BLB2: 70%
(BLB1) Online Time - Export Pumping Time Only	-	-	Not part of operations (Jan 2014)	503	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Total no of ships: 82 Cargo size: - 10,000 m3 (12 ships, 8hrs pumping time) - 20,000 m3 (21 ships, 17hrs pumping time) - 30,000 m3 (49 ships, 25hrs pumping time) Export Philosophy: BLB1: 30% and BLB2: 70%
(BLB1) % Wharf Online - Export Berth Time	-	-	Not part of operations (Jan 2014)	8%	per year	Pumping Time + Dead Time
(BLB1) % Wharf Online - Export Pumping Time	-	-	Not part of operations (Jan 2014)	6%	per year	Pumping Time only
(BLB2) Export Transfer Rate	-	-	Not part of operations (Jan 2014)	1,250	m^3/hr	Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Note: For assessment: 1,250 m3/hr (BLB2 average - upper limit) Calculated based on: - Cargo size (m3) - Pumping time (hrs)

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(BLB2) Export Transfer Pressure	-	-	Not part of operations (Jan 2014)	10	barg	As advised by Vopak Transfer Pressure for BLB2: 5-10 barg Upper limit taken at 10 barg for asessment.
(BLB2) Online Time - Export Berth Time	-	-	Not part of operations (Jan 2014)	1,634	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Total no of ships: 95 Cargo size: - 10,000 m3 (12 ships, 16hrs berth time) - 20,000 m3 (21 ships, 25hrs berth time) - 30,000 m3 (49 ships, 33hrs berth time) Export Philosophy: BLB1: 30% and BLB2: 70%
(BLB2) Online Time - Export Pumping Time Only	-	-	Not part of operations (Jan 2014)	1,175	hours/year	Calculated Ref: Berth Occupancy Study (Rev G) Projected 2030 Operation - Mid Case (Export) Total no of ships: 95 Cargo size: - 10,000 m3 (12 ships, 8hrs pumping time) - 20,000 m3 (21 ships, 17hrs pumping time) - 30,000 m3 (49 ships, 25hrs pumping time) Export Philosophy: BLB1: 30% and BLB2: 70%
(BLB 2) % Wharf Online - Export Berth Time	-	-	Not part of operations (Jan 2014)	19%	per year	Pumping Time + Dead Time
(BLB2) % Wharf Online - Export Pumping Time	-	-	Not part of operations (Jan 2014)	13%	per year	Pumping Time only
(Road Tanker) Number of daily movements	169	per day	As advised by Vopak - 169 vehicles/day Forecast Year 2016 - 266 vehicles/day 30% Single; 70% B-Double	306	per day	As advised by Vopak Year 2012 - 169 vehicles/day 70% Single; 30% B-Double 66% Increase
(Road Tanker) Number of liquid loading arm connection	123,370	times/year	Average 169 vehicles/day across all products 2 connection each (coupling and decoupling)	335,070	times/year	Average 306 vehicles/day across all products 3 connections each A road tanker can have up to 5 compartments to store different products (eg ULP, ULP95, ULP98, etc). However not all tankers would be filled/equipped this way, hence an average of 3 connections is used. Additionally, in the future, it is expected that there will be more B-doubles onsite. The average 3 connections per tanker is still deemed as appropriate across all tankers as average

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(Road Tanker) Average Load	33,210	L/tanker	As advised by Vopak	33,210	L/tanker	As advised by Vopak
(Road Tanker) Average Loading Time	25	minutes/loadout	As advised by Vopak	25	minutes/loadout	As advised by Vopak
(Road Tanker) Average Loading Rate	80	m^3/hr	Calculated based on the above assumption Note: 1. Actual pump rate is 120m3/hr. Allowing for connection/disconnection ~80m3/hr 2. Maximum loading rate is 3 arms each at 2,400 litres/minute per truck	80	m^3/hr	Calculated based on the above assumption Note: 1. Actual pump rate is 120m3/hr. Allowing for connection/disconnection ~80m3/hr 2. Maximum loading rate is 3 arms each at 2,400 litres/minute per truck
(Road Tanker) % Gantry Online Time	100%	per year	Assumption (High demand, assumed always in operation) Average 169 vehicles/day across all products Average time to load is 25 minutes ~70 hrs/day across all bays	100%	per year	Assumption (High demand, assumed always in operation)
(JUHI Pipeline) Average no of transfers/month	6	transfer/month	As provided ("Throughput Summary")	11	transfer/month	As advised by Vopak
(JUHI Pipeline) Average duration/transfer	24	hrs/transfer	Calculated based on transfer duration (Jan 2013 - May 2013)	24	hrs/transfer	Calculated based on transfer duration (Jan 2013 - May 2013)
(JUHI Pipeline) Transfer Pressure	36	barg	Transfer pump (70m head ~7 barg) Booster pump (290m head ~ 29 barg)	45	barg	Transfer pump (70m head ~7 barg) Booster pump (380m head ~ 38 barg)
(JUHI Pipeline) Transfer Rate	332	m^3/hr	As provided ("Throughput Summary")	415	m^3/hr	As advised by Vopak Maximum pumping rate
(JUHI Pipeline) Average quantity/per transfer	7,978	m^3/transfer	Calculated based on transfer rate and duration (Jan 2013 - May 2013)	10,000	m^3/transfer	As advised by Vopak
(JUHI Pipeline) Online Time (Static)	8,760	hours/year	Line is kept full at all times (post transfer)	8,760	hours/year	Line is kept full at all times (post transfer)
(JUHI) Online Time (Pumping)	1,670	hours/year	Pumping Mode	3,168	hours/year	Calculated, based on: - 11 transfer/month - 12 months/year - 24 hours/transfer
(JUHI) % Pipeline Online Time (Static)	100%	per year	-	100%	per year	-
(JUHI) % Pipeline Online Time (Pumping)	19%	per year	-	36%	per year	-
(CTP) Average no of transfers/month	2	transfer/month	As provided ("Throughput Summary")	7	transfer/month	As advised by Vopak

	Current Operation			Proposed Future Operation (Mid Case - 2030)		
(CTP) Average duration/transfer	16	hrs/transfer	Calculated based on transfer quantity and rate (Jan 2013 - May 2013)	10	hrs/transfer	Calculated based on transfer duration and rate (Proposed Future Operation)
(CTP) Average quantity/per transfer	7,580	m^3/transfer	Calculated based on transfer quantity (Jan 2013 - May 2013)	10,000	m^3/transfer	As advised by Vopak
(CTP) Transfer Pressure	24	barg	Transfer pump (70m head ~7 barg) Booster pump (170m head ~ 17 barg)	40	barg	Transfer pump (70m head ~7 barg) Booster pump (330m head ~ 33 barg)
(CTP) Transfer Rate	480	m^3/hr	Calculated based on transfer duration (Jan 2013 - May 2013)	1,000	m^3/hr	As advised by Vopak
(CTP) % Pipeline Online Time (Static)	8,760	hours/year	Line is kept full at all times (post transfer)	8,760	hours/year	Line is kept full at all times (post transfer)
(CTP) Online Time (Pumping)	341	hours/year	Calculated, based on: - 2 transfer/month - 7.580 m3/transfer - 12 months/year - 480 m3/hr average transfer rate	840	hours/year	Calculated, based on: - 7 transfer/month - 10,000 m3/transfer - 12 months/year - 1,000 m3/hr average transfer rate
(CTP) % Pipeline Online Time (Static)	100%	per year	-	100%	per year	-
(CTP) % Pipeline Online Time (Pumping)	4%	per year	-	10%	per year	-

APPENDIX B. HAZARD IDENTIFICATION TABLE

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Product leak from: - BLB/Wharf - Import Pipeline - Manifold	- Valve stem leak. - Flange/gasket leak. - Pipework leak.	- Jet/spray fire if ignited. - Mist and pool evaporation, flash fire if sufficient vapours and ignited.	- Daily operational check of terminal. - Leaks observed by operator during manual opening and closing of valves during tank filling. - Ignition source control onsite.	Yes
Loading arm failure (BLB1/BLB2)	Ship movement (bad weather, poor monitoring)	Pool fire (including combustion products), if ignited. Potential spill into sea and environmental impact.	- Sydney Ports weather advisory (ship unloading stopped during bad weather) - Loading arm instrumented trip triggered by ship movement (position switches on loading arm) - Manual detection (attended operation) - Shutdown of pumping and remote isolation of valves. - Foam and cooling water application via hydrants and monitors (fixed/ portable). - Spill collection boom and emergency response.	Yes
Loading arm equipment pipework integrity failure	Corrosion/wear and tear	Routine operator surveillance. 10 yearly inspections. Attended operation (wharf watch and shore officer)	- Routine operator surveillance. - Loading arm inspections prior to commencement of transfer. - Attended operation - Manual detection (attended operation) - Shutdown of pumping and remote isolation of valves. - Foam and cooling water application via hydrants and monitors (fixed/ portable). - Spill collection boom and emergency response.	Yes

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Pipework failure (within the Terminal)	- Corrosion - Impact - Maintenance work - Pressure surge	- Major spillage of flammable material. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- Regular maintenance and inspection procedures - Emergency isolation valves - Fire fighting system (including foam) - Pipes in bunded areas - Pipelines surge study - The piping is designed to ASME 31.3 / AS 4041 to resist the combined effects on internal pressure due to contents, wind loads, earthquake forces and hydrostatic test loads	Yes
Pipeline failure (external to the Terminal)	- Corrosion - Impact - Maintenance work - Pressure surge	- Major spillage of flammable material. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- Regular maintenance and inspection procedures - Emergency isolation valves - Fire fighting system (including foam) - Pipelines surge study - Routine inspections during transfers	Yes
Tank overfill	- Failure of tank gauging system or failure to monitor adequately by operator - Human error – failure to line-up or changeover to correct tank.	- Pool fire and potential full-surface bund fire. - Tank roof fire and escalation to adjacent tanks. - Flash fire and vapour cloud explosion (RMG/PMG only).	- High high level trip (equivalent to SIL2) on each tank that is independent to gauging system for filling. Initiates terminal ESD. - Tank levels checked every 30 minutes during transfer. - Slow fill rates during changeover. - Foam system on tanks for extinguishing fire. - Water cooling rings on each tank for exposure protection if a tank fire occurs.	Yes

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Leak from tank	- Tank rupture - Fitting leak on tank connection.	- Pool fire in bund. - Potential full surface fire if rupture of tank or connection. - Flash fire and vapour cloud explosion	- Remote actuated emergency shutdown valves on tank outlet line. - Daily operational check of terminal. - Leaks observed by operator during manual opening and closing of valves during tank filling. - 10 yearly tank inspection and tests including hydrostatic pressure test. - Ignition source control onsite (tank bunds classified Zone 2 hazardous areas).	Yes
Major mechanical failure of tank	- Metal fatigue - Faulty fabrication - Corrosion of tank base / weld - Tank explosion due to lightning strike / breach of hazardous area ignition source controls - Adjacent tank on fire - Blocked vent - Fitting leak on tank connection.	- Large spillage of flammable materials in bund. Fire if ignited - Potential full surface bund fire if rupture of tank or connection. - Flash fire / explosion - For historical tank explosions, some tanks have rocketed away from the foundations - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- Remote actuated emergency shutdown valves on tank outlet line. - Daily operational check of terminal. - Leaks observed by operator during manual opening and closing of valves during tank filling. - 10 yearly tank inspection and tests including hydrostatic pressure test. - Ignition source control onsite (tank bunds classified Zone 2 hazardous areas). - Tank designed to API 650 - Regular maintenance and inspection procedures - Tank and site fire protection facilities available - Explosions only occur when ullage vapour is between LEL and UEL. At steady state conditions, diesel ullage is below LEL and gasoline ullage is above UEL. All bulk tanks have floating roofs. Design conforms to AS1940 requirements. Slops tanks are nitrogen padded	Yes

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Flammable atmosphere in tank vapour space between external dome and IFR	- Damage to floating roof resulting in sinking or partial sinking (eg nitrogen blowthrough from clearing import line or pontoon damage) - Vents blocked during filling procedure -	- Ignition by lightning / breach of hazardous area ignition source controls / hot work on tank or high velocity filling resulting in static during filling tank. Results in ○ Initial explosion in tank vapour space ○ rim seal fire (floating roof tanks) ○ leading to a tank full surface area fire - Potential for spill into the bund with a bund fire - Boil over possible if water layer exists - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- Internal floating roof (IFR) with mechanical shoe seal minimises vapour egress - External domed roof protects IFR from rain water accumulation and minimises likelihood of lightening leading to rim seal fires - Regular tank dewatering minimised water in tanks - Permit to work controls - Regular maintenance and inspection procedures - Level alarms, controlled tank filling - Filling rate less than critical velocity for static. - Site earthing of equipment. - 10 yearly tank inspection and tests including roof inspection. - Full tank surface foam injection system (remote and local activation both possible)	Tank top full surface fire is included in QRA model (Rim seal fires and internal explosions in tank vapour space not included).

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Spillage of flammable material to the bunds	- Tank overfilled during transfer - Tank drain valve left open or tank sampling valve left open, e.g. human error - Loss of containment at pigging stations - IBC or additive tank leak	- Spill into bund - Bund fire if ignited - Possible tank fire and boil over -	- Fire fighting (as above) and mobile foam monitors - Two independent tank level devices installed - Emergency shutdown system - Operating procedures - High level alarms in bund sump and also slops tanks - Tank sample and dewatering valves are double valved with last valve spring-closed (deadman). - Other drain valves etc are blanked off or in the manifold area have camlok dry-breaks	Yes
Pump leak	- Pump seal failure. - Valve stem leak. - Flange/gasket leak. - Pipework leak.	- Jet/spray fire if ignited. - Mist and pool evaporation, flash fire if sufficient vapours and ignited.	- Daily operational check of terminal. - Condition monitoring and preventative maintenance of pumps - Emergency stop buttons on site shut pumps and tank outlet valves. - Pumps operated during tanker loading only which is a manned operation. Pumps located approx. 20 m from road tanker gantry. - Condition monitoring and preventative maintenance of pumps - Drain to the sump tank which is level alarmed in major pump pits B2 and B3. - Ignition source control onsite (pump raft classified Zone 2 hazardous areas). - Fire fighting system (fire detection and foam deluge on B2/B3 pumps)	Yes
Leak at vapour recovery unit	Failure of vessel due to corrosion or other cause	- Potential for fires and environmental impact	- Regular maintenance and inspection procedures - Stoppage of road tanker filling - Fire fighting systems as above	No (small hydrocarbon inventory)

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Fire involving additive storage	- Container rupture due to handling error during delivery to site. - Impact by road tanker. - Pump leak during blending.	- Pool fire if ignited.	- Additives delivered in tote tanks with protection cage (or iso-tanks), limiting inventory size and providing some impact protection. - Additives also delivered in 20 m^3 iso-tanker. - Low pump dosing rate. - Grading to drains, bunding.	No Small inventory same bunded areas as other larger flammable inventories
Leak during filling of road tanker	- Failure of flexible connection / hose - Leak from valves or fittings - Tanks overfill due to incorrect parcel size entered.	- Leak of petroleum product in loading area - Fire if ignited - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- AIP bottom loading arm with dry break coupling - High level of surveillance and use of leak detection & shutdown systems - Truck overfill shutdown system with 2 actuated valves in series - Vopak Safe Load Program and drivers are well trained so as to minimise chance of operator error & ensure quick response to leaks - Road tanker bays fitted with fire detection which automatically initiates foam deluge system - Ignition sources controlled - Truck maintenance audits	Yes
Road tanker drive-away incident	Failure of procedures and hardware interlocks	- Leak of petroleum product in loading area - Fire if ignited - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion) Note: Ignition source present (road tanker engine), hence fire more likely	- Driver training - Driver not in cab during filling - Loading line is NRV protected - Brakes interlocked prior to connection and until disconnection - Road tanker bays fitted with automatic foam deluge system - "Dry-break" hose couplings - Truck sump has manual pump-out system and containment designed in accordance to AS1940	Yes

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Ethanol tanker unloading leak	- Driver error in coupling. - Truck driveaway while connected.	- Pool fire if ignited. - Evaporation from pool and flammable vapour cloud.	- Manned operation. - Procedures. - Ignition source control onsite (pump raft and ethanol unloading classified Zone 2 hazardous areas).	Yes
Road accident (off-site)	Bad road or traffic conditions	- Most likely outcome is no loss of load - Leak may occur, leading to fire - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- Design of road tankers to survive accident without a loss of containment - pipes and running gear designed to shear off - Driver training and choice of routes to reduce accident potential	No (outside of Site B)
Aircraft crash	- Pilot error - Bad weather - Plane fault	- Propagation to tank / bund fires - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	- As per aviation standards	No
Strong winds, earthquakes	Strong winds causes equipment damage	Loss of containment leading to a fire if ignited (as above)	- The tanks are designed API 650 / AS 1692 / AS 1170 to resist the combined effects on internal pressure due to contents, weight of platforms, ladders, live loads, wind loads, earthquake forces and hydrostatic test loads - Operations stopped in adverse weather conditions	No

Scenario	Cause	Possible Consequences	Safeguards	Included in QRA
Breach of Security / Sabotage	Disgruntled employee or intruder	- Possible release of product with consequences as per above	- Security measures include fencing, CCTV, intruder beams, security patrols, operator / driver vigilance (as per MHF security plan) - Process SCADA computer alarms monitored - Drain valves etc are blanked off or in the manifold area have cam-lock dry-breaks - Pressure tests prior to transfer - Pipe inspections prior to transfer	No

APPENDIX C. CONSEQUENCE ANALYSIS

The following types of event were evaluated to determine the characteristics of unignited and ignited scenarios of hydrocarbon releases on Site B:

- Jet fires
- Pool fires
- Flash Fires
- Tank roof fires
- Tank bund fires
- Tank overfill ('Buncefield' scenario).

Consequence analysis was undertaken for both current (2013) and projected future operation of the Site B terminal. These results are presented in the following sections.

Main differences between the current and projected future operations include:

1. Increased product throughput (eg via road tanker and pipeline exports)
2. Increased ship import rate (BLB2)
3. Increased product export rate (eg pressure and quantity).

C1. Jet fires

Jet fire results for the current and future case operations are summarised in Table C.1 and Table C.2, respectively. These tables provide the dimensions of the jet fires for each identified release conditions (ie based on the product type and pressure) for release sizes less than 25mm, as per rule set outlined in Table 5.2. Additionally, distance to heat radiation levels of interest (as per Table 5.4) are also reported.

These results represent continuous release without isolation which represents the worst case scenario for any given leak.

TABLE C. 1: JET FIRE CONSEQUENCE RESULTS – CURRENT OPERATION

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Jet Fire (at wind speed 6 m/s)						
					Length (m)	Width (m)	Distance to Heat Radiation (m)				
							4.7 kW/m^2	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
CURRENT OPERATION											
Ship Import (BLB1/2) Pipeline - CTP Import Manifold B1, B2, B3 Pipework Road Gantry	Gasoline	7	2	0.1	3	1	7	5	5	5	4
			6	0.6	8	3	18	15	14	13	12
			22	7.8	23	10	59	48	44	40	39
Pipeline (CTP - Export)	Gasoline	24	2	0.1	3	1	8	6	6	5	5
			6	1.1	9	4	22	18	16	15	15
			22	14.1	27	11	71	57	53	48	47
Ship Import (BLB1/2) Manifold B1, B2, B3 Pipework	Diesel	7	2	0.1	3	1	6	5	5	4	4
			6	0.6	7	3	18	14	13	12	12
			22	7.9	22	10	58	47	43	40	38
Pipeline (CTP - Export)	Diesel	24	2	0.1	3	1	8	6	6	5	5
			6	1.1	9	3	21	17	16	15	14
			22	14.3	27	11	69	56	52	47	46
Pipeline - Ship Import (BLB1) Pipework (Manifold to Tank)	Jet Fuel	7	2	0.1	3	1	6	5	5	4	4
			6	0.6	7	3	18	15	13	12	12
			22	7.8	23	10	58	47	43	40	39

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Jet Fire (at wind speed 6 m/s)						
					Length (m)	Width (m)	Distance to Heat Radiation (m)				
							4.7 kW/m^2	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
Pipeline (JUHI - Export)	Jet Fuel	36	2	0.1	4	1	8	7	6	6	6
			6	1.3	9	4	22	18	17	16	15
			22	17.2	28	11	73	60	55	51	49
Pipeline - Ship Import (BLB1) Pipework (Manifold to Tank)	Ethanol (Ship Import)	7	2	0.1	3	1	5	4	4	4	4
			6	0.6	9	3	14	13	12	11	11
			22	8.2	29	9	48	42	40	38	37

TABLE C. 2: JET FIRE CONSEQUENCE RESULTS – FUTURE OPERATION (PROJECTED)

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Jet Fire (at wind speed 6 m/s)						
					Length (m)	Width (m)	Distance to Heat Radiation (m)				
							4.7 kW/m^2	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
FUTURE OPERATION											
Ship Import (BLB1/2) Manifold B1, B2, B3 Pipework Road Gantry Ship Export (BLB1/2)	Gasoline	10	2	0.1	3	1	7	6	5	5	5
			6	0.7	8	3	19	15	14	13	13
			22	8.5	24	10	62	50	46	43	41
Pipeline (CTP - Import)	Gasoline	7	2	0.1	3	1	7	5	5	5	4
			6	0.6	8	3	18	15	14	13	12
			22	7.8	23	10	59	48	44	40	39
Pipeline (CTP - Export)	Gasoline	40	2	0.2	4	1	8	7	6	6	6
			6	1.4	9	4	23	19	17	16	16
			22	18.4	29	11	74	60	55	51	49
Ship Import (BLB1/2) Manifold B1, B2, B3 Pipework Road Gantry Ship Export (BLB1/2)	Diesel	10	2	0.1	3	1	7	5	5	5	4
			6	0.7	8	3	19	15	14	13	13
			22	9.4	24	10	61	49	45	42	41
Pipeline (CTP – Import	Diesel	7	2	0.1	3	1	6	5	5	4	4
			6	0.6	7	3	18	14	13	12	12
			22	7.9	22	10	58	47	43	40	38

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Jet Fire (at wind speed 6 m/s)						
					Length (m)	Width (m)	Distance to Heat Radiation (m)				
							4.7 kW/m^2	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
Pipeline (CTP - Export)	Diesel	40	2	0.2	4	1	8	7	6	6	6
			6	1.4	9	4	23	19	17	16	15
			22	18.6	29	11	71	58	54	50	48
Ship Import (BLB1/2) Pipework (Manifold to Tank) Ship Export (BLB1/2)	Jet Fuel	10	2	0.1	3	1	7	5	5	5	4
			6	0.7	8	3	19	15	14	13	13
			22	9.2	24	10	61	50	46	42	41
Pipeline (JUHI - Export)	Jet Fuel	45	2	0.2	4	1	8	7	6	6	6
			6	1.4	10	4	24	19	18	16	16
			22	19.4	29	11	73	59	55	51	49
Ship Import (BLB1/2) Manifold B1, B2, B3 Pipework	Ethanol	10	2	0.1	4	1	5	5	4	4	4
			6	0.7	10	3	15	13	13	12	12
			22	9.6	31	9	51	45	42	40	40
Road Gantry (Ethanol Import)	Ethanol	5	2	0.1	3	1	5	4	4	4	4
			6	0.5	7	3	14	12	11	11	11
			22	7.0	27	9	46	40	38	36	35
Road Gantry (Biodiesel Import)	Biodiesel	5	2	0.1	3	1	6	5	5	4	4
			6	0.6	7	3	18	14	13	12	12
			22	7.9	22	10	58	47	43	40	38

C2. Pool fires

Pool fire results for the current and future case operations are summarised in Table C.3 and Table C.4, respectively. The reported results include the release rate, equivalent pool diameter and distance to heat radiation levels of interest (as specified in Table 5.4).

In this assessment, liquid hydrocarbon from a leak was assumed to form a circular pool (spreading in all directions), unless limited by the bund. Subsequently, the pool fire dimensions were calculated assuming equilibrium where the burn rate equals the release rate of the material.

The fire duration and potentially the size of a pool fire is dependent upon the time to detect and stop a leak. These results generally represent continuous release without isolation which represents the worst case scenario for any given leak. The size of the liquid pool in most areas may also be limited by bunds, the terrain and drainage.

The limiting size used in the QRA for different release locations were:

- BLB Import pipelines: 491 m^2
  - Basis - limited by the physical terrain of Fishburn Road and pipeline corridor located adjacent to Botany Bay
  - Equivalent to 25 m pool diameter based on the width of Fishburn Road).
  - Spills at the BLB1 / 2 were also constrained to a maximum of 25m equivalent diameter as ESD was assumed to occur with a few minutes.
- Manifold: 600 m^2
  - Basis - limited by the kerbing provided around the manifold which would limit pool growth for large releases
  - Equivalent to 27.6 m pool diameter.
- Pipework to/from manifold: 600 m^2
  - Basis - limited by the kerbing/drainage provided around the pipework routes, assumed similar as limiting size for the manifold
  - Equivalent to 27.6 m pool diameter.
- Booster Pump: 600 m^2
  - Basis – CTP and JUHI booster pumps are located in close vicinity to the main transfer manifold, limited by the kerbing provided around the manifold which would limit pool growth for large releases
  - Equivalent to 27.6 m pool diameter.
- Intermediate Bund and Full Bund
  - Basis – Any large releases from major tank leaks will be contained within the bund (intermediate and/or full bund).
  - Bund sizes are provided in Table 3.3.

TABLE C. 3: POOL FIRE CONSEQUENCE RESULTS – CURRENT OPERATION

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Pool Fire (at wind speed 6 m/s)					
						Flame Length	4.7 kW/m3	10 kW/m2	14 kW/m2	20 kW/m2	23 kW/m2\
CURRENT OPERATION											
Gasoline Tanks	Gasoline	-	Overfill	171	62.9	63	105	84	75	66	63
Diesel Tanks	Diesel	-	Overfill	189	78.6	66	110	88	79	68	66
Jet Fuel Tanks	Jet Fuel	-	Overfill	182	77.1	66	109	87	78	68	66
Ethanol Tanks	Ethanol	-	Overfill	180	86.9	118	201	158	143	131	127
Ship Import (BLB1)	Gasoline	7	85	117	52.1	31	48	39	35	31	31
			Full Bore	171*	62.9	31	48	39	35	31	31
Manifold B1, B2, B3 Pipework	Gasoline	7	85	117	52.1	33	53	42	38	34	33
			Full Bore	171*	62.9	33	53	42	38	34	33
Pipeline - CTP Import	Gasoline	7	85	115	51.6	33	53	42	38	34	33
			Full Bore	115*	51.6	33	53	42	38	34	33
Road Gantry	Gasoline	7	85	25	24.1	30	47	38	34	30	30
			Full Bore	25*	24.1	30	47	38	34	30	30
Pipeline (CTP - Export)	Gasoline	24	85	100	48.1	51	82	66	59	52	51
			Full Bore	100*	48.1	51	82	66	59	52	51
Ship Import (BLB1)	Diesel	7	85	118	62.2	31	47	38	34	30	31
			Full Bore	189*	78.6	31	47	38	34	30	31
Manifold B1, B2, B3 Pipework	Diesel	7	85	118	62.2	33	52	42	38	33	33
			Full Bore	189*	78.6	33	52	42	38	33	33

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Pool Fire (at wind speed 6 m/s)					
						Flame Length	4.7 kW/m^3	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m$^{2\backslash}$
Pipeline - CTP Import	Diesel	7	85	118	62.2	33	52	42	38	33	33
			Full Bore	127*	64.5	33	52	42	38	33	33
Road Gantry	Diesel	7	85	28	30.1	29	45	36	33	29	29
			Full Bore	28*	30.1	29	45	36	33	29	29
Pipeline (CTP - Export)	Diesel	24	85	111	60.1	51	83	67	60	53	51
			Full Bore	111*	60.1	51	83	67	60	53	51
Ship Import (BLB1)	Jet Fuel	7	85	117	61.8	32	51	41	37	32	32
			Full Bore	182*	77.1	32	51	41	37	32	32
Manifold B1, B2, B3 Pipework	Jet Fuel	7	85	117	61.8	35	56	45	40	35	35
			Full Bore	182*	77.1	35	56	45	40	35	35
Pipeline (JUHI - Export)	Jet Fuel	36	85	74	49.1	44	70	56	50	44	44
			Full Bore	74*	49.1	44	70	56	50	44	44
Road Gantry	Jet Fuel	7	85	27	29.5	29	46	37	33	29	29
			Full Bore	27*	29.5	29	46	37	33	29	29
Ship Import (BLB1)	Ethanol	7	85	122	101.7	57	83	68	64	60	59
			Full Bore	180*	123.5	57	83	68	64	60	59
Manifold B1, B2 Pipework	Ethanol	7	85	122	101.7	61	88	73	68	64	63
			Full Bore	180*	123.5	61	88	73	68	64	63

TABLE C. 4: POOL FIRE CONSEQUENCE RESULTS – FUTURE OPERATION (PROJECTED)

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Pool Fire (at wind speed 6 m/s)					
						Flame Length	4.7 kW/m^3	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
FUTURE OPERATION											
Gasoline Tanks	Gasoline	-	Overfill	365	92	86	145	115	104	91	86
Diesel Tanks	Diesel	-	Overfill	403	115	90	152	121	109	96	90
Jet Fuel Tanks	Jet Fuel	-	Overfill	389	113	83	141	112	101	88	83
Ethanol Tanks	Ethanol	-	Overfill	384	87	118	201	158	143	131	127
Ship Import (BLB1/2) Ship Export (BLB1/2)	Gasoline	10	85	138	25	31	48	39	35	31	31
			Full Bore	365*	25	31	48	39	35	31	31
Manifold Pipework	Gasoline	10	85	138	25	33	53	42	38	34	33
			Full Bore	365*	25	33	53	42	38	34	33
Pipeline - CTP Import	Gasoline	7	85	117	28	33	53	42	38	34	33
			Full Bore	208*	28	33	53	42	38	34	33
Road Gantry (RTL 1-7)	Gasoline	10	85	25*	24	30	47	38	34	30	30
			Full Bore	25*	24	30	47	38	34	30	30
Road Gantry (RTL 8-9)	Gasoline	10	85	25*	24	26	40	32	29	26	26
			Full Bore	25*	24	26	40	32	29	26	26
Pipeline CTP - Export	Gasoline	40	85	208*	69	67	111	88	79	70	67
			Full Bore	208*	69	67	111	88	79	70	67

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Pool Fire (at wind speed 6 m/s)					
						Flame Length	4.7 kW/m^3	10 kW/m^2	14 kW/m^2	20 kW/m^2	23 kW/m^2
Ship Import (BLB1/2) Ship Export (BLB1/2)	Diesel	10	85	140	25	30	47	38	34	30	30
			Full Bore	403*	25	30	47	38	34	30	30
Manifold Pipework	Diesel	10	85	140	28	33	52	42	38	33	33
			Full Bore	403*	28	33	52	42	38	33	33
Pipeline - CTP Import	Diesel	7	85	118	28	33	52	42	38	33	33
			Full Bore	231*	28	33	52	42	38	33	33
Road Gantry (RTL 1-7)	Diesel	10	85	28*	30	29	45	36	33	29	29
			Full Bore	28*	30	29	45	36	33	29	29
Road Gantry (RTL 8-9)	Diesel	10	85	28*	30	25	39	32	29	25	25
			Full Bore	28*	30	25	39	32	29	25	25
Pipeline CTP - Export	Diesel	40	85	231*	87	69	115	92	83	73	69
			Full Bore	231*	87	69	115	92	83	73	69
Ship Import (BLB1/2) Ship Export (BLB1/2)	Jet Fuel	10	85	138	25	32	51	41	37	32	32
			Full Bore	389*	25	32	51	41	37	32	32
Manifold Pipework	Jet Fuel	10	85	138	28	35	56	45	40	35	35
			Full Bore	389*	28	35	56	45	40	35	35
Pipeline JUHI - Export	Jet Fuel	45	85	92*	55	48	78	62	56	49	48
			Full Bore	92*	55	48	78	62	56	49	48

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Pool Fire (at wind speed 6 m/s)					
						Flame Length	4.7 kW/m3	10 kW/m2	14 kW/m2	20 kW/m2	23 kW/m2
Road Gantry	Jet Fuel	7	85	27*	30	29	46	37	33	29	29
			Full Bore	27*	30	29	46	37	33	29	29
Ship Import (BLB1/2) Ship Export (BLB1/2)	Ethanol	10	85	144	25	57	83	68	64	60	59
			Full Bore	384*	25	57	83	68	64	60	59
Manifold Pipework	Ethanol	10	85	144	28	61	88	73	68	64	63
			Full Bore	384*	28	61	88	73	68	64	63
Road Gantry (Import RTL10)	Ethanol	5	85	13*	15	38	60	49	45	43	42
			Full Bore	13*	15	38	60	49	45	43	42
Road Gantry (Import RTL10)	Biodiesel	5	85	14*	15	18	30	24	22	19	18
			Full Bore	14*	15	18	30	24	22	19	18

Note:
1. * indicates that the release rate is limited by the process/transfer flow rate
2. Where appropriate, pool growth from large liquid releases of liquid are limited by physical restriction on site (eg by design - kerbing and bunding). These include areas such as the import pipeline, transfer manifold and pump manifold.

C3. Flash Fires

Apart from the tank overfill scenario, vapour clouds result from the evaporation of light components of releases of gasoline which pool on the ground. Similar to pool fires, the maximum size of a pool can be limited by bund walls. The limiting sizes are described in Section C.2 (Pool fires).

The rate of evaporation and the dispersion characteristics from a spill are dependent on the weather conditions. Apart from tank overfill scenarios, the modelling showed that flammable clouds only develop under very stable and low wind speed condition (represented by F2 weather stability class).

Flash fire modelling was only undertaken for gasoline due to the presence of hydrocarbon 'light ends' (typically C4-C5), which are not prevalent for heavier fuel such as diesel and jet fuels. Typical vapour clouds from gasoline spills are denser than air.

Consequence modelling was also undertaken for ethanol. However, the results indicate that the flammable vapour cloud downwind distances are very small and less than the pool diameter. Hence, it was assumed that pool fire is the more likely scenario as the small vapour cloud may directly flash back to the source pool resulting in a pool fire.

The results for the vapour cloud dispersion (unignited case) and flash fire (ignited case) assessment are summarised as follows:

- Major leaks from storage tanks resulting in pool evaporation of bund contents resulting in flammable vapour clouds (Table C.5)
- Current operation: small, medium and large releases (Table C.6)
- Future operation: small, medium and large releases (Table C.7).

Modelling results for flash fires are reported in terms of fire width and length to 50% LFL and 100% LFL concentrations for each isolatable section.

Flash fires were modelled for steady state (equilibrium) case assuming a continuous release without isolation or detection, and therefore represent the worst case cloud size. Ignition of the cloud before equilibrium would result in a smaller flash fire.

TABLE C. 5: FLASH FIRE CONSEQUENCE RESULTS – STORAGE TANKS (MAJOR LEAK – POOL EVAPORATION)

Tank ID	Product	Bund Area (m^2)	Equivalent Pool Diameter (m)	Flash Fire - Distance to LEL (m)								
				D6			E4			F2		
				Evap Rate (kg/s)	Length	Width	Evap Rate (kg/s)	Length	Width	Evap Rate (kg/s)	Length	Width
TK105	Gasoline	1351	41	15	-	-	11	-	-	6	49	95
TK206	Gasoline	2046	51	22	-	-	16	-	-	9	64	124
TK207	Gasoline	2071	51	22	-	-	16	-	-	9	64	124
TK208	Gasoline	2100	52	22	-	-	16	-	-	9	65	126
TK726	Gasoline	3020	62	31	-	-	23	-	-	13	82	156
TK727	Gasoline	1878	49	20	-	-	15	-	-	9	61	118
TK728	Gasoline	1865	49	20	-	-	15	-	-	9	61	118
TK729	Gasoline	2959	61	31	-	-	23	-	-	13	82	156
TK730	Gasoline	1296	41	14	-	-	10	-	-	6	48	94
TK941	Gasoline	1243	40	14	-	-	10	-	-	6	47	92
TK942	Gasoline	3026	62	31	-	-	23	-	-	13	82	158
Bund B1-2	Gasoline	6217	89	62	-	-	45	-	-	26	128	240
Bund B1-3	Gasoline	2321	54	24	-	-	18	-	-	10	69	133
Bund B3A	Gasoline	11018	118	107	-	-	78	-	-	45	183	340
Bund B3B	Gasoline	10115	113	71	-	-	52	-	-	30	140	264

TABLE C. 6: FLASH FIRE CONSEQUENCE RESULTS – CURRENT OPERATION

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Flash Fire - Distance to LEL (m) - F2		
						Evap Rate (kg/s)	Length	Width
CURRENT OPERATION								
Ship Import (BLB1/2)	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	25.0	2.0	23	41
			85	117	25.0	2.3	25	45
			RUP	171	25.0	2.4	26	51
Manifold B1, B2, B3 Pipework	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	27.6	2.3	26	48
			85	117	27.6	2.8	28	56
			RUP	171	27.6	2.8	29	57
Pipeline - CTP Import	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	24.1	2.3	25	44
			85	115	27.6	2.8	28	55
			RUP	115	27.6	2.8	29	56
Road Gantry	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	24.1	2.0	23	44
			85	25	24.1	2.0	23	44
			RUP	25	24.1	2.0	23	44
Pipeline (CTP - Export)	Gasoline	24	2	0.1	4.6	0.07	-	-
			6	1.1	14.2	0.6	-	-
			22	14.1	48.1	7.6	56	107
			85	100	48.1	14.3	86	164
			RUP	100	48.1	14.3	86	164
Note: For D6 and E4 stability classes, there were no vapour cloud generated that reach the LFL envelope								

TABLE C. 7: FLASH FIRE CONSEQUENCE RESULTS – FUTURE OPERATION (PROJECTED)

Component/ Equipment	Product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Equivalent Pool Diameter (m)	Flash Fire - Distance to LEL (m) - F2		
						Evap Rate (kg/s)	Length	Width
FUTURE OPERATION								
Ship Import (BLB1/2) Ship Export (BLB1/2)	Gasoline	10	2	0.1	3.8	0.04	-	-
			6	0.7	11.5	0.4	-	-
			22	9.3	25.0	2.0	23	41
			85	138	25.0	2.3	25	45
			RUP	365	25.0	2.4	26	51
Manifold B1, B2, B3 Pipework	Gasoline	10	2	0.1	3.8	0.04	-	-
			6	0.7	11.5	0.4	-	-
			22	9.3	25.0	2.3	26	48
			85	138	27.6	2.8	28	56
			RUP	365	27.6	2.8	29	57
Pipeline CTP Import	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	24.1	2.3	25	44
			85	117.1	27.6	2.8	28	55
			RUP	208	27.6	2.8	29	56
Road Gantry	Gasoline	7	2	0.1	3.5	0.04	-	-
			6	0.6	10.5	0.3	-	-
			22	7.8	24.1	2.0	23	44
			85	25	24.1	2.0	23	44
			RUP	25	24.1	2.0	23	44
Pipeline CTP - Export	Gasoline	40	2	0.2	5.3	0.09	-	-
			6	1.4	16.1	0.75	-	-
			22	18.4	60.2	9.8	66	129
			85	208	69.4	15	88	169
			RUP	208	69.4	15	88	169
Note: For D6 and E4 stability classes, there were no vapour cloud generated that reach the LFL envelope								

C4. Tank Roof Fire

The tank top full surface area fire scenario was assessed to represent the collapse of internal floating roof resulting in a full surface roof fire and subsequent collapse of the external roof. The tank bund fire consequence results are presented in Table C.9.

TABLE C. 8: TANK ROOF FIRE CONSEQUENCE RESULTS

Tank Number	Diameter (m)	Height (m)	Product	Distance (m) to Heat Radiation from Tank Centre - 6 m/s (Perpendicular - worst case distance)					
				Flame Length	4.7 kW/m²	10 kW/m²	14 kW/m²	20 kW/m²	23 kW/m²
TK101	36	18	Jet Fuel	44	70	56	50	44	44
TK102	36	18	Jet Fuel	44	70	56	50	44	44
TK103	36	18	Jet Fuel	44	70	56	50	44	44
TK104	20	18	Jet Fuel	27	42	34	30	27	27
TK105	20	18	Gasoline	26	40	32	29	26	26
TK206	28	18	Gasoline	34	53	43	39	34	34
TK207	28	18	Gasoline	34	53	43	39	34	34
TK208	28	18	Gasoline	34	53	43	39	34	34
TK309	12	18	Gasoline	17	26	21	19	17	17
TK310	12	18	Diesel	17	25	20	19	17	17
TK311	12	18	Gasoline	17	26	21	19	17	17
TK312	12	18	Gasoline	17	26	21	19	17	17
TK621	36.6	24	Diesel	42	66	53	48	42	42
TK622	36.6	24	Diesel	42	66	53	48	42	42
TK623	36.6	24	Jet Fuel	44	71	57	51	45	44
TK624	19.1	24	Ethanol	48	70	58	54	51	50
TK625	15	18	Ethanol	41	63	52	48	45	44
TK726	37.75	24	Gasoline	43	69	56	50	44	43
TK727	27	24	Gasoline	33	52	42	38	33	33
TK728	27	24	Gasoline	33	52	42	38	33	33
TK729	37.75	24	Gasoline	43	69	56	50	44	43
TK730	16.5	24	Gasoline	22	34	27	25	22	22
TK940	35	24	Diesel	40	64	51	46	40	40
TK941	20	24	Gasoline	26	40	32	29	26	26
TK942	35.9	24	Gasoline	41	66	53	48	42	41
TK943	35.9	24	Diesel	41	65	52	47	41	41

C5. Tank Bund Fire

This scenario was assessed to represent mechanical failure / leaks from storage tank forming a large pool which may cover up to the full bund area (eg instantaneous release). The tank bund fire consequence results are presented in Table C.9.

TABLE C. 9: TANK BUND FIRE CONSEQUENCE RESULTS

Compound	Bund Surface area (m^2)	Equivalent Diameter (m)	Product	Distance (m) to Heat Radiation from Bund Centre (at wind speed 6 m/s)					
				Flame Length	4.7 kW/m²	10 kW/m²	14 kW/m²	20 kW/m²	23 kW/m²
TK101	2854	60	Jet Fuel	67	111	88	79	69	67
TK102	2835	60	Jet Fuel	67	111	88	79	69	67
TK103	2816	60	Jet Fuel	67	111	88	79	69	67
TK104	1334	41	Jet Fuel	49	79	63	57	50	49
TK105	1351	41	Gasoline	47	75	60	54	48	47
TK206	2046	51	Gasoline	56	92	73	66	58	56
TK207	2071	51	Gasoline	56	92	73	66	58	56
TK208	2100	52	Gasoline	56	92	73	66	58	56
TK621	3737	69	Diesel	70	116	93	83	73	70
TK622	3689	69	Diesel	70	116	93	83	73	70
TK623	3597	68	Jet Fuel	73	123	98	88	77	73
TK624	1340	41	Ethanol	77	115	94	87	81	80
TK625	991	36	Ethanol	71	105	86	80	75	74
TK726	3020	62	Gasoline	65	108	86	77	68	65
TK727	1878	49	Gasoline	53	87	70	63	55	53
TK728	1865	49	Gasoline	53	87	70	63	55	53
TK729	2959	61	Gasoline	65	108	86	77	68	65
TK730	1296	41	Gasoline	46	74	59	53	47	46
TK940	2878	61	Diesel	64	105	84	75	66	64
TK941	1243	40	Gasoline	45	73	58	52	46	45
TK942	3026	62	Gasoline	65	108	86	77	68	65
TK943	2968	61	Diesel	64	105	84	75	66	64
Bund B1-1	11189	119	Jet Fuel	118	203	161	145	127	118
Bund B1-2	6217	89	Gasoline	88	148	118	106	94	88
Bund B1-3	2321	54	Gasoline	58	96	77	69	61	58
Bund B2	13354	130	Diesel	120	204	163	147	130	120
Bund B3A	11018	118	Gasoline	117	192	152	137	121	117
Bund B3B	10115	113	Dodecane	106	181	144	130	114	106

C6. Tank Overfill – Vapour Cloud/Flash Fire

In addition to the bund and tank roof fires historically accounted for in hydrocarbon tank farm consequence assessment, flash fire scenarios due to large spills of hydrocarbons (such as those that have occurred in Buncefield and Jaipur in recent years) have been included. The industry has previously considered these scenarios to be unlikely and have been excluded from hydrocarbon tank farm QRAs

The investigations into the Buncefield (2005) and Jaipur (2009) events have not yet fully explained the severity of the explosion and resulting damage to surrounding buildings due to high overpressures. However a number of common factors have been identified in the incidents that have occurred including:

- Potential for overfill of hydrocarbon containing volatile material that continues undetected for some time
- Low wind speed, stable atmospheric conditions
- An ignition source in the vicinity
- Factors that may result in localised congestion or confinement of the dispersing flammable vapours.

A tank was overfilled and released product (gasoline) subsequently cascaded over the tank edge/girder resulting in large amounts of spray and vapour formation due to vaporisation of volatile components and formation of very fine hydrocarbon droplets.

Loss of containment of gasoline due to tank overfill and the extent of the flammable cloud envelope was modelled following the UK HSE's Vapour Cloud Assessment (VCA) method, which provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident.

UK HSE VCA Method

In 2013, the UK HSE and the industry body the Fire and Blast Information Group (FABIG) have issued a model for use based on the Health Safety and Laboratory (HSL) paper that can be used to estimate cloud sizes for zero wind speed conditions (Ref. 9). This is primarily dependent on falling droplets drawing in air as they spray, forming a cold, well-mixed flammable cloud that moves due to gravity and local eddies rather than bulk air windspeed. The technique, (known as the UK HSE VCA model) can also be applied to large leaks from tank failures.

The technique provides a more specific model for assessing the physical behaviour of an overfill from a specific tank geometry and uses empirical correlations to predict a mass addition rate and concentration of hydrocarbon in the initial cloud from a cascading overfill. An extension of this correlation can also be applied to overfills and large leaks from tank base / flange failures to estimate the extent of the LEL (for zero windspeeds only).

TABLE C. 10: TANK OVERFILL – FLASH FIRE CONSEQUENCE RESULTS

Tank ID	Product	Diameter (m)	Height (m)	Distance to LFL (m) (30 min release duration, assumed worst case assumes both high level trip and operator initiated ESD have failed)			
				Current Operation (820 m^3/hr)		Future Operation (1750 m^3/hr)	
				Length	Width	Length	Width
TK105	Gasoline	20	18	362	362	409	409
TK206	Gasoline	28	18	407	407	458	458
TK207	Gasoline	28	18	407	407	458	458
TK208	Gasoline	28	18	407	407	458	458
TK309	Gasoline	12	18	304	304	345	345
TK311	Gasoline	12	18	304	304	345	345
TK312	Gasoline	12	18	304	304	345	345
TK726	Gasoline	37.75	24	480	480	538	538
TK727	Gasoline	27	24	427	427	480	480
TK728	Gasoline	27	24	427	427	480	480
TK729	Gasoline	37.75	24	480	480	538	538
TK730	Gasoline	16.5	24	360	360	406	406
TK941	Gasoline	20	24	384	384	433	433
TK942	Gasoline	35.9	24	472	472	529	529
Note: Width of the LFL cloud is assumed to be similar to the LFL downwind distance ('Length'). This is consistent with CFD modelling results undertaken as part of the Buncefield investigation but may be affected by specific bund and building configurations.							

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APPENDIX D. FREQUENCY ANALYSIS

D1. Equipment leak frequencies

Table D.1 gives the historical equipment leak frequencies. Data from the OGP Risk Assessment Data Directory was used where available (Ref. 9). For process equipment, the ‘Full Releases’ leak frequencies were used.

TABLE D.1: HISTORICAL EQUIPMENT LEAK FREQUENCIES

Equipment type and size	Frequency (per year) by Hole Size[1]					Source
	2 mm	6 mm	22 mm	85 mm	Full bore	
Process piping (50 mm)	5.5E-05	1.8E-05	7.0E-06			OGP
Process piping (150 mm)	2.6E-05	8.5E-06	2.7E-06	6.0E-07		OGP
Process piping (300 mm)	2.3E-05	7.6E-06	2.4E-06	3.7E-07	1.7E-07	OGP
Process piping (450 mm)	2.3E-05	7.5E-06	2.4E-06	3.6E-07	1.7E-07	OGP
Process piping (600 mm)	2.3E-05	7.4E-06	2.4E-06	3.6E-07	1.6E-07	OGP
Process piping (900 mm)	2.3E-05	7.4E-06	2.4E-06	3.6E-07	1.6E-07	OGP
Flange, raised face (50 mm)	2.6E-06	7.6E-07	1.2E-06			OGP
Flange, raised face (150 mm)	3.7E-06	1.1E-06	9.0E-07	6.0E-07		OGP
Flange, raised face (300 mm)	5.9E-06	1.7E-06	1.4E-06	1.8E-07	3.4E-07	OGP
Flange, raised face (450 mm)	8.3E-06	2.4E-06	2.0E-06	2.6E-07	3.6E-07	OGP
Flange, raised face (600 mm)	1.1E-05	3.2E-06	2.6E-06	3.3E-07	3.8E-07	OGP
Flange, raised face (900 mm)	1.7E-05	4.9E-06	4.2E-06	5.4E-07	4.4E-07	OGP
Valve Actuating (50 mm)	2.4E-04	7.3E-05	3.0E-05			OGP
Valve Actuating (150 mm)	2.2E-04	6.6E-05	1.9E-05	8.6E-06		OGP
Valve Actuating (300 mm)	2.1E-04	6.3E-05	1.8E-05	2.4E-06	6.0E-06	OGP
Valve Actuating (450 mm)	2.0E-04	6.0E-05	1.7E-05	2.3E-06	5.9E-06	OGP
Valve Actuating (600 mm)	2.0E-04	5.9E-05	1.7E-05	2.2E-06	5.9E-06	OGP
Valve Actuating (900 mm)	1.9E-04	5.6E-05	1.6E-05	2.2E-06	5.9E-06	OGP
Valve Manual (50 mm)	2.0E-05	7.7E-06	4.9E-06			OGP
Valve Manual (150 mm)	3.1E-05	1.2E-05	4.7E-06	2.4E-06		OGP
Valve Manual (300 mm)	4.3E-05	1.7E-05	6.5E-06	1.2E-06	1.7E-06	OGP
Valve Manual (450 mm)	5.3E-05	2.1E-05	8.0E-06	1.5E-06	1.9E-06	OGP
Valve Manual (600 mm)	6.2E-05	2.4E-05	9.4E-06	1.8E-06	2.1E-06	OGP
Valve Manual (900 mm)	7.8E-05	3.0E-05	1.2E-05	2.2E-05	2.3E-06	OGP
Instrument fitting	1.8E-04	6.8E-05	2.5E-05			OGP
Filter	1.3E-03	5.1E-04	1.9E-04	3.5E-05	2.0E-05	OGP
Pump Centrifugal	5.1E-03	1.8E-03	5.9E-04	9.7E-05	4.8E-05	OGP
Tank Rupture					3.0E-06	OGP
Loading arm – per operation (Road Tanker & Ship)[2]			3.0E-07		3.0E-08	TNO Purple Book
Major Tank Failure (1000mm hole)					1.0E-04	DNV Report Buncefield

Note: 1. Piping release frequencies are per metre-year.
2. Hole sizes are 10% of diameter up to a max of 50mm & full bore

D3. Parts Count

A parts count was completed for the terminal areas and operations type where a potential for hydrocarbon release was identified.

The Site B terminal was rationalised into 6 systems, including:

- WHF (Wharf)
- SHP (Import Pipeline)
- PPW (Pipework)
- MAN (Manifold)
- PMP (Pumps)
- RTL (Road Tanker Gantry).

These systems were further expanded for parts count based on the product handled and the type of operation (eg import, export or both). These sections are summarised in Table D.2.

The export pipeline is excluded from the QRA as the scope was limited only to the site boundary and does not account for cumulative risks from other adjacent facilities within the NSW Ports site which utilise the same export pipeline corridor.

The parts count and line length calculations were undertaken using the P&IDs and site layout diagrams listed in Table D.3.

TABLE D.2: SECTIONS DEFINED FOR THE QRA

Section ID	Scenario description	Area Description
WHF-01G	BLB1 Ship Import - Gasoline	Wharf
WHF-02D	BLB1 Ship Import - Diesel	Wharf
WHF-03J	BLB1 Ship Import - Jet Fuel	Wharf
WHF-04E	BLB1 Ship Import - Ethanol	Wharf
WHF-05G	BLB2 Ship Import - Gasoline	Wharf
WHF-06D	BLB2 Ship Import - Diesel	Wharf
WHF-07J	BLB2 Ship Import - Jet Fuel	Wharf
WHF-08E	BLB2 Ship Import - Ethanol	Wharf
WHF-09G	BLB1 Ship Export - Gasoline	Wharf
WHF-10D	BLB1 Ship Export - Diesel	Wharf
WHF-11J	BLB1 Ship Export - Jet Fuel	Wharf
WHF-12G	BLB2 Ship Export - Gasoline	Wharf
WHF-13D	BLB2 Ship Export - Diesel	Wharf
WHF-14J	BLB1 Ship Export - Ethanol	Wharf
WHF-15E	BLB2 Ship Export - Ethanol	Wharf
WHF-16E	BLB2 Ship Export - Jet Fuel	Wharf
SHP-01G	BLB1 Ship Import PPL - Gasoline	Import Pipeline
SHP-02D	BLB1 Ship Import PPL - Diesel	Import Pipeline

Section ID	Scenario description	Area Description
SHP-03J	BLB1 Ship Import PPL - Jet Fuel	Import Pipeline
SHP-04E	BLB1 Ship Import PPL - Ethanol	Import Pipeline
SHP-05G	BLB2 Ship Import PPL - Gasoline	Import Pipeline
SHP-06D	BLB2 Ship Import PPL - Diesel	Import Pipeline
SHP-07J	BLB2 Ship Import PPL - Jet Fuel	Import Pipeline
SHP-08E	BLB2 Ship Import PPL - Ethanol	Import Pipeline
SHP-09G	BLB1 Ship Export PPL - Gasoline	Export Pipeline
SHP-10D	BLB1 Ship Export PPL - Diesel	Export Pipeline
SHP-11J	BLB1 Ship Export PPL - Jet Fuel	Export Pipeline
SHP-12G	BLB2 Ship Export PPL - Gasoline	Export Pipeline
SHP-13D	BLB2 Ship Export PPL - Diesel	Export Pipeline
SHP-14J	BLB2 Ship Export PPL - Jet Fuel	Export Pipeline
SHP-15E	BLB2 Ship Import PPL - Ethanol	Import Pipeline
SHP-16E	BLB2 Ship Export PPL - Ethanol	Export Pipeline
PPW-01G	Manifold to B1 T-105 (Gasoline)	Pipework
PPW-02G	Manifold to B1 T206-208 (Gasoline)	Pipework
PPW-03G	Manifold to B3A T726-T730 (Gasoline)	Pipework
PPW-04G	Manifold to B3B T941-942 (Gasoline)	Pipework
PPW-05G	B1 T-105 to RTL (Gasoline)	Pipework
PPW-06G	B3A T726-730 to B3A Pumps (Gasoline)	Pipework
PPW-07G	B3B T941-942 to B3A Pumps (Gasoline)	Pipework
PPW-08G	B3A T726-730 to CTP Pumps (Gasoline)	Pipework
PPW-09G	Day Tank T309/311/312 to RTL (Gasoline)	Pipework
PPW-10D	Manifold to B2 T621-622 (Diesel)	Pipework
PPW-11D	Manifold to B3B T940/943 (Diesel)	Pipework
PPW-12D	Manifold to RTL from B2 Tanks (Diesel)	Pipework
PPW-13D	Manifold B2 to CTP Pumps (Diesel)	Pipework
PPW-14D	B3B T940/943 to B3A Pumps (Diesel)	Pipework
PPW-15J	Manifold to B1 T-101-3 (Jet Fuel)	Pipework
PPW-16J	Manifold to B1 T-104 (Jet Fuel)	Pipework
PPW-17J	Manifold to B2 T-623 (Jet Fuel)	Pipework
PPW-18J	Manifold B1-B2 to RTL (Jet Fuel)	Pipework
PPW-19J	B1 T-102/3 to Manifold (Jet Fuel)	Pipework
PPW-20J	Manifold to JUHI Pumps (Jet Fuel)	Pipework
PPW-21E	Manifold to B2 T-624 (Ethanol)	Pipework
PPW-22E	Manifold to B2 T-625 (Ethanol)	Pipework
PPW-23G	Pipe Bridge B1-B2 & B3 (Gasoline)	Pipework
PPW-24D	Pipe Bridge B1-B2 & B3 (Diesel)	Pipework
PPW-25G	B3A Pumps Manifold to RTL (Gasoline)	Pipework
PPW-26D	B3A Pumps Manifold to RTL (Diesel)	Pipework
MAN-01G	Manifold B1&B2 - Gasoline	Manifold
MAN-02D	Manifold B1&B2 - Diesel	Manifold
MAN-03J	Manifold B1&B2 - Jet Fuel	Manifold
MAN-04E	Manifold B1&B2 - Ethanol	Manifold
MAN-05G	Manifold B3 - Gasoline	Manifold
MAN-06D	Manifold B3 - Diesel	Manifold
PMP-01G	B1 Day Tank T-309 Pump - Gasoline	Pump
PMP-02G	B1 Day Tank T-311 Pump - Gasoline	Pump

Section ID	Scenario description	Area Description
PMP-03G	B1 Day Tank T-312 Pump - Gasoline	Pump
PMP-04D	B1 Day Tank T-310 Pump - Diesel	Pump
PMP-05G	B3A Pump Manifold - Gasoline	Pump
PMP-06D	B3A Pump Manifold - Diesel	Pump
PMP-07J	JUHI Booster Pump - Jet Fuel	Pump
PMP-08G	CTP Booster Pump - Gasoline	Pump
PMP-09D	CTP Booster Pump - Diesel	Pump
RTL-01G	RTL1-7 (Gasoline)	Road Tanker Gantry
RTL-02D	RTL1-7 (Diesel)	Road Tanker Gantry
RTL-03J	RTL1-7 (Jet Fuel)	Road Tanker Gantry
RTL-04G	RTL8-9 (Gasoline)	Road Tanker Gantry
RTL-05D	RTL8-9 (Diesel)	Road Tanker Gantry
RTL-06E	RTL10 (Ethanol Unloading)	Road Tanker Gantry
RTL-07D	RTL10 (Biodiesel Unloading)	Road Tanker Gantry

TABLE D.3: DRAWINGS USED FOR PARTS COUNT

Drawing Number	Title / Description	Revision	Rev Date
02-0032-86-009	Jet Export to JUHI Process Flow Diagram	1	21/09/2005
5640-86-002	B1 & B2 Process Flow Diagram	A	22/07/2010
5640-86-013	Transfer Manifold P&ID	E	16/02/2013
5640-86-014	Transfer Manifold P&ID	E	16/02/2013
5640-86-015	Tank 0101	C	22/01/2013
5640-86-016	Tank 0102	D	10/10/2012
5640-86-017	Tank 0103	D	22/01/2013
5640-86-018	Jet fuel filter booster pump & valve pit	C	27/01/2012
5640-86-019	Tank 0104	C	27/01/2011
5640-86-020	Tank 0105	D	10/12/2012
5640-86-021	Tank 0206	C	27/01/2012
5640-86-022	Tank 0207	C	27/01/2012
5640-86-023	Tank 0208	D	10/10/2012
5640-86-024	Tank 309	C	27/01/2012
5640-86-025	Tank 0310	C	27/01/2012
5640-86-026	Tank 0311	E	17/02/2013
5640-86-027	Tank 0312	C	27/01/2012
5640-86-028	Tank 0621	C	27/01/2012
5640-86-029	Tank 0622	C	27/01/2012
5640-86-030	Tank 0623	D	22/01/2013
5640-86-031	Tank 0624	C	27/01/2012
5640-86-032	Tank 0625	B	30/01/2012
5640-86-041	Slops Tanks	C	30/01/2012
5640-86-051	Truck Loading Bay 4, Arms 1-3	C	17/10/2012
5640-86-052	Truck Loading Bay 4, Arms 4-6	B	30/01/2012
5640-86-053	Truck Loading Bay 4, Arms 7-8	B	30/01/2012
5640-86-120	B3 Manifold	B	23/09/2011
5640-86-121	Tank 0726	B	23/09/2011

Drawing Number	Title / Description	Revision	Rev Date
5640-86-122	Tank 0727	B	23/09/2011
5640-86-123	Tank 0728	A	20/07/2010
5640-86-124	Tank 0729	B	23/09/2011
5640-86-125	Tank 0730	A	21/07/2010
5640-86-126	B3A Pump Manifold	B	23/09/2011
5640-86-127	B3A ULP Pumps	B	23/09/2011
5640-86-128	B3A Diesel Pumps	A	21/07/2010
5640-86-129	B3A Ethanol Pumps	B	23/09/2011
5640-86-130	Tank TK0940	A	23/07/2010
5640-86-131	Tank TK0941	B	17/01/2013
5640-86-132	Tank TK0942	A	23/07/2010
35640-86-132	Tank TK0943	A	23/07/2010
5640-86-135	B3B Tank Inlet Manifold	D	31/01/2013
5640-86-136	B3B Pump Manifold	D	31/01/2013
5640-86-170	Caltex Transfer Pipeline	B	23/09/2011
5640-86-171	Caltex BMT Manifold - Eastern End	B	23/09/2011
5640-86-172	Caltex BMT Manifold - Western End	A	21/07/2010

A typical parts count sheet used for the QRA is presented below. The example below applies for the main transfer manifold on B1-B2. The complete parts count sheets for all the sections are not reproduced in this report.

Parts Count Sheet

CLIENT	Vopak Australia
JOB DESC	(Port Botany) Site B QRA
Area Code	MAN
Area Desc	Manifold
Section No	01G
Initiating Event ID	MAN-01G
Event Description	Manifold B1&B2 - Gasoline
Release Type	L

Equipment Item	Tag	Number	Move-ments per year	Op. Hrs per year	ak Frequency per Hole Size in mm x 10 (Leaks/Ye 002	006	022	085	RUP
Instrument fitting	PIP_FTA	7		5519	7.94E-04	3.00E-04	1.10E-04		
Flanges ANSI Raised Face - 50mm	FLG_RF_05	6		5519	9.83E-06	2.87E-06	4.54E-06		
Flanges ANSI Raised Face - 300mı	FLG_RF_3(	500		5519	1.86E-03	5.36E-04	4.44E-04	5.76E-05	1.07E-04
Valve (manual) - 50mm	VLM_050	40		5519	5.04E-04	1.94E-04	1.23E-04		
Valve (manual) - 150mm	VLM_150	7		5519	1.37E-04	5.29E-05	2.07E-05	1.06E-05	
Valve (manual) - 300mm	VLM_300	15		5519	4.06E-04	1.61E-04	6.14E-05	1.13E-05	1.61E-05
Valve (automated) - 300mm	VLA_300	25		5519	3.31E-03	9.92E-04	2.84E-04	3.78E-05	9.45E-05
Filter	VES_FLT	3		5519	2.46E-03	9.64E-04	3.59E-04	6.62E-05	3.78E-05
Process Piping - 300mm	PIP_300	300		5519	4.35E-03	1.44E-03	4.54E-04	6.99E-05	3.21E-05

D4. Online Time Factor

An online factor was applied to the leak frequencies of each identified section (as provided in Table D.2). The online time factor reduces the leak frequency based on the proportion of time that the equipment is used.

The online time factor for all sections assessed in the QRA are summarised in Table D.6.

D5. Ignition Probability

The ignition probability values used in this study were based on the assessment done by Cox, Less and Ang (Ref. 11). The probabilities are based on the release rate and the phase of the fluid assessed. The ignition probability values used in the QRA are provided in Table D.4.

Using the values described in Table D.4, further analysis was undertaken to calculate the ignition probabilities of the assessed flammable substances that result into fires. These values are presented in Table D.5.

Releases for combustible liquids such as diesel are more difficult to ignite due to their high flash point. In this study, an assumption was factored to the ignition probability for diesel to be one-tenth that of flammable liquids such as gasoline. Likewise, for jet fuel which possess higher flash point compared to gasoline, a factor of 0.3 was included to the ignition probabilities specified in Table D.5.

TABLE D.4: IGNITION PROBABILITIES

Mass Flow Rate	Ignition probability of a gas or mixture	Ignition probability of a liquid.	Fraction of explosions given ignition of a gas, liquid or mixture	Explosion probability of a gas or mixture	Explosion probability of a liquid
<1 kg/s	0.01	0.01	0.04	0.0004	0.0004
1 - 50 kg/s	0.07	0.03	0.12	0.0084	0.0036
>50 kg/s	0.3	0.08	0.3	0.09	0.024

TABLE D.5: IGNITION PROBABILITIES FOR FIRES

Mass Flow rate	Immediate Ignition of gas/mixture resulting in fire	Delayed Ignition of gas/mixture resulting in fire	Immediate Ignition of liquid resulting in fire
<1 kg/s	0.0096	0.0004	0.0096
1 - 50 kg/s	0.0616	0.0084	0.0264
>50 kg/s	0.21	0.09	0.056

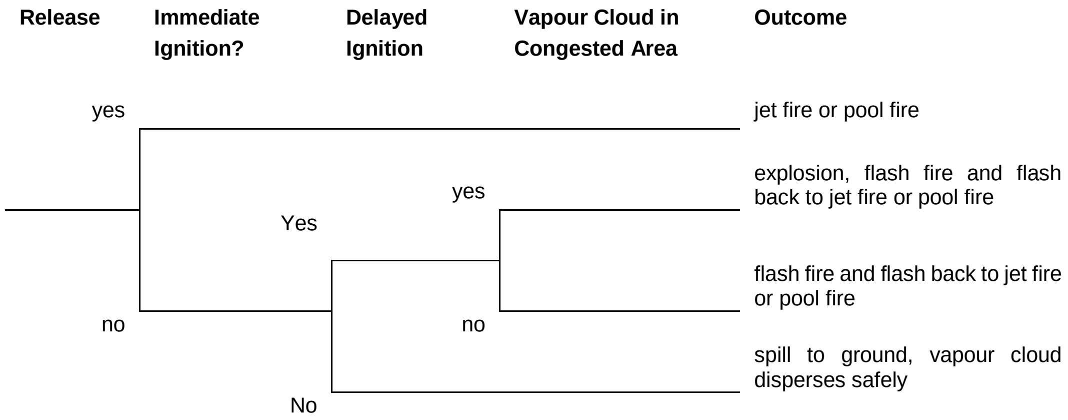
The ignition probabilities for all sections (as provided in Table D.2) and relevant leak sizes assessed in the QRA are summarised in Table D.6.

D6. Event Tree Analysis

A release of flammable liquid (eg gasoline, diesel, jet fuel and ethanol) may lead to a variety of consequences, including jet fire, pool fire, flash fire and vapour cloud explosion - subject to the occurrence of particular events following the release (eg ignition).

An event tree is a logic diagram that identifies, for a single initiating event, a variety of consequences resulting from the success or failure of systems intended to mitigate that event. The frequency of these consequences is then estimated using the event tree logic and probabilistic analyses.

The possible outcomes following loss of containment of a flammable or combustible liquid are described in the event trees shown below.



The event tree probabilities used in the QRA model (projected future case) are presented in Table D.6, which includes:

- Operating time (online time factor)
- Ignition probability adjustment factor
- Probability of detection
- Probability of isolation
- Release rates
- Probability of immediate ignition
- Probability of delayed ignition.

The event tree analyses were undertaken for all leak sizes applicable to all identified sections to generate the outcome frequencies for all leak events identified. The outcome frequencies (fire) for all leak events are presented in Section D7.

D6.1. Fire Detection and Protection

Fire detection and protection systems include:

- Tank full surface foam injection (remotely or locally activated)
- Ultraviolet/Infrared flame detection at each end of road tanker loading bays and automatic initiation of foam deluge. This also initiates ESD.
- Ultraviolet/Infrared flame detection at B2/B3 pumps and automatic initiation of foam deluge to cover the large B2 / B3 pump bays. This also initiates ESD.

During working hours detection of leaks or other fire pre-conditions is also provided by regular inspection of the site and equipment by operations personnel. It should also be noted that the tanks, pumps and pipework undergo regular inspections during critical procedures, such as material transfers to and from the tanks. This includes all pipelines to / from Site B as well as to / from the Bulk Liquids Berth.

There is no statistical evidence of full surface fires in IFR tanks (refer to Section D8.2). To estimate the likelihood that a rim seal progresses to a full tank surface roof fire, a failure probability of the activation of tank top foam pourer fire protection by the operator has been included at 0.1, i.e. 10% of rim seal fires will progress to a full surface fire eg if detection by operator (CCTV, plant rounds) and activation of tank surface fire protection has not occurred.

For all other scenarios, fire protection has not been explicitly included as safeguard since this is an after-event mitigation to minimise escalation and damage rather than a preventative safeguard.

D6.2. Isolation/Shutdown

Terminal ESD can be manually initiated from various ESD buttons on site and also by independent high level shutdown in any tank. Fire detection around the B2/B3 pumps and road tanker bay also initiates ESD.

Terminal ESD results in closure of all valves in the terminal and turns off all electrical power on site.

Operator initiated ESD has been included as a safeguard and assumed to occur within 3 minutes at the following locations:

- Wharf (BLB1/BLB2)
- Road tanker gantries.

For large hole sizes / high leak rates, the maximum pool size is already constrained by the bunding at the BLBs or gantry, hence the ESD action within 3 minutes has a relatively small effect in reducing the scale of the scenario compared to the worst case scenario.

Operator initiated ESD has also been included as an additional safeguard (if high level trip fails) for storage tank overfill during import from wharf (with a probability of failure of 0.1).

TABLE D.6: EVENT TREE PROBABILITIES

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
WHF-01G	BLB1 Ship Import - Gasoline	1,180	1	002	WHF-01G-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput
			1	006	WHF-01G-006	0.7	0.0096	0.0004	
			1	022	WHF-01G-022	8.5	0.0616	0.0084	
			1	085	WHF-01G-085	138	0.21	0.09	
			1	RUP	WHF-01G-RUP	365	0.21	0.21	
WHF-02D	BLB1 Ship Import - Diesel	555	0.1	002	WHF-02D-002	0.1	0.00096	0.00004	BLB1 Online Time x % Product Throughput
			0.1	006	WHF-02D-006	0.7	0.00096	0.00004	
			0.1	022	WHF-02D-022	9.4	0.00616	0.00084	
			0.1	085	WHF-02D-085	140.0	0.021	0.00900	
			0.1	RUP	WHF-02D-RUP	403.0	0.021	0.02100	
WHF-03J	BLB1 Ship Import - Jet Fuel	555	0.3	002	WHF-03J-002	0.1	0.00288	0.00012	BLB1 Online Time x % Product Throughput
			0.3	006	WHF-03J-006	0.7	0.00288	0.00012	
			0.3	022	WHF-03J-022	9.2	0.01848	0.00252	
			0.3	085	WHF-03J-085	138	0.063	0.027	
			0.3	RUP	WHF-03J-RUP	389	0.063	0.063	
WHF-04E	BLB1 Ship Import - Ethanol	23	1	002	WHF-04E-002	0.1	0.0096	0.00040	BLB1 Online Time x % Product Throughput
			1	006	WHF-04E-006	0.7	0.0096	0.00040	
			1	022	WHF-04E-022	9.6	0.0616	0.00840	
			1	085	WHF-04E-085	144	0.21	0.09000	
			1	RUP	WHF-04E-RUP	384	0.21	0.21000	
WHF-05G	BLB2 Ship Import - Gasoline	2,192	1	002	WHF-05G-002	0.1	0.0096	0.0004	BLB2 Online Time x % Product Throughput
			1	006	WHF-05G-006	0.7	0.0096	0.0004	
			1	022	WHF-05G-022	8.5	0.0616	0.0084	
			1	085	WHF-05G-085	138	0.21	0.09	
			1	RUP	WHF-05G-RUP	365	0.21	0.21	
WHF-06D	BLB2 Ship Import - Diesel	1,031	0.1	002	WHF-06D-002	0.1	0.00096	0.00004	BLB2 Online Time x % Product Throughput
			0.1	006	WHF-06D-006	0.7	0.00096	0.00004	
			0.1	022	WHF-06D-022	9.4	0.00616	0.00084	
			0.1	085	WHF-06D-085	140.0	0.021	0.00900	
			0.1	RUP	WHF-06D-RUP	403.0	0.021	0.02100	
WHF-07J	BLB2 Ship Import - Jet Fuel	1,031	0.3	002	WHF-07J-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			0.3	006	WHF-07J-006	0.7	0.00288	0.00012	
			0.3	022	WHF-07J-022	9.2	0.01848	0.00252	
			0.3	085	WHF-07J-085	138	0.063	0.027	
			0.3	RUP	WHF-07J-RUP	389	0.063	0.063	
WHF-08E	BLB2 Ship Import - Ethanol	43	1	002	WHF-08E-002	0.1	0.0096	0.0004	BLB2 Online Time x % Product Throughput
			1	006	WHF-08E-006	0.7	0.0096	0.0004	
			1	022	WHF-08E-022	9.6	0.0616	0.0084	
			1	085	WHF-08E-085	144	0.21	0.09	
			1	RUP	WHF-08E-RUP	384	0.21	0.21	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
WHF-09G	BLB1 Ship Export - Gasoline	350	1	002	WHF-09G-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput
			1	006	WHF-09G-006	0.7	0.0096	0.0004	
			1	022	WHF-09G-022	8.5	0.0616	0.0084	
			1	085	WHF-09G-085	138	0.21	0.09	
			1	RUP	WHF-09G-RUP	365	0.21	0.21	
WHF-10D	BLB1 Ship Export - Diesel	224	0.1	002	WHF-10D-002	0.1	0.00096	4E-05	BLB1 Online Time x % Product Throughput
			0.1	006	WHF-10D-006	0.7	0.00096	4E-05	
			0.1	022	WHF-10D-022	9.4	0.00616	0.00084	
			0.1	085	WHF-10D-085	140	0.021	0.009	
			0.1	RUP	WHF-10D-RUP	403	0.021	0.021	
WHF-11J	BLB1 Ship Export - Jet Fuel	119	0.3	002	WHF-11J-002	0.1	0.00288	0.00012	BLB1 Online Time x % Product Throughput
			0.3	006	WHF-11J-006	0.7	0.00288	0.00012	
			0.3	022	WHF-11J-022	9.2	0.01848	0.00252	
			0.3	085	WHF-11J-085	138	0.063	0.027	
			0.3	RUP	WHF-11J-RUP	389	0.063	0.063	
WHF-12G	BLB2 Ship Export - Gasoline	817	1	002	WHF-12G-002	0.1	0.0096	0.0004	BLB2 Online Time x % Product Throughput
			1	006	WHF-12G-006	0.7	0.0096	0.0004	
			1	022	WHF-12G-022	8.5	0.0616	0.0084	
			1	085	WHF-12G-085	138	0.21	0.09	
			1	RUP	WHF-12G-RUP	365	0.21	0.21	
WHF-13D	BLB2 Ship Export - Diesel	523	0.1	002	WHF-13D-002	0.1	0.00096	4E-05	BLB2 Online Time x % Product Throughput
			0.1	006	WHF-13D-006	0.7	0.00096	4E-05	
			0.1	022	WHF-13D-022	9.4	0.00616	0.00084	
			0.1	085	WHF-13D-085	140	0.021	0.009	
			0.1	RUP	WHF-13D-RUP	403	0.021	0.021	
WHF-14J	BLB2 Ship Export - Jet Fuel	278	0.3	002	WHF-14J-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			0.3	006	WHF-14J-006	0.7	0.00288	0.00012	
			0.3	022	WHF-14J-022	9.2	0.01848	0.00252	
			0.3	085	WHF-14J-085	138	0.063	0.027	
			0.3	RUP	WHF-14J-RUP	389	0.063	0.063	
WHF-15E	BLB1 Ship Export - Ethanol	14	1	002	WHF-15E-002	0.1	0.00096	4E-05	BLB1 Online Time x % Product Throughput
			1	006	WHF-15E-006	0.7	0.00096	4E-05	
			1	022	WHF-15E-022	9.6	0.00616	0.00084	
			1	085	WHF-15E-085	144	0.021	0.009	
			1	RUP	WHF-15E-RUP	384	0.021	0.021	
WHF-16E	BLB2 Ship Export - Ethanol	33	1	002	WHF-16E-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			1	006	WHF-16E-006	0.7	0.00288	0.00012	
			1	022	WHF-16E-022	9.2	0.01848	0.00252	
			1	085	WHF-16E-085	144	0.063	0.027	
			1	RUP	WHF-16E-RUP	263	0.063	0.063	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
SHP-01G	BLB1 Ship Import PPL - Gasoline	1,244	1	002	SHP-01G-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput
			1	006	SHP-01G-006	0.7	0.0096	0.0004	
			1	022	SHP-01G-022	8.5	0.0616	0.0084	
			1	085	SHP-01G-085	138	0.21	0.0900	
			1	RUP	SHP-01G-RUP	365	0.21	0.2100	
SHP-02D	BLB1 Ship Import PPL - Diesel	622	0.1	002	SHP-02D-002	0.1	0.00096	0.00004	BLB1 Online Time x % Product Throughput
			0.1	006	SHP-02D-006	0.7	0.00096	0.00004	
			0.1	022	SHP-02D-022	9.4	0.00616	0.00084	
			0.1	085	SHP-02D-085	140.0	0.021	0.009	
			0.1	RUP	SHP-02D-RUP	403.0	0.021	0.021	
SHP-03J	BLB1 Ship Import PPL - Jet Fuel	502	0.3	002	SHP-03J-002	0.1	0.00288	0.00012	BLB1 Online Time x % Product Throughput
			0.3	006	SHP-03J-006	0.7	0.00288	0.00012	
			0.3	022	SHP-03J-022	9.2	0.01848	0.00252	
			0.3	085	SHP-03J-085	138	0.063	0.02700	
			0.3	RUP	SHP-03J-RUP	389	0.063	0.06300	
SHP-04E	BLB1 Ship Import PPL - Ethanol	24	1	002	SHP-04E-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput
			1	006	SHP-04E-006	0.7	0.0096	0.0004	
			1	022	SHP-04E-022	9.6	0.0616	0.0084	
			1	085	SHP-04E-085	144	0.21	0.09	
			1	RUP	SHP-04E-RUP	384	0.21	0.21	
SHP-05G	BLB2 Ship Import PPL - Gasoline	1,528	1	002	SHP-05G-002	0.1	0.0096	0.00040	BLB2 Online Time x % Product Throughput
			1	006	SHP-05G-006	0.7	0.0096	0.00040	
			1	022	SHP-05G-022	8.5	0.0616	0.00840	
			1	085	SHP-05G-085	138	0.21	0.09000	
			1	RUP	SHP-05G-RUP	365	0.21	0.21000	
SHP-06D	BLB2 Ship Import PPL - Diesel	764	0.1	002	SHP-06D-002	0.1	0.00096	0.00004	BLB2 Online Time x % Product Throughput
			0.1	006	SHP-06D-006	0.7	0.00096	0.00004	
			0.1	022	SHP-06D-022	9.4	0.00616	0.00084	
			0.1	085	SHP-06D-085	140.0	0.021	0.009	
			0.1	RUP	SHP-06D-RUP	403.0	0.021	0.021	
SHP-07J	BLB2 Ship Import PPL - Jet Fuel	617	0.3	002	SHP-07J-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			0.3	006	SHP-07J-006	0.7	0.00288	0.00012	
			0.3	022	SHP-07J-022	9.2	0.01848	0.00252	
			0.3	085	SHP-07J-085	138	0.063	0.027	
			0.3	RUP	SHP-07J-RUP	389	0.063	0.063	
SHP-08E	BLB2 Ship Import PPL - Ethanol	29	1	002	SHP-08E-002	0.1	0.0096	0.00040	BLB2 Online Time x % Product Throughput
			1	006	SHP-08E-006	0.7	0.0096	0.00040	
			1	022	SHP-08E-022	9.6	0.0616	0.00840	
			1	085	SHP-08E-085	144	0.21	0.09000	
			1	RUP	SHP-08E-RUP	384	0.21	0.21000	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
SHP-09G	BLB1 Ship Export PPL - Gasoline	400	1	002	SHP-09G-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput
			1	006	SHP-09G-006	0.7	0.0096	0.0004	
			1	022	SHP-09G-022	8.5	0.0616	0.0084	
			1	085	SHP-09G-085	138	0.21	0.09	
			1	RUP	SHP-09G-RUP	365	0.21	0.21	
SHP-10D	BLB1 Ship Export PPL - Diesel	400	0.1	002	SHP-10D-002	0.1	0.00096	4E-05	BLB1 Online Time x % Product Throughput
			0.1	006	SHP-10D-006	0.7	0.00096	4E-05	
			0.1	022	SHP-10D-022	9.4	0.00616	0.00084	
			0.1	085	SHP-10D-085	140	0.021	0.009	
			0.1	RUP	SHP-10D-RUP	403	0.021	0.021	
SHP-11J	BLB1 Ship Export PPL - Jet Fuel	89	0.3	002	SHP-11J-002	0.1	0.00288	0.00012	BLB1 Online Time x % Product Throughput
			0.3	006	SHP-11J-006	0.7	0.00288	0.00012	
			0.3	022	SHP-11J-022	9.2	0.01848	0.00252	
			0.3	085	SHP-11J-085	138	0.063	0.027	
			0.3	RUP	SHP-11J-RUP	389	0.063	0.063	
SHP-12G	BLB2 Ship Export PPL - Gasoline	1600	1	002	SHP-12G-002	0.1	0.0096	0.0004	BLB2 Online Time x % Product Throughput
			1	006	SHP-12G-006	0.7	0.0096	0.0004	
			1	022	SHP-12G-022	8.5	0.0616	0.0084	
			1	085	SHP-12G-085	138	0.21	0.09	
			1	RUP	SHP-12G-RUP	365	0.21	0.21	
SHP-13D	BLB2 Ship Export PPL - Diesel	1600	0.1	002	SHP-13D-002	0.1	0.00096	4E-05	BLB2 Online Time x % Product Throughput
			0.1	006	SHP-13D-006	0.7	0.00096	4E-05	
			0.1	022	SHP-13D-022	9.4	0.00616	0.00084	
			0.1	085	SHP-13D-085	140	0.021	0.009	
			0.1	RUP	SHP-13D-RUP	403	0.021	0.021	
SHP-14J	BLB2 Ship Export PPL - Jet Fuel	356	0.3	002	SHP-14J-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			0.3	006	SHP-14J-006	0.7	0.00288	0.00012	
			0.3	022	SHP-14J-022	9.2	0.01848	0.00252	
			0.3	085	SHP-14J-085	138	0.063	0.027	
			0.3	RUP	SHP-14J-RUP	389	0.063	0.063	
SHP-15E	BLB1 Ship Export PPL - Ethanol	14	1	002	WHF-15E-002	0.1	0.00096	4E-05	BLB1 Online Time x % Product Throughput
			1	006	WHF-15E-006	0.7	0.00096	4E-05	
			1	022	WHF-15E-022	9.6	0.00616	0.00084	
			1	085	WHF-15E-085	144	0.021	0.009	
			1	RUP	WHF-15E-RUP	384	0.021	0.021	
SHP-16E	BLB2 Ship Export PPL - Ethanol	33	1	002	WHF-16E-002	0.1	0.00288	0.00012	BLB2 Online Time x % Product Throughput
			1	006	WHF-16E-006	0.7	0.00288	0.00012	
			1	022	WHF-16E-022	9.2	0.01848	0.00252	
			1	085	WHF-16E-085	144	0.063	0.027	
			1	RUP	WHF-16E-RUP	263	0.063	0.063	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PPW-01G	Manifold to B1 T-105 (Gasoline)	590	1	002	PPW-01G-002	0.1	0.0096	0.0004	BLB1 Online Time x % Product Throughput x 0.5 0.5 = Manifold to either T105 or T-206/207/208
			1	006	PPW-01G-006	0.7	0.0096	0.0004	
			1	022	PPW-01G-022	8.5	0.0616	0.0084	
			1	085	PPW-01G-085	138	0.21	0.09	
			1	RUP	PPW-01G-RUP	365	0.21	0.21	
PPW-02G	Manifold to B1 T206-208 (Gasoline)	4,729	1	002	PPW-02G-002	0.1	0.0096	0.00040	Import - BLB1 Online Time x % Product Throughput x 0.5 0.5 = to/from T105 or T-206/207/208 Export - RTL Online Time (100%) x % Product Throughput x (3/4) (3/4) -from T206/207/208 excl T-105
			1	006	PPW-02G-006	0.7	0.0096	0.00040	
			1	022	PPW-02G-022	8.5	0.0616	0.00840	
			1	085	PPW-02G-085	138	0.21	0.09000	
			1	RUP	PPW-02G-RUP	365	0.21	0.21000	
PPW-03G	Manifold to B3A T726-T730 (Gasoline)	1,096	1	002	PPW-03G-002	0.1	0.0096	0.0004	BLB2 Online Time x % Product Throughput x 0.5 0.5 = Manifold to either B3A tanks or B3B tanks (majority are gasoline tanks)
			1	006	PPW-03G-006	0.7	0.0096	0.0004	
			1	022	PPW-03G-022	8.5	0.0616	0.0084	
			1	085	PPW-03G-085	138	0.21	0.09	
			1	RUP	PPW-03G-RUP	365	0.21	0.21	
PPW-04G	Manifold to B3B T941-942 (Gasoline)	1,096	1	002	PPW-04G-002	0.1	0.0096	0.00040	BLB2 Online Time x % Product Throughput x 0.5 0.5 = Manifold to either B3A tanks or B3B tanks (majority are gasoline tanks)
			1	006	PPW-04G-006	0.7	0.0096	0.00040	
			1	022	PPW-04G-022	8.5	0.0616	0.00840	
			1	085	PPW-04G-085	138	0.21	0.09000	
			1	RUP	PPW-04G-RUP	365	0.21	0.21000	
PPW-05G	B1 T-105 to RTL (Gasoline)	1,380	1	002	PPW-05G-002	0.1	0.0096	0.0004	RTL Online Time (100%) x % Product Throughput x (1/4) (1/4) - Export from T105 excl T206/207/208 (Gasoline tanks on B1&B2)
			1	006	PPW-05G-006	0.7	0.0096	0.0004	
			1	022	PPW-05G-022	8.5	0.0616	0.0084	
			1	085	PPW-05G-085	25	0.0616	0.0084	
			1	RUP	PPW-05G-RUP	25	0.21	0.21	
PPW-06G	B3A T726-730 to B3A Pumps (Gasoline)	2,759	1	002	PPW-06G-002	0.1	0.0096	0.0004	RTL Online Time x % Product Throughput x 0.5 0.5 = Export from either B3A tanks or B3B tanks Worst Case Scenario (CTP export is only 8% of the year)
			1	006	PPW-06G-006	0.7	0.0096	0.0004	
			1	022	PPW-06G-022	8.5	0.0616	0.0084	
			1	085	PPW-06G-085	138	0.21	0.09	
			1	RUP	PPW-06G-RUP	365	0.21	0.21	
PPW-07G	B3B T941-942 to B3A Pumps (Gasoline)	2,759	1	002	PPW-07G-002	0.1	0.0096	0.00040	RTL Online Time x % Product Throughput x 0.5 0.5 = Export from either B3A tanks or B3B tanks Worst Case Scenario (CTP export is only 8% of the year)
			1	006	PPW-07G-006	0.7	0.0096	0.00040	
			1	022	PPW-07G-022	8.5	0.0616	0.00840	
			1	085	PPW-07G-085	138	0.21	0.09000	
			1	RUP	PPW-07G-RUP	365	0.21	0.21000	
PPW-08G	B3A T726-730 to CTP Pumps	560	1	002	PPW-08G-002	0.1	0.0096	0.0004	CTP Online Time x % Product Throughput Product Throughput Gasoline: Diesel = 2:1 via CTP
			1	006	PPW-08G-006	0.7	0.0096	0.0004	
			1	022	PPW-08G-022	8.5	0.0616	0.0084	
			1	085	PPW-08G-085	138	0.21	0.09	
			1	RUP	PPW-08G-RUP	365	0.21	0.21	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PPW-09G	Day Tank T309/311/312 to RTL	5,519	1	002	PPW-09G-002	0.1	0.0096	0.00040	RTL Online Time x % Product Throughput (assumed always used - portion for gasoline)
			1	006	PPW-09G-006	0.7	0.0096	0.00040	
			1	022	PPW-09G-022	8.5	0.0616	0.00840	
			1	085	PPW-09G-085	25	0.0616	0.00840	
			1	RUP	PPW-09G-RUP	25	0.21	0.21000	
PPW-10D	Manifold to B2 T621-622 (Diesel)	3,183	0.1	002	PPW-10D-002	0.1	0.00096	0.00004	Import - BLB1 Online Time x % Product Throughput Export - RTL Online Time (100%) x % Product Throughput These are the only diesel tanks on B1&B2
			0.1	006	PPW-10D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-10D-022	9.4	0.00616	0.00084	
			0.1	085	PPW-10D-085	140	0.021	0.009	
			0.1	RUP	PPW-10D-RUP	403	0.021	0.021	
PPW-11D	Manifold to B3B T940/943 (Diesel)	1,031	0.1	002	PPW-11D-002	0.1	0.00096	0.00004	BLB2 Online Time x % Product Throughput These are the only diesel tanks on B3
			0.1	006	PPW-11D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-11D-022	9.4	0.00616	0.00084	
			0.1	085	PPW-11D-085	140	0.021	0.00900	
			0.1	RUP	PPW-11D-RUP	403	0.021	0.02100	
PPW-12D	Manifold to RTL from B2 Tanks (Diesel)	1,314	0.1	002	PPW-12D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput 0.5 0.5 = Export from either B2 or B3 Diesel Tanks
			0.1	006	PPW-12D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-12D-022	9.2	0.00616	0.00084	
			0.1	085	PPW-12D-085	28	0.00616	0.00084	
			0.1	RUP	PPW-12D-RUP	28	0.021	0.021	
PPW-13D	Manifold B2 to CTP Pumps (Diesel)	280	0.1	002	PPW-13D-002	0.1	0.00096	0.00004	CTP Online Time x % Product Throughput Product Throughput Gasoline: Diesel = 2:1 via CTP
			0.1	006	PPW-13D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-13D-022	9.4	0.00616	0.00084	
			0.1	085	PPW-13D-085	140	0.021	0.009	
			0.1	RUP	PPW-13D-RUP	403	0.021	0.021	
PPW-14D	B3B T940/943 to B3A Pumps (Diesel)	1,314	0.1	002	PPW-14D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput x 0.5 0.5 = Export from either B2 or B3 Diesel Tanks (see PPW_12D)
			0.1	006	PPW-14D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-14D-022	9.4	0.00616	0.00084	
			0.1	085	PPW-14D-085	140	0.021	0.00900	
			0.1	RUP	PPW-14D-RUP	403	0.021	0.02100	
PPW-15J	Manifold to B1 T-101-3 (Jet Fuel)	456	0.3	002	PPW-15J-002	0.1	0.00288	0.00012	BLB1 Online Time x % Product Throughput x (3/5) (3/5) = T-101/102/103 (Not T-104/623) RTL Online Time (100%) x % Product Throughput x (1/5) (1/5) = to/from T-101 only
			0.3	006	PPW-15J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-15J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-15J-085	138	0.063	0.027	
			0.3	RUP	PPW-15J-RUP	389	0.063	0.063	
PPW-16J	Manifold to B1 T-104 (Jet Fuel)	234	0.3	002	PPW-16J-002	0.1	0.00288	0.00012	Import - BLB1 Online Time x % Product Throughput x (1/5) Export - RTL Online Time (100%) x % Product Throughput x (1/5) (1/5) = Manifold to/from T-104 and NOT T-101/102/103 or T-623
			0.3	006	PPW-16J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-16J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-16J-085	138	0.063	0.02700	
			0.3	RUP	PPW-16J-RUP	389	0.063	0.06300	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PPW-17J	Manifold to B2 T-623 (Jet Fuel)	234	0.3	002	PPW-17J-002	0.1	0.00288	0.00012	Import - BLB1 Online Time x % Product Throughput x (1/5) Export - RTL Online Time (100%) x % Product Throughput x (1/5) (1/5) = Manifold to/from T-104 and NOT T-101/102/103 or T-623
			0.3	006	PPW-17J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-17J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-17J-085	138	0.063	0.027	
			0.3	RUP	PPW-17J-RUP	389	0.063	0.063	
PPW-18J	Manifold B1-B2 to RTL (Jet Fuel)	368	0.3	002	PPW-18J-002	0.1	0.00288	0.00012	RTL Online Time x % Product Throughput T-101, T-104 and T-623 only T-102 & T-103 = to JUHI pumps
			0.3	006	PPW-18J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-18J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-18J-085	27	0.01848	0.00252	
			0.3	RUP	PPW-18J-RUP	27	0.063	0.06300	
PPW-19J	B1 T-102/3 to Manifold (Jet Fuel)	3,168	0.3	002	PPW-19J-002	0.1	0.00288	0.00012	JUHI Online Time x % Product Throughput 100% Jet Fuel
			0.3	006	PPW-19J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-19J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-19J-085	138	0.063	0.027	
			0.3	RUP	PPW-19J-RUP	389	0.063	0.063	
PPW-20J	Manifold to JUHI Pumps (Jet Fuel)	3,168	0.3	002	PPW-20J-002	0.1	0.00288	0.00012	JUHI Online Time x % Product Throughput 100% Jet Fuel
			0.3	006	PPW-20J-006	0.7	0.00288	0.00012	
			0.3	022	PPW-20J-022	9.2	0.01848	0.00252	
			0.3	085	PPW-20J-085	138	0.063	0.027	
			0.3	RUP	PPW-20J-RUP	389	0.063	0.063	
PPW-21E	Manifold to B2 T-624 (Ethanol)	1,678	1	002	PPW-21E-002	0.1	0.0096	0.00040	SHIP BLB1 Online Time x % Product Throughput x 0.5 0.5 = Manifold to either T624 or T625 RTL RTL Bay 10 Online Time
			1	006	PPW-21E-006	0.7	0.0096	0.00040	
			1	022	PPW-21E-022	9.6	0.0616	0.00840	
			1	085	PPW-21E-085	144	0.21	0.09000	
			1	RUP	PPW-21E-RUP	384	0.21	0.21000	
PPW-22E	Manifold to B2 T-625 (Ethanol)	1,678	1	002	PPW-22E-002	0.1	0.0096	0.0004	SHIP BLB1 Online Time x % Product Throughput x 0.5 0.5 = Manifold to either T624 or T625 RTL RTL Bay 10 Online Time
			1	006	PPW-22E-006	0.7	0.0096	0.0004	
			1	022	PPW-22E-022	9.6	0.0616	0.0084	
			1	085	PPW-22E-085	144	0.21	0.09	
			1	RUP	PPW-22E-RUP	384	0.21	0.21	
PPW-23G	Pipe Bridge B1-B2 & B3 (Gasoline)	8,760	1	002	PPW-23G-002	0.1	0.0096	0.00040	Online at all times
			1	006	PPW-23G-006	0.7	0.0096	0.00040	
			1	022	PPW-23G-022	8.5	0.0616	0.00840	
			1	085	PPW-23G-085	138	0.21	0.09000	
			1	RUP	PPW-23G-RUP	365	0.21	0.21000	
PPW-24D	Pipe Bridge B1-B2 & B3 (Diesel)	8,760	0.1	002	PPW-24D-002	0.1	0.00096	0.00004	Online at all times
			0.1	006	PPW-24D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-24D-022	8.5	0.00616	0.00084	
			0.1	085	PPW-24D-085	138	0.021	0.009	
			0.1	RUP	PPW-24D-RUP	365	0.021	0.021	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PPW-25G	B3A Pumps Manifold to RTL (Gasoline)	5,519	1	002	PPW-25G-002	0.1	0.0096	0.00040	RTL Online Time x % Product Throughput Worst Case Scenario - does not further divide between B1-B2 & B3
			1	006	PPW-25G-006	0.7	0.0096	0.00040	
			1	022	PPW-25G-022	8.5	0.0616	0.00840	
			1	085	PPW-25G-085	25	0.0616	0.00840	
			1	RUP	PPW-25G-RUP	25	0.21	0.21000	
PPW-26D	B3A Pumps Manifold to RTL (Diesel)	2,628	0.1	002	PPW-26D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput Worst Case Scenario - does not further divide between B1-B2 & B3
			0.1	006	PPW-26D-006	0.7	0.00096	0.00004	
			0.1	022	PPW-26D-022	9.4	0.00616	0.00084	
			0.1	085	PPW-26D-085	28.0	0.00616	0.00084	
			0.1	RUP	PPW-26D-RUP	28.0	0.021	0.021	
MAN-01G	Manifold B1&B2 - Gasoline	3,885	1	002	MAN-01G-002	0.1	0.0096	0.0004	BLB1 and BLB2: Import/Export Online Time x %Product Allocation x (4 /11) tanks CTP: Import/Export Online Time x %Product Allocation x (4/11) tanks RTL Export: 100% time x % Product Allocation x (4/11) tanks
			1	006	MAN-01G-006	0.7	0.0096	0.0004	
			1	022	MAN-01G-022	8.5	0.0616	0.0084	
			1	085	MAN-01G-085	138	0.21	0.09	
			1	RUP	MAN-01G-RUP	365	0.21	0.21	
MAN-02D	Manifold B1&B2 - Diesel	2,821	0.1	002	MAN-02D-002	0.1	0.00096	0.00004	BLB1 and BLB2: Import/Export Online Time x %Product Allocation x (2/4) tanks CTP: Import/Export Online Time x %Product Allocation x (2/4) tanks RTL Import/Export: % time x % Product Allocation x (2/4) tanks
			0.1	006	MAN-02D-006	0.7	0.00096	0.00004	
			0.1	022	MAN-02D-022	9.4	0.00616	0.00084	
			0.1	085	MAN-02D-085	140	0.021	0.00900	
			0.1	RUP	MAN-02D-RUP	403	0.021	0.02100	
MAN-03J	Manifold B1&B2 - Jet Fuel	5,765	0.3	002	MAN-03J-002	0.1	0.00288	0.00012	BLB1 and BLB2: Import/Export Online Time x %Product Allocation RTL Import: % RTL time x % Product Allocation
			0.3	006	MAN-03J-006	0.7	0.00288	0.00012	
			0.3	022	MAN-03J-022	9.2	0.01848	0.00252	
			0.3	085	MAN-03J-085	138	0.063	0.027	
			0.3	RUP	MAN-03J-RUP	389	0.063	0.063	
MAN-04E	Manifold B1&B2 - Ethanol	1,779	1	002	MAN-04E-002	0.1	0.0096	0.00040	BLB1 and BLB2: Import/Export Online Time x %Product Allocation JUHI: Export Online Time x %Product Allocation RTL Export: % time x % Product Allocation
			1	006	MAN-04E-006	0.7	0.0096	0.00040	
			1	022	MAN-04E-022	9.6	0.0616	0.00840	
			1	085	MAN-04E-085	144	0.21	0.09000	
			1	RUP	MAN-04E-RUP	384	0.21	0.21000	
MAN-05G	Manifold B3 - Gasoline	6,653	1	002	MAN-05G-002	0.1	0.0096	0.0004	BLB1 and BLB2: Import/Export Online Time x %Product Allocation x (7 /11) tanks CTP: Import/Export Online Time x %Product Allocation x (7/11) tanks RTL Export: 100% time x % Product Allocation x (7/11) tanks
			1	006	MAN-05G-006	0.7	0.0096	0.0004	
			1	022	MAN-05G-022	8.5	0.0616	0.0084	
			1	085	MAN-05G-085	138	0.21	0.09	
			1	RUP	MAN-05G-RUP	365	0.21	0.21	
MAN-06D	Manifold B3 - Diesel	2,821	0.1	002	MAN-06D-002	0.1	0.00096	0.00004	BLB1 and BLB2: Import/Export Online Time x %Product Allocation x (2/4) tanks CTP: Import/Export Online Time x %Product Allocation x (2/4) tanks RTL Import/Export: % time x % Product Allocation x (2/4) tanks
			0.1	006	MAN-06D-006	0.7	0.00096	0.00004	
			0.1	022	MAN-06D-022	9.4	0.00616	0.00084	
			0.1	085	MAN-06D-085	140	0.021	0.00900	
			0.1	RUP	MAN-06D-RUP	403	0.021	0.02100	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PMP-01G	B1 Day Tank T-309 Pump - Gasoline	1,840	1	002	PMP-01G-002	0.1	0.0096	0.0004	RTL Online Time x % Product Throughput RTL x (1/3) (1/3) = either one of tank T309/311/312
			1	006	PMP-01G-006	0.7	0.0096	0.0004	
			1	022	PMP-01G-022	8.5	0.0616	0.0084	
			1	085	PMP-01G-085	25	0.0616	0.0084	
			1	RUP	PMP-01G-RUP	25	0.21	0.21	
PMP-02G	B1 Day Tank T-311 Pump - Gasoline	1,840	1	002	PMP-02G-002	0.1	0.0096	0.0004	RTL Online Time x % Product Throughput RTL x (1/3) (1/3) = either one of tank T309/311/312
			1	006	PMP-02G-006	0.7	0.0096	0.0004	
			1	022	PMP-02G-022	8.5	0.0616	0.0084	
			1	085	PMP-02G-085	25	0.0616	0.0084	
			1	RUP	PMP-02G-RUP	25	0.21	0.21	
PMP-03G	B1 Day Tank T-312 Pump - Gasoline	1,840	1	002	PMP-03G-002	0.1	0.0096	0.00040	RTL Online Time x % Product Throughput RTL x (1/3) (1/3) = either one of tank T309/311/312
			1	006	PMP-03G-006	0.7	0.0096	0.00040	
			1	022	PMP-03G-022	8.5	0.0616	0.00840	
			1	085	PMP-03G-085	25	0.0616	0.00840	
			1	RUP	PMP-03G-RUP	25	0.21	0.21000	
PMP-04D	B1 Day Tank T-310 Pump - Diesel	1,314	0.1	002	PMP-04D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput 0.5 0.5 = Export from either B2 or B3 Diesel Tanks
			0.1	006	PMP-04D-006	0.7	0.00096	0.00004	
			0.1	022	PMP-04D-022	9.4	0.00616	0.00084	
			0.1	085	PMP-04D-085	28.0	0.00616	0.00084	
			0.1	RUP	PMP-04D-RUP	28.0	0.021	0.021	
PMP-05G	B3A Pump Manifold - Gasoline	5,519	1	002	PMP-05G-002	0.1	0.0096	0.00040	RTL Online Time x % Product Throughput Worst Case Scenario - does not further divide between B1-B2 & B3
			1	006	PMP-05G-006	0.7	0.0096	0.00040	
			1	022	PMP-05G-022	8.5	0.0616	0.00840	
			1	085	PMP-05G-085	25	0.0616	0.00840	
			1	RUP	PMP-05G-RUP	25	0.21	0.21000	
PMP-06D	B3A Pump Manifold - Diesel	2,628	0.1	002	PMP-06D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput Worst Case Scenario - does not further divide between B1-B2 & B3
			0.1	006	PMP-06D-006	0.7	0.00096	0.00004	
			0.1	022	PMP-06D-022	9.4	0.00616	0.00084	
			0.1	085	PMP-06D-085	28.0	0.00616	0.00084	
			0.1	RUP	PMP-06D-RUP	28.0	0.021	0.021	
PMP-07J	JUHI Booster Pump - Jet Fuel	3,168	0.3	002	PMP-07J-002	0.1	0.00288	0.00012	JUHI Online Time x % Product Throughput 100% Jet Fuel
			0.3	006	PMP-07J-006	0.6	0.00288	0.00012	
			0.3	022	PMP-07J-022	7.8	0.01848	0.00252	
			0.3	085	PMP-07J-085	92	0.063	0.02700	
			0.3	RUP	PMP-07J-RUP	92	0.063	0.06300	
PMP-08G	CTP Booster Pump - Gasoline	560	1	002	PMP-08G-002	0.1	0.0096	0.0004	CTP Online Time x % Product Throughput Product Throughput Gasoline: Diesel = 2:1 via CTP
			1	006	PMP-08G-006	0.8	0.0096	0.0004	
			1	022	PMP-08G-022	10.1	0.0616	0.0084	
			1	085	PMP-08G-085	148	0.21	0.09	
			1	RUP	PMP-08G-RUP	208	0.21	0.21	

Scenario	Description	Operating Time (hours/year)	Ignition Probability Adjustment Factor	Leak Size (mm)	Scenario Tag	Release Rate (kg/s)	Ignition Probability		Comments on Online Time Calculation
							Immediate	Delayed	
PMP-09D	CTP Booster Pump - Diesel	280	0.1	002	PMP-09D-002	0.1	0.00096	0.00004	CTP Online Time x % Product Throughput
			0.1	006	PMP-09D-006	0.8	0.00096	0.00004	Product Throughput Gasoline: Diesel = 2:1 via CTP
			0.1	022	PMP-09D-022	10.2	0.00616	0.00084	
			0.1	085	PMP-09D-085	152	0.021	0.009	
			0.1	RUP	PMP-09D-RUP	231	0.021	0.021	
RTL-01G	RTL1-7 (Gasoline)	4,292	1	002	RTL-01G-002	0.1	0.0096	0.0004	RTL Online Time x % Product Throughput x (7/9)
			1	006	RTL-01G-006	0.7	0.0096	0.0004	(7/9) = total of 9 loading bays, RTL1-7 and 8-9
			1	022	RTL-01G-022	8.5	0.0616	0.0084	
			1	085	RTL-01G-085	25	0.0616	0.0084	
			1	RUP	RTL-01G-RUP	25	0.21	0.21	
RTL-02D	RTL1-7 (Diesel)	2,044	0.1	002	RTL-02D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput x (7/9)
			0.1	006	RTL-02D-006	0.7	0.00096	0.00004	
			0.1	022	RTL-02D-022	9.4	0.00616	0.00084	(7/9) = total of 9 loading bays, RTL1-7 and 8-9
			0.1	085	RTL-02D-085	28.0	0.00616	0.00084	
			0.1	RUP	RTL-02D-RUP	28.0	0.021	0.021	
RTL-03J	RTL1-7 (Jet Fuel)	613	0.3	002	RTL-03J-002	0.1	0.00288	0.00012	RTL Online Time x % Product Throughput x (7/9)
			0.3	006	RTL-03J-006	0.7	0.00288	0.00012	
			0.3	022	RTL-03J-022	9.2	0.01848	0.00252	(7/9) = total of 9 loading bays, RTL1-7 and 8-9
			0.3	085	RTL-03J-085	27	0.01848	0.00252	
			0.3	RUP	RTL-03J-RUP	27	0.063	0.063	
RTL-04G	RTL8-9 (Gasoline)	1,226	1	002	RTL-04G-002	0.1	0.0096	0.0004	RTL Online Time x % Product Throughput x (7/9)
			1	006	RTL-04G-006	0.7	0.0096	0.0004	
			1	022	RTL-04G-022	8.5	0.0616	0.0084	(2/9) = total of 9 loading bays, RTL 8-9
			1	085	RTL-04G-085	25	0.0616	0.0084	
			1	RUP	RTL-04G-RUP	25	0.21	0.21	
RTL-05D	RTL8-9 (Diesel)	584	0.1	002	RTL-05D-002	0.1	0.00096	0.00004	RTL Online Time x % Product Throughput x (7/9)
			0.1	006	RTL-05D-006	0.7	0.00096	0.00004	
			0.1	022	RTL-05D-022	9.4	0.00616	0.00084	(2/9) = total of 9 loading bays, RTL 8-9
			0.1	085	RTL-05D-085	28.0	0.00616	0.00084	
			0.1	RUP	RTL-05D-RUP	28.0	0.021	0.021	
RTL-06E	RTL10 (Ethanol Unloading)	1,667	1	002	RTL-06E-002	0.1	0.0096	0.0004	RTL Unloading Online Time x % Product Throughput
			1	006	RTL-06E-006	0.5	0.0096	0.0004	
			1	022	RTL-06E-022	7.0	0.0616	0.0084	
			1	085	RTL-06E-085	13	0.0616	0.0084	
			1	RUP	RTL-06E-RUP	13	0.21	0.21	
RTL-07D	RTL10 (Biodiesel Unloading)	367	0.1	002	RTL-07E-002	0.1	0.00096	0.00004	RTL Unloading Online Time x % Product Throughput
			0.1	006	RTL-07E-006	0.5	0.00096	0.00004	
			0.1	022	RTL-07E-022	7.0	0.00616	0.00084	
			0.1	085	RTL-07E-085	14	0.00616	0.00084	
			0.1	RUP	RTL-07E-RUP	14	0.021	0.021	

D7. Outcome Frequencies

The release and fire outcome frequencies for all events (projected future case) are summarised in Table D.7.

Fire frequencies by location and hole size are typically in the order of 1 x 10^{-6} per year to 1 x 10^{-5} per year, or 1 chance in 1 million years to 1 chance in 100,000 years per event.

TABLE D.7: OUTCOME FREQUENCIES – FUTURE CASE OPERATION

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
WHF-01G_002	4.17E-4	1.65E-7	4.00E-6
WHF-01G_006	1.52E-4	6.02E-8	1.46E-6
WHF-01G_022	4.12E-4	3.25E-6	2.54E-5
WHF-01G_085	2.89E-4	2.06E-5	6.08E-5
WHF-01G_RUP	4.17E-5	6.92E-6	8.76E-6
WHF-02D_002	1.96E-4	7.84E-9	1.88E-7
WHF-02D_006	7.15E-5	2.86E-9	6.86E-8
WHF-02D_022	1.94E-4	1.62E-7	1.19E-6
WHF-02D_085	1.37E-4	1.21E-6	2.88E-6
WHF-02D_RUP	1.96E-5	4.03E-7	4.12E-7
WHF-03J_002	1.96E-4	2.35E-8	5.65E-7
WHF-03J_006	7.15E-5	8.55E-9	2.06E-7
WHF-03J_022	1.94E-4	4.79E-7	3.58E-6
WHF-03J_085	1.37E-4	3.47E-6	8.65E-6
WHF-03J_RUP	1.96E-5	1.16E-6	1.24E-6
WHF-04E_002	8.18E-6	3.24E-9	7.85E-8
WHF-04E_006	2.98E-6	1.18E-9	2.86E-8
WHF-04E_022	8.08E-6	6.37E-8	4.97E-7
WHF-04E_085	2.40E-7	1.71E-8	5.05E-8
WHF-04E_RUP	8.18E-7	1.36E-7	1.72E-7
WHF-05G_002	7.75E-4	3.07E-7	7.44E-6
WHF-05G_006	2.82E-4	1.12E-7	2.71E-6
WHF-05G_022	7.65E-4	6.03E-6	4.71E-5
WHF-05G_085	5.46E-4	3.88E-5	1.15E-4
WHF-05G_RUP	7.74E-5	1.28E-5	1.63E-5
WHF-06D_002	3.65E-4	1.46E-8	3.50E-7
WHF-06D_006	1.33E-4	5.30E-9	1.27E-7
WHF-06D_022	3.60E-4	3.01E-7	2.22E-6
WHF-06D_085	2.51E-4	2.21E-6	5.27E-6
WHF-06D_RUP	3.64E-5	7.49E-7	7.65E-7
WHF-07J_002	3.65E-4	4.36E-8	1.05E-6
WHF-07J_006	1.33E-4	1.59E-8	3.82E-7
WHF-07J_022	3.60E-4	8.90E-7	6.65E-6
WHF-07J_085	2.51E-4	6.35E-6	1.58E-5
WHF-07J_RUP	3.64E-5	2.15E-6	2.30E-6
WHF-08E_002	1.52E-5	6.02E-9	1.46E-7

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
WHF-08E_006	5.53E-6	2.19E-9	5.31E-8
WHF-08E_022	1.50E-5	1.18E-7	9.24E-7
WHF-08E_085	1.45E-5	1.03E-6	3.04E-6
WHF-08E_RUP	1.52E-6	2.52E-7	3.19E-7
SHP-01G_002	2.63E-3	1.04E-6	2.53E-5
SHP-01G_006	8.47E-4	3.36E-7	8.14E-6
SHP-01G_022	2.63E-4	2.08E-6	1.62E-5
SHP-01G_085	4.12E-5	2.93E-6	8.66E-6
SHP-01G_RUP	1.83E-5	3.04E-6	3.85E-6
SHP-02D_002	1.24E-3	4.95E-8	1.19E-6
SHP-02D_006	3.99E-4	1.59E-8	3.83E-7
SHP-02D_022	1.24E-4	1.03E-7	7.64E-7
SHP-02D_085	1.94E-5	1.71E-7	4.07E-7
SHP-02D_RUP	8.62E-6	1.77E-7	1.81E-7
SHP-03J_002	1.24E-3	1.48E-7	3.57E-6
SHP-03J_006	3.99E-4	4.77E-8	1.15E-6
SHP-03J_022	1.24E-4	3.07E-7	2.29E-6
SHP-03J_085	1.94E-5	4.91E-7	1.22E-6
SHP-03J_RUP	8.62E-6	5.09E-7	5.43E-7
SHP-04E_002	5.16E-5	2.05E-8	4.96E-7
SHP-04E_006	1.66E-5	6.58E-9	1.60E-7
SHP-04E_022	5.16E-6	4.07E-8	3.18E-7
SHP-04E_085	8.08E-7	5.75E-8	1.70E-7
SHP-04E_RUP	3.59E-7	5.96E-8	7.54E-8
SHP-05G_002	3.74E-3	1.48E-6	3.59E-5
SHP-05G_006	1.20E-3	4.77E-7	1.16E-5
SHP-05G_022	3.74E-4	2.95E-6	2.30E-5
SHP-05G_085	5.86E-5	4.16E-6	1.23E-5
SHP-05G_RUP	2.60E-5	4.32E-6	5.46E-6
SHP-06D_002	1.76E-3	7.03E-8	1.69E-6
SHP-06D_006	5.66E-4	2.26E-8	5.44E-7
SHP-06D_022	1.76E-4	1.47E-7	1.08E-6
SHP-06D_085	2.76E-5	2.43E-7	5.79E-7
SHP-06D_RUP	1.22E-5	2.52E-7	2.57E-7
SHP-07J_002	1.76E-3	2.11E-7	5.07E-6
SHP-07J_006	5.66E-4	6.78E-8	1.63E-6
SHP-07J_022	1.76E-4	4.35E-7	3.25E-6
SHP-07J_085	2.76E-5	6.97E-7	1.74E-6
SHP-07J_RUP	1.22E-5	7.23E-7	7.71E-7
SHP-08E_002	7.33E-5	2.91E-8	7.04E-7
SHP-08E_006	2.36E-5	9.35E-9	2.27E-7
SHP-08E_022	7.33E-6	5.78E-8	4.52E-7
SHP-08E_085	1.15E-6	8.16E-8	2.41E-7
SHP-08E_RUP	5.10E-7	8.46E-8	1.07E-7
PPW-01G_002	1.88E-4	7.43E-8	1.80E-6
PPW-01G_006	6.24E-5	2.47E-8	5.99E-7
PPW-01G_022	2.02E-5	1.59E-7	1.24E-6

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
PPW-01G_085	3.08E-6	2.19E-7	6.46E-7
PPW-01G_RUP	1.60E-6	2.66E-7	3.37E-7
PPW-02G_002	4.73E-3	1.87E-6	4.54E-5
PPW-02G_006	1.63E-3	6.47E-7	1.57E-5
PPW-02G_022	5.39E-4	4.24E-6	3.32E-5
PPW-02G_085	8.63E-5	6.13E-6	1.81E-5
PPW-02G_RUP	3.85E-5	6.38E-6	8.08E-6
PPW-03G_002	3.27E-4	1.29E-7	3.14E-6
PPW-03G_006	1.09E-4	4.31E-8	1.05E-6
PPW-03G_022	3.69E-5	2.91E-7	2.27E-6
PPW-03G_085	5.15E-6	3.66E-7	1.08E-6
PPW-03G_RUP	2.64E-6	4.38E-7	5.54E-7
PPW-04G_002	6.19E-4	2.45E-7	5.95E-6
PPW-04G_006	2.06E-4	8.16E-8	1.98E-6
PPW-04G_022	6.95E-5	5.48E-7	4.28E-6
PPW-04G_085	1.02E-5	7.25E-7	2.14E-6
PPW-04G_RUP	5.32E-6	8.82E-7	1.12E-6
PPW-05G_002	1.70E-3	6.73E-7	1.63E-5
PPW-05G_006	5.85E-4	2.32E-7	5.61E-6
PPW-05G_022	1.95E-4	1.54E-6	1.20E-5
PPW-05G_085	3.17E-5	2.50E-7	1.96E-6
PPW-05G_RUP	1.43E-5	2.37E-6	3.00E-6
PPW-06G_002	1.12E-3	4.43E-7	1.07E-5
PPW-06G_006	3.68E-4	1.46E-7	3.53E-6
PPW-06G_022	1.28E-4	1.01E-6	7.87E-6
PPW-06G_085	1.83E-5	1.30E-6	3.84E-6
PPW-06G_RUP	1.23E-5	2.05E-6	2.59E-6
PPW-07G_002	1.59E-3	6.30E-7	1.53E-5
PPW-07G_006	5.22E-4	2.07E-7	5.01E-6
PPW-07G_022	1.84E-4	1.45E-6	1.14E-5
PPW-07G_085	2.66E-5	1.89E-6	5.58E-6
PPW-07G_RUP	1.82E-5	3.02E-6	3.82E-6
PPW-08G_002	1.33E-3	5.27E-7	1.28E-5
PPW-08G_006	4.56E-4	1.81E-7	4.38E-6
PPW-08G_022	1.55E-4	1.22E-6	9.53E-6
PPW-08G_085	2.32E-5	1.65E-6	4.86E-6
PPW-08G_RUP	1.34E-5	2.22E-6	2.81E-6
PPW-09G_002	1.85E-3	7.33E-7	1.78E-5
PPW-09G_006	6.28E-4	2.49E-7	6.03E-6
PPW-09G_022	2.13E-4	1.68E-6	1.31E-5
PPW-09G_085	2.40E-5	1.89E-7	1.48E-6
PPW-09G_RUP	1.20E-5	1.99E-6	2.52E-6
PPW-10D_002	3.05E-3	1.22E-7	2.93E-6
PPW-10D_006	1.07E-3	4.26E-8	1.02E-6
PPW-10D_022	3.59E-4	3.00E-7	2.21E-6
PPW-10D_085	5.39E-5	4.75E-7	1.13E-6
PPW-10D_RUP	2.58E-5	5.31E-7	5.43E-7

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
PPW-11D_002	5.83E-4	2.33E-8	5.60E-7
PPW-11D_006	1.94E-4	7.75E-9	1.86E-7
PPW-11D_022	6.54E-5	5.46E-8	4.03E-7
PPW-11D_085	9.60E-6	8.46E-8	2.02E-7
PPW-11D_RUP	5.00E-6	1.03E-7	1.05E-7
PPW-12D_002	4.32E-4	1.72E-8	4.14E-7
PPW-12D_006	1.42E-4	5.66E-9	1.36E-7
PPW-12D_022	4.54E-5	3.79E-8	2.80E-7
PPW-12D_085	1.06E-5	8.87E-9	6.54E-8
PPW-12D_RUP	0.00E+0	0.00E+0	0.00E+0
PPW-13D_002	8.37E-5	3.34E-9	8.03E-8
PPW-13D_006	2.77E-5	1.11E-9	2.66E-8
PPW-13D_022	9.83E-6	8.21E-9	6.06E-8
PPW-13D_085	9.59E-7	8.45E-9	2.01E-8
PPW-13D_RUP	1.48E-6	3.04E-8	3.11E-8
PPW-14D_002	7.48E-4	2.99E-8	7.18E-7
PPW-14D_006	2.43E-4	9.72E-9	2.33E-7
PPW-14D_022	8.56E-5	7.15E-8	5.28E-7
PPW-14D_085	1.24E-5	1.09E-7	2.59E-7
PPW-14D_RUP	8.21E-6	1.69E-7	1.72E-7
PPW-15J_002	1.79E-4	2.14E-8	5.15E-7
PPW-15J_006	5.94E-5	7.11E-9	1.71E-7
PPW-15J_022	1.90E-5	4.69E-8	3.51E-7
PPW-15J_085	3.03E-6	7.67E-8	1.91E-7
PPW-15J_RUP	1.47E-6	8.67E-8	9.25E-8
PPW-16J_002	2.83E-4	3.39E-8	8.15E-7
PPW-16J_006	9.96E-5	1.19E-8	2.87E-7
PPW-16J_022	3.44E-5	8.50E-8	6.35E-7
PPW-16J_085	6.16E-6	1.56E-7	3.88E-7
PPW-16J_RUP	1.97E-6	1.16E-7	1.24E-7
PPW-17J_002	2.30E-4	2.75E-8	6.61E-7
PPW-17J_006	8.00E-5	9.57E-9	2.30E-7
PPW-17J_022	2.73E-5	6.75E-8	5.05E-7
PPW-17J_085	4.08E-6	1.03E-7	2.57E-7
PPW-17J_RUP	2.15E-6	1.27E-7	1.35E-7
PPW-18J_002	2.07E-4	2.48E-8	5.98E-7
PPW-18J_006	7.33E-5	8.78E-9	2.11E-7
PPW-18J_022	2.79E-5	6.90E-8	5.15E-7
PPW-18J_085	4.01E-6	9.93E-9	7.42E-8
PPW-18J_RUP	1.61E-6	9.51E-8	1.02E-7
PPW-19J_002	3.77E-3	4.51E-7	1.09E-5
PPW-19J_006	1.33E-3	1.59E-7	3.84E-6
PPW-19J_022	4.57E-4	1.13E-6	8.44E-6
PPW-19J_085	7.28E-5	1.84E-6	4.59E-6
PPW-19J_RUP	2.98E-5	1.76E-6	1.88E-6
PPW-20J_002	1.15E-3	1.37E-7	3.31E-6
PPW-20J_006	4.20E-4	5.03E-8	1.21E-6

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
PPW-20J_022	1.58E-4	3.91E-7	2.92E-6
PPW-20J_085	2.01E-5	5.10E-7	1.27E-6
PPW-20J_RUP	1.20E-5	7.07E-7	7.55E-7
PPW-21E_002	1.73E-3	6.85E-7	1.66E-5
PPW-21E_006	6.00E-4	2.38E-7	5.76E-6
PPW-21E_022	2.04E-4	1.61E-6	1.25E-5
PPW-21E_085	3.05E-5	2.17E-6	6.40E-6
PPW-21E_RUP	1.56E-5	2.58E-6	3.27E-6
PPW-22E_002	1.67E-3	6.63E-7	1.61E-5
PPW-22E_006	5.77E-4	2.29E-7	5.54E-6
PPW-22E_022	1.91E-4	1.51E-6	1.18E-5
PPW-22E_085	3.47E-5	2.47E-6	7.28E-6
PPW-22E_RUP	9.20E-6	1.53E-6	1.93E-6
PPW-23G_002	4.90E-3	1.94E-6	4.70E-5
PPW-23G_006	1.62E-3	6.41E-7	1.55E-5
PPW-23G_022	5.11E-4	4.03E-6	3.15E-5
PPW-23G_085	7.88E-5	5.60E-6	1.66E-5
PPW-23G_RUP	3.62E-5	6.01E-6	7.60E-6
PPW-24D_002	4.90E-3	1.96E-7	4.70E-6
PPW-24D_006	1.62E-3	6.47E-8	1.55E-6
PPW-24D_022	5.11E-4	4.27E-7	3.15E-6
PPW-24D_085	7.88E-5	6.94E-7	1.66E-6
PPW-24D_RUP	3.62E-5	7.44E-7	7.60E-7
PPW-25G_002	1.53E-3	6.06E-7	1.47E-5
PPW-25G_006	5.05E-4	2.00E-7	4.85E-6
PPW-25G_022	1.63E-4	1.28E-6	1.00E-5
PPW-25G_085	2.45E-5	1.93E-7	1.51E-6
PPW-25G_RUP	1.16E-5	1.92E-6	2.43E-6
PPW-26D_002	7.31E-4	2.92E-8	7.02E-7
PPW-26D_006	2.42E-4	9.66E-9	2.32E-7
PPW-26D_022	7.84E-5	6.55E-8	4.83E-7
PPW-26D_085	1.18E-5	9.82E-9	7.25E-8
PPW-26D_RUP	5.71E-6	1.17E-7	1.20E-7
MAN-01G_002	9.73E-3	3.85E-6	9.34E-5
MAN-01G_006	3.27E-3	1.29E-6	3.13E-5
MAN-01G_022	1.31E-3	1.03E-5	8.07E-5
MAN-01G_085	1.78E-4	1.27E-5	3.75E-5
MAN-01G_RUP	2.02E-4	3.36E-5	4.25E-5
MAN-02D_002	7.06E-3	2.82E-7	6.78E-6
MAN-02D_006	2.37E-3	9.47E-8	2.28E-6
MAN-02D_022	9.51E-4	7.94E-7	5.86E-6
MAN-02D_085	1.30E-4	1.14E-6	2.72E-6
MAN-02D_RUP	1.47E-4	3.02E-6	3.09E-6
MAN-03J_002	1.44E-2	1.73E-6	4.16E-5
MAN-03J_006	4.85E-3	5.80E-7	1.40E-5
MAN-03J_022	1.94E-3	4.81E-6	3.59E-5
MAN-03J_085	2.65E-4	6.70E-6	1.67E-5

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
MAN-03J_RUP	3.00E-4	1.77E-5	1.89E-5
MAN-04E_002	4.46E-3	1.77E-6	4.28E-5
MAN-04E_006	1.50E-3	5.92E-7	1.44E-5
MAN-04E_022	6.00E-4	4.73E-6	3.70E-5
MAN-04E_085	8.17E-5	5.81E-6	1.72E-5
MAN-04E_RUP	9.27E-5	1.54E-5	1.95E-5
MAN-05G_002	9.68E-3	3.83E-6	9.29E-5
MAN-05G_006	3.47E-3	1.37E-6	3.33E-5
MAN-05G_022	1.36E-3	1.07E-5	8.36E-5
MAN-05G_085	1.77E-4	1.26E-5	3.72E-5
MAN-05G_RUP	1.27E-4	2.10E-5	2.66E-5
MAN-06D_002	4.10E-3	1.64E-7	3.94E-6
MAN-06D_006	1.47E-3	5.87E-8	1.41E-6
MAN-06D_022	5.75E-4	4.80E-7	3.54E-6
MAN-06D_085	7.51E-5	6.62E-7	1.58E-6
MAN-06D_RUP	5.38E-5	1.11E-6	1.13E-6
PMP-01G_002	1.25E-3	4.95E-7	1.20E-5
PMP-01G_006	4.40E-4	1.74E-7	4.22E-6
PMP-01G_022	1.46E-4	1.15E-6	9.01E-6
PMP-01G_085	2.49E-5	1.96E-7	1.53E-6
PMP-01G_RUP	1.01E-5	1.67E-6	2.12E-6
PMP-02G_002	1.25E-3	4.95E-7	1.20E-5
PMP-02G_006	4.40E-4	1.74E-7	4.22E-6
PMP-02G_022	1.46E-4	1.15E-6	9.01E-6
PMP-02G_085	2.49E-5	1.96E-7	1.53E-6
PMP-02G_RUP	1.01E-5	1.67E-6	2.12E-6
PMP-03G_002	2.50E-3	9.90E-7	2.40E-5
PMP-03G_006	8.79E-4	3.48E-7	8.44E-6
PMP-03G_022	2.93E-4	2.31E-6	1.80E-5
PMP-03G_085	4.98E-5	3.93E-7	3.07E-6
PMP-03G_RUP	2.02E-5	3.34E-6	4.23E-6
PMP-04D_002	2.30E-3	9.20E-8	2.21E-6
PMP-04D_006	8.30E-4	3.31E-8	7.96E-7
PMP-04D_022	2.89E-4	2.41E-7	1.78E-6
PMP-04D_085	4.61E-5	3.85E-8	2.84E-7
PMP-04D_RUP	2.04E-5	4.19E-7	4.28E-7
PMP-05G_002	1.11E-2	4.40E-6	1.07E-4
PMP-05G_006	3.91E-3	1.55E-6	3.75E-5
PMP-05G_022	1.31E-3	1.03E-5	8.06E-5
PMP-05G_085	2.08E-4	1.64E-6	1.28E-5
PMP-05G_RUP	9.97E-5	1.65E-5	2.09E-5
PMP-06D_002	2.11E-3	8.44E-8	2.03E-6
PMP-06D_006	7.46E-4	2.98E-8	7.17E-7
PMP-06D_022	2.56E-4	2.13E-7	1.57E-6
PMP-06D_085	3.86E-5	3.22E-8	2.38E-7
PMP-06D_RUP	1.64E-5	3.38E-7	3.45E-7
PMP-07J_002	2.43E-3	2.91E-7	7.00E-6

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
PMP-07J_006	8.58E-4	1.03E-7	2.47E-6
PMP-07J_022	2.88E-4	7.13E-7	5.33E-6
PMP-07J_085	4.50E-5	1.14E-6	2.83E-6
PMP-07J_RUP	2.15E-5	1.27E-6	1.35E-6
PMP-08G_002	5.49E-4	2.18E-7	5.28E-6
PMP-08G_006	1.97E-4	7.81E-8	1.89E-6
PMP-08G_022	6.94E-5	5.47E-7	4.28E-6
PMP-08G_085	7.39E-6	5.25E-7	1.55E-6
PMP-08G_RUP	4.15E-6	6.88E-7	8.71E-7
PMP-09D_002	2.75E-4	1.10E-8	2.64E-7
PMP-09D_006	9.86E-5	3.94E-9	9.46E-8
PMP-09D_022	3.47E-5	2.90E-8	2.14E-7
PMP-09D_085	3.69E-6	3.25E-8	7.76E-8
PMP-09D_RUP	2.07E-6	4.26E-8	4.35E-8
RTL-01G_002	1.24E-1	4.92E-5	1.19E-3
RTL-01G_006	4.68E-2	1.85E-5	4.49E-4
RTL-01G_022	8.19E-2	6.46E-4	5.05E-3
RTL-01G_085	4.72E-1	3.72E-3	2.90E-2
RTL-01G_RUP	7.42E-3	1.23E-3	1.56E-3
RTL-02D_002	5.91E-2	2.36E-6	5.67E-5
RTL-02D_006	2.23E-2	8.91E-7	2.14E-5
RTL-02D_022	3.90E-2	3.26E-5	2.40E-4
RTL-02D_085	2.24E-1	1.87E-4	1.38E-3
RTL-02D_RUP	3.53E-3	7.26E-5	7.42E-5
RTL-03J_002	1.77E-2	2.12E-6	5.11E-5
RTL-03J_006	6.69E-3	8.00E-7	1.93E-5
RTL-03J_022	1.17E-2	2.89E-5	2.16E-4
RTL-03J_085	6.76E-2	1.67E-4	1.25E-3
RTL-03J_RUP	1.06E-3	6.26E-5	6.68E-5
RTL-04G_002	1.13E-2	4.49E-6	1.09E-4
RTL-04G_006	4.28E-3	1.70E-6	4.11E-5
RTL-04G_022	7.49E-3	5.90E-5	4.61E-4
RTL-04G_085	1.50E-1	1.19E-3	9.26E-3
RTL-04G_RUP	6.78E-4	1.13E-4	1.42E-4
RTL-05D_002	5.40E-3	2.16E-7	5.19E-6
RTL-05D_006	2.04E-3	8.14E-8	1.96E-6
RTL-05D_022	3.57E-3	2.98E-6	2.20E-5
RTL-05D_085	7.14E-2	5.96E-5	4.40E-4
RTL-05D_RUP	3.23E-4	6.64E-6	6.78E-6
RTL-06E_002	1.93E-3	7.64E-7	1.85E-5
RTL-06E_006	7.27E-4	2.88E-7	6.98E-6
RTL-06E_022	1.27E-3	1.00E-5	7.84E-5
RTL-06E_085	1.06E-2	8.36E-5	6.53E-4
RTL-06E_RUP	1.15E-4	1.91E-5	2.42E-5
RTL-07D_002	4.24E-4	1.69E-8	4.07E-7
RTL-07D_006	1.60E-4	6.39E-9	1.54E-7
RTL-07D_022	2.80E-4	2.34E-7	1.72E-6

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
RTL-07D_085	2.32E-3	1.94E-6	1.43E-5
RTL-07D_RUP	2.53E-5	5.21E-7	5.32E-7
WHF-09G_002	1.24E-4	4.90E-8	1.19E-6
WHF-09G_006	4.50E-5	1.78E-8	4.32E-7
WHF-09G_022	1.22E-4	9.63E-7	7.53E-6
WHF-09G_085	5.45E-5	3.88E-6	1.14E-5
WHF-09G_RUP	1.24E-5	2.05E-6	2.60E-6
WHF-10D_002	7.92E-5	3.16E-9	7.60E-8
WHF-10D_006	2.88E-5	1.15E-9	2.77E-8
WHF-10D_022	7.82E-5	6.53E-8	4.82E-7
WHF-10D_085	3.74E-5	3.30E-7	7.86E-7
WHF-10D_RUP	7.92E-6	1.63E-7	1.66E-7
WHF-11J_002	4.21E-5	5.03E-9	1.21E-7
WHF-11J_006	1.53E-5	1.83E-9	4.41E-8
WHF-11J_022	4.15E-5	1.03E-7	7.68E-7
WHF-11J_085	2.23E-5	5.64E-7	1.40E-6
WHF-11J_RUP	4.21E-6	2.48E-7	2.65E-7
WHF-12G_002	2.89E-4	1.14E-7	2.77E-6
WHF-12G_006	1.05E-4	4.16E-8	1.01E-6
WHF-12G_022	2.85E-4	2.25E-6	1.76E-5
WHF-12G_085	1.30E-4	9.21E-6	2.72E-5
WHF-12G_RUP	2.89E-5	4.79E-6	6.06E-6
WHF-13D_002	1.85E-4	7.38E-9	1.77E-7
WHF-13D_006	6.73E-5	2.69E-9	6.46E-8
WHF-13D_022	1.82E-4	1.52E-7	1.12E-6
WHF-13D_085	8.61E-5	7.59E-7	1.81E-6
WHF-13D_RUP	1.85E-5	3.80E-7	3.88E-7
WHF-14J_002	9.82E-5	1.17E-8	2.83E-7
WHF-14J_006	3.57E-5	4.28E-9	1.03E-7
WHF-14J_022	9.69E-5	2.40E-7	1.79E-6
WHF-14J_085	4.67E-5	1.18E-6	2.94E-6
WHF-14J_RUP	9.81E-6	5.79E-7	6.18E-7
WHF-15E_002	4.95E-6	1.96E-9	4.75E-8
WHF-15E_006	1.80E-6	7.14E-10	1.73E-8
WHF-15E_022	4.89E-6	3.85E-8	3.01E-7
WHF-15E_085	1.45E-7	1.03E-8	3.05E-8
WHF-15E_RUP	4.95E-7	8.21E-8	1.04E-7
WHF-16E_002	1.15E-5	4.58E-9	1.11E-7
WHF-16E_006	4.20E-6	1.67E-9	4.04E-8
WHF-16E_022	1.14E-5	8.99E-8	7.02E-7
WHF-16E_085	7.36E-6	5.23E-7	1.54E-6
WHF-16E_RUP	1.15E-6	1.92E-7	2.42E-7
SHP-09G_002	7.81E-4	3.10E-7	7.50E-6
SHP-09G_006	2.51E-4	9.96E-8	2.41E-6
SHP-09G_022	7.81E-5	6.16E-7	4.81E-6
SHP-09G_085	1.22E-5	8.70E-7	2.57E-6
SHP-09G_RUP	5.44E-6	9.02E-7	1.14E-6

Scenario ID	Total Release Frequency	Flash Fire* (Flash Fire + VCE)	Jet Fire/ Pool Fire
SHP-10D_002	5.00E-4	2.00E-8	4.80E-7
SHP-10D_006	1.61E-4	6.43E-9	1.54E-7
SHP-10D_022	5.00E-5	4.17E-8	3.08E-7
SHP-10D_085	7.83E-6	6.90E-8	1.64E-7
SHP-10D_RUP	3.48E-6	7.15E-8	7.31E-8
SHP-11J_002	2.66E-4	3.18E-8	7.65E-7
SHP-11J_006	8.55E-5	1.02E-8	2.46E-7
SHP-11J_022	2.66E-5	6.57E-8	4.91E-7
SHP-11J_085	4.16E-6	1.05E-7	2.62E-7
SHP-11J_RUP	1.85E-6	1.09E-7	1.16E-7
SHP-12G_002	1.39E-3	5.52E-7	1.34E-5
SHP-12G_006	4.49E-4	1.78E-7	4.31E-6
SHP-12G_022	1.39E-4	1.10E-6	8.59E-6
SHP-12G_085	2.18E-5	1.55E-6	4.58E-6
SHP-12G_RUP	9.70E-6	1.61E-6	2.04E-6
SHP-13D_002	8.92E-4	3.57E-8	8.57E-7
SHP-13D_006	2.87E-4	1.15E-8	2.76E-7
SHP-13D_022	8.92E-5	7.45E-8	5.50E-7
SHP-13D_085	1.40E-5	1.23E-7	2.93E-7
SHP-13D_RUP	6.21E-6	1.28E-7	1.30E-7
SHP-14J_002	4.74E-4	5.67E-8	1.37E-6
SHP-14J_006	1.53E-4	1.82E-8	4.39E-7
SHP-14J_022	4.74E-5	1.17E-7	8.76E-7
SHP-14J_085	7.42E-6	1.88E-7	4.67E-7
SHP-14J_RUP	3.30E-6	1.95E-7	2.08E-7
SHP-15E_002	3.13E-5	1.24E-8	3.00E-7
SHP-15E_006	1.01E-5	3.98E-9	9.65E-8
SHP-15E_022	3.13E-6	2.46E-8	1.93E-7
SHP-15E_085	4.89E-7	3.48E-8	1.03E-7
SHP-15E_RUP	2.17E-7	3.61E-8	4.57E-8
SHP-16E_002	5.58E-5	2.21E-8	5.35E-7
SHP-16E_006	1.79E-5	7.11E-9	1.72E-7
SHP-16E_022	5.58E-6	4.40E-8	3.44E-7
SHP-16E_085	8.73E-7	6.21E-8	1.83E-7
SHP-16E_RUP	3.88E-7	6.44E-8	8.15E-8

D8. Storage Tank Incident Frequencies

D8.1. Tank Overfill

For this study, the tank overfill frequency was calculated as a function of tank level gauging failure, failure of operator during stock reconciliation and failure of independent high level shutdown of the tank.

Basis:

Failure rate of gauging system = once every 10 years

Failure of stock reconciliation = 0.1

PFD of independent high level shutdown per gasoline tank: 0.01 (assuming SIL 2)

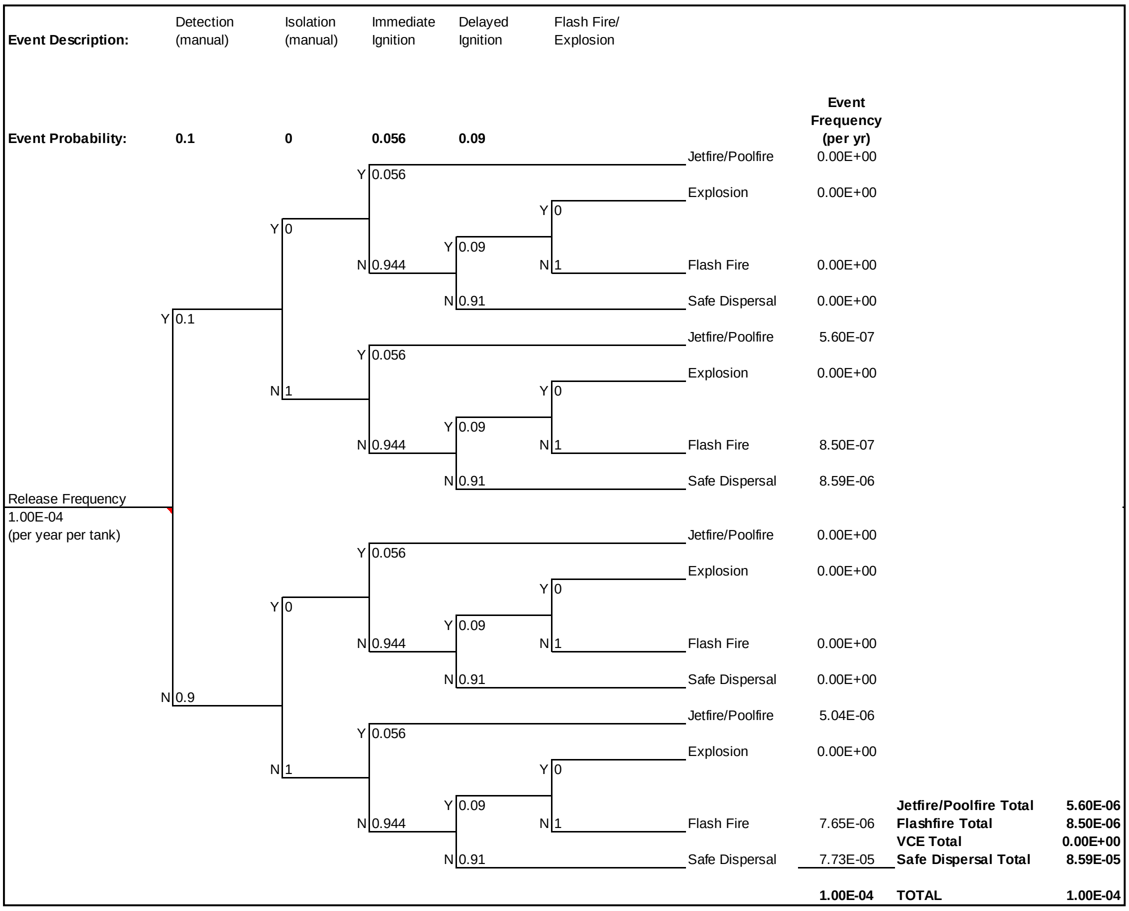
Calculation:

= Level gauging failure x operator stock reconciliation failure x high level shutdown failure on demand

= 0.1 x 0.1 x 0.01

= 1E-04 per year.

Using the event tree analysis, the frequency of flash fires (delayed ignition) due to tank overfill was determined to be 8.5E-06 per tank-year, as follows:



D8.2. Tank Roof Fire

The tank roof fire frequencies used in the QRA study were obtained from the most recent LASTFIRE Project Update (2012, Ref.12).

LASTFIRE Project Update 2012 indicates that there have been no full-surface tank roof fires recorded for internal-floating-roof (IFR) tanks. The rim seal fire frequency for IFR tanks is given as 4.4 x 10^{-5} per year.

The probability that a rim seal fire will escalate to a full surface tank roof fire will depend on the response to the seal fire and the behaviour of the floating roof. Tanks on Site B are provided with tank top foam pourers that would cover the floating blanket/pan and the rim seals with foam upon activation.

Assuming that there is a 10% chance that the foam pouring system fails to prevent a rim seal fire escalating to a full surface roof fire (based on the assumed detection by operator and reliability of the foam pouring system), a tank fire frequency of 4.4 x 10^{-6} per year was adopted for this study.

D8.3. Tank Bund Fire

Both intermediate and full bund fires were assessed in the QRA. The tank bund fire frequencies were calculated using the event tree analyses. Derivation of these frequencies are provided below

Small Bund Fire

This frequency was applied for all intermediate bund fire events. An event tree was developed using tank overfill frequency as the base frequency for the analysis. This is deemed to be appropriate for small bund fires as these type of failures are easier to isolate (eg closing valves, ESD and pumps), allowing quicker response and minimising the resulting pool size.

The frequency of small bund fire used in the QRA was determined to be 5.6E-06 per tank-year (refer to event tree provided on Section D8.1).

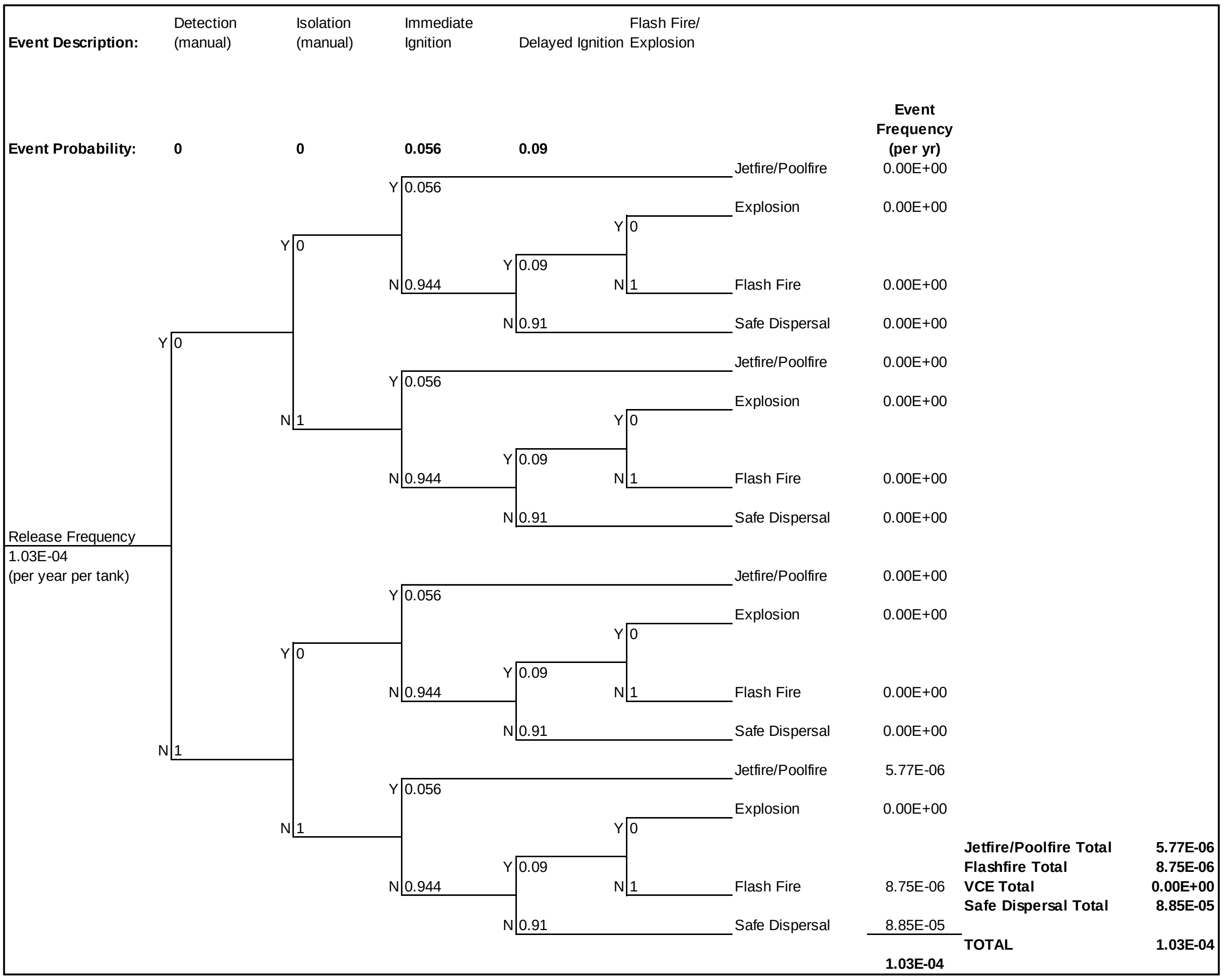
Large Bund Fire

This frequency was applied for all full bund fire events. An event tree was developed using summation of major tank failure and rupture frequencies as the base frequency of the analysis (1.03E-04 per tank-year), where:

- Major tank failure (1.0E-04 per tank-year, DNV Buncefield Report)
- Tank rupture (3,0E-06 per tank-year, OGP).

This is deemed to be appropriate for large bund fires as these failures are difficult to isolate depending on the leak source location and may result in large pool size (restricted by the bund area).

Using the event tree analysis, the frequency of large bund fires was determined to be 5.8E-06 per tank-year.


Event Description:
Detection (manual)
Isolation (manual)
Immediate Ignition
Delayed Ignition
Flash Fire/ Explosion
Event Frequency (per yr)
Event Probability:
0
0
0.056
0.09
Release Frequency
1.03E-04
(per year per tank)
Y 0
N 1
Y 0
N 1
Y 0
N 1
Y 0.056
N 0.944
Y 0.056
N 0.944
Y 0.056
N 0.944
Y 0.056
N 0.944
Y 0.09
N 0.91
Y 0.09
N 0.91
Y 0.09
N 0.91
Y 0.09
N 0.91
Y 0
N 1
Y 0
N 1
Y 0
N 1
Y 0
N 1
Jetfire/Poolfire 0.00E+00
Explosion 0.00E+00
Flash Fire 0.00E+00
Safe Dispersal 0.00E+00
Jetfire/Poolfire 0.00E+00
Explosion 0.00E+00
Flash Fire 0.00E+00
Safe Dispersal 0.00E+00
Jetfire/Poolfire 0.00E+00
Explosion 0.00E+00
Flash Fire 0.00E+00
Safe Dispersal 0.00E+00
Jetfire/Poolfire 5.77E-06
Explosion 0.00E+00
Flash Fire 8.75E-06
Safe Dispersal 8.85E-05
1.03E-04
Jetfire/Poolfire Total 5.77E-06
Flashfire Total 8.75E-06
VCE Total 0.00E+00
Safe Dispersal Total 8.85E-05
TOTAL 1.03E-04

APPENDIX E. IMPACT OF CHANGES IN PRODUCT ALLOCATION ON SITE B RISK - ASSESSMENT CHECKLISTS

E1.1. Key Assumptions

A number of simplifying assumptions need to be made to prepare a QRA and the results are therefore dependent on the assumptions made in defining the input scenarios. This is particularly true of bulk terminal sites due to the potential variety of products and throughputs.

Vopak may change product allocations within tanks from time to time depending on market demands. Change in product allocation is done under the Vopak Change Management procedure and a formal modification raised.

There are two main factors that may affect the risk results as shown in this QRA report:

1. *Increased storage of ethanol*. Ethanol has different radiant heat properties and a larger radiant heat impact for an otherwise equivalently sized gasoline fire. An assessment of the effect of conversion to ethanol has been previously prepared (ref Sherpa Consulting *Impact of Proposed Ethanol Storage Consequence and Risk Review J20595-001 Rev 0 June 2012).* The assessment is contained in this appendix and broadly concludes that the offsite risk results are not significantly changed. These QRA results presented here will remain valid even if a greater proportion of the terminal is converted to ethanol storage.
2. *Increased throughput of gasoline*. The largest impact events are vapour cloud explosion / flashfire events due to extended an overfill of a gasoline storage tank and subsequent ignition. These are the only events with the potential to significantly affect the extent of the $1x10^{-6}$ per year risk contour as shown in the Port Botany Land Use planning study (Ref 5). The likelihood of these scenarios is a function of the number of ship imports (into any tank) of gasoline. So long as the Site B terminal gasoline throughput remains within the basis given in APPENDIX A (ie around 50% of total throughput of 7,900,000m^3/year = 3,950,000 m^3 of gasoline per year as included in the future growth case) the results in the QRA remain valid.

Note that change of product within a tank between diesel / jet / gasoline has minimal impact on the tank or bund fire consequences however will affect the predicted fire frequency for a specific tank. This has an effect on onsite risk levels, and minimal effect on offsite risk except very close to the site boundary hence will not substantially change the offsite risk contours.

E1.2. Implications of changes in terminal operations

As Vopak respond to commercial drivers, changes to the terminal operation are a fairly frequent occurrence.

Site B is designed to allow storage of higher hazard products (ie gasoline) in any tank and the QRA has been prepared on this basis with the average probability of gasoline stored in a particular tank adjusted based on terminal throughput.

As noted throughout previous sections of this QRA, various upper limit assumptions have been made that mean that the hazard analysis already covers most changes in product allocation and use of the pipelines for any fuel hydrocarbon as long as they are within the fuel types already handled at Site B.

Minor changes in piping arrangements within the site (eg additions to manifolds or tanker loading bays, changes relating to additives and slops handling in small tanks or at the road tanker loading point) have minimal effect on offsite risk, and hence can be regarded as already within the scope of this QRA.

However some changes are not within the scope of the QRA, with some examples listed below. Generally these would relate to introduction of an entirely new product or major engineering change. These would require a review of the QRA assumptions and may require an update to the QRA. Examples of changes requiring a review are:

- Introduction of products with different properties to hydrocarbon fuels (eg toxic monomers, solvents, liquified gases such as LPG etc).
- Changes in storage tank design (eg replacement of an existing tank with a larger tank).
- New pipeline between BLB and Site B.

To simplify the hazard analysis and fire safety study update requirements for future changes, checklists identifying the key assumptions in the QRA and also the Site B Fire Safety Study (FSS) have been developed that can be completed to determine whether the proposed change is already covered, or whether an update to the QRA may be required. These are provided on the following pages.

E1.3. Checklists to determine if update to Hazard Analysis and FSS is required

Change in Product Allocation: Checklist for Assessment of Effect on Hazard Analysis		
	If all answers below are "Yes" the existing hazard analysis in the form of the *Vopak Site B QRA Doc Ref 20940-RP-001, Sherpa Consulting Pty Ltd* which was prepared by a qualified person approved by the Director-General remains valid for the proposed change in product allocation. There will be minimal effect on offsite risk, HIPAP 4 criteria will remain satisfied by Site B operations and there will be no increase in the port area cumulative individual fatality risk as per Figure 2 of the *Port Botany Land Use Safety Study Overview Report (Planning NSW 1996)* due to the proposed change in product allocation. If any answers are "no", a review and update or addendum to the Site B QRA should be prepared.	
Proposed Change:	**[Describe Change]**	**Criteria Met? (Yes or No)**
	Is product being introduced to tank a Class 3 or combustible liquid as listed below or a liquid with similar flammability and toxicity properties: - Gasoline (any grade) - Diesel - Jet fuel - Biodiesel - Ethanol - Methanol If so the change in product allocation does not introduce any new hazards as all tanks are suitable for highest hazard product (gasoline).	
	Product will be stored in an existing tank without modification to tank height or diameter. If so, the fire scenarios modelled in the QRA and FSS remain valid	
	Tank independent high level shutdown remains in place	
	A review of all materials of construction of the tank and associated equipment has been undertaken to confirm compatibility with new product (this step is required to ensure that products such as biodiesel or ethanol which can be incompatible with elastomers are specifically checked against the proposed storage). If so, there is no new mechanical integrity risk.	
	Product will be stored in compliance with AS1940	
	Site B terminal total fuel throughput remains at or below 7,900,000 m^3/year and Total annual gasoline throughput remains at or below 3,950,000 m^3/year	
	Maximum product import rate into a single tank remains at or below 1750m^3/hr. If so there will be no change to risk associated with static accumulation (ignition risk) or tank overfill resulting in large spills / flammable vapour clouds. Note: The mechanical capacity from BLB1 is 2 x 1,250m^3/hr and BLB2 is 2 x 1,750m^3/hr but this cannot be filled into a single tank.	
	Import will occur from either BLB1 or BLB2 via an existing pipeline in existing pipeline corridor from BLBs to Site B	
Assessment:	This change is assessed as **within / not within** the scope of the existing Site B Hazard Analysis in the form of the Site B QRA and a hazard analysis **is / is not** required to be prepared under the applicable planning legislation.	

Change in Product Allocation: Checklist for Assessment of Effect on Fire Safety Study		
	If all answers below are "Yes" the existing fire safety study (FSS) *VOPAK B3 EXPANSION PROJECT PORT BOTANY CONDITION OF CONSENT STUDY FIRE SAFETY STUDY Doc Ref 20294-007 Rev 0 Aug 2009, Sherpa Consulting Pty Ltd* which was prepared by a qualified person approved by the Director-General remains valid for the proposed change in product allocation. There will be minimal effect on fire prevention, detection or protection requirements at the site. If any answers are "no", an update or addendum to the Site B FSS should be prepared.	
Proposed Change:	**[Describe Change]**	**Criteria Met? (Yes or No)**
	Is product being introduced to tank a Class 3 or combustible liquid as listed below or a liquid with similar flammability and toxicity properties: - Gasoline (any grade) - Diesel - Jet fuel - Biodiesel - Ethanol - Methanol If so the change in product allocation does not introduce any new fire hazards as all tanks are suitable for highest hazard product (gasoline).	
	Product will be stored in an existing tank without modification to tank height or diameter. If so, the fire scenarios modelled in the QRA and FSS remain valid	
	Tank top foam pourers and external spray cooling remains in place	
	The foam used at Site B (currently ANSULITE 3x3 Low-Viscosity AR-AFFF) is compatible with the new product.	
	Product will be stored in compliance with AS1940	
	Ethanol will not be stored in any tanks except TK101, TK207, TK730, TK624 TK625 or TK943. Note: The heat radiation impacts of ethanol fires are larger than equivalent gasoline fires. The potential impact for ethanol fires in TK101. TK207, TK730, TK624, TK625, TK943 or associated bund has been assessed in previous studies to determine if there are any effects on occupied areas (eg the Site B control room) or impairment of fire protection equipment. If a different tank is required for ethanol storage the heat radiation effect distances in Appendix E Section E1.4 should be used to assess either there are any heat radiation impacts on occupied areas or equipment that have not been previously considered.	
	Only diesel or biodiesel will be stored in TK621 Note: if a higher hazard material such as gasoline or ethanol is to be stored in TK621, an assessment of the potential risk of a fire affecting the fire pump house should be undertaken	
	Import will occur from either BLB1 or BLB2 via an existing pipeline in existing pipeline corridor from BLBs to Site B	
Assessment:	This change is assessed as **within / not within** the scope of the existing Site B FSS and an FSS **is / is not** required to be prepared under the applicable planning legislation.	

E1.4. Ethanol Storage Risk Review

IMPACT OF PROPOSED ETHANOL STORAGE

CONSEQUENCE AND RISK REVIEW

SITE B, PORT BOTANY, NSW

VOPAK TERMINALS AUSTRALIA PTY LTD

PREPARED FOR: **Eric Strautins,**
Engineering Manager
VOPAK

DOCUMENT NO: **J20595-001**
REVISION: **0**
DATE: **13 June 2012**

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DOCUMENT REVISION RECORD

REV	DATE	DESCRIPTION	PREPARED	CHECKED	APPROVED	METHOD OF ISSUE
DRAFT	29 Feb 12	Draft for internal review	F Wong			
A	13 Mar 12	Draft for client review	J Polich	-	-	PDF
0	13 Jun 12	Final Issue	J Polich	G Peach	J Polich	PDF

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Title: **Impact of Proposed Ethanol Storage** **Consequence and Risk Review** **Site B, Port Botany, NSW**	**QA Verified:** G PEACH **Date: 13 June 2012**

CONTENTS

TABLES

1. INTRODUCTION

1.1. Background

Vopak is proposing to convert some existing storage tanks at Site B, Friendship Rd Port Botany from typical hydrocarbon fuels (e.g. gasoline, diesel) to ethanol storage. Ethanol has different heat radiation characteristics to standard hydrocarbon fuels, hence the change may affect the risk profile, both offsite and onsite.

Key considerations are whether:

- the change in tank use will affect the existing fire protection requirements (i.e result in changed heat radiation impacts) on site, specifically for the control room building.
- the site's offsite risk profile will be affected to an extent that compliance is not achieved when assessed against the land use planning risk criteria in use in NSW (as published in NSW Department of Planning's HIPAP 4).
- the is an effect on the overall Port Botany cumulative risk contours as published in Figures 2 and 9 of the *Port Botany Land Use Safety Study 1996* (Ref 1).

Vopak retained Sherpa Consulting to prepare an assessment of the impact of the change of tank use on the existing Site B risk levels.

1.2. Scope

Vopak propose to store ethanol in existing Site B tanks:

- TK0207
- TK0624
- TK0625

The risk review covers these tanks and also covers storage of ethanol in other tanks generically. All tanks at Site B are designed to store either hydrocarbon fuels or ethanol so it is possible other tanks may also be converted in the future depending on market demands. TK0730 was previously approved for ethanol storage.

1.3. Methodology

The risk review included:

- Literature review of latest information regarding large ethanol tank fires (e.g. ETANKFIRE) to establish best practice with respect to predicting heat radiation levels from ethanol fires.
- Quantitative modeling of ethanol tank and bund fires to establish heat radiation effect distances. Results were prepared for the range of tank sizes at Site B and the worst case results used to assess likely effect on:

- the Site B offsite risk profile. The risk profile already exists in the form of individual fatality risk contours in the FHA for Site B, Pinnacle Risk Management, Ref 2 and Lloyds QRA for Vopak and the neighbouring Elgas site(Ref 3).
- the Port Botany cumulative risk contours (Ref 1) .

- Quantitative modeling of ethanol tank and bund fires in Tanks 624 and 625 to confirm any additional effects on the proposed control room that were not identified in the previous assessment based on standard hydrocarbon fuels (Tech Note 20463-TN-001 Rev 0, Oct 2010, Sherpa Consulting).
- Overlay of consequence distances to site layout (23kW/m2 and 4.7 kW/m2) to determine whether there are any effects within the site, e.g. compromise of access to manually activated fire protection equipment such as hydrants

2. ETHANOL HAZARDS

A literature view was carried out to determine latest knowledge with respect to ethanol fires. This is contained in APPENDIX A with the key points summarised below.

2.1. Ethanol Fire Hazards

Overall whilst ethanol has a lower heat of combustion than gasoline, large pool fires produce less soot than gasoline pool fires which tends to block the visible parts of the flames thereby reducing the heat radiation.

Experimental heat radiation impacts are therefore around 30% higher to double that of gasoline at an equivalent distance from an equivalent fire.

Ethanol is fully miscible with water, however it is still flammable at quite dilute levels (>10% ethanol in water), i.e, concentration must be diluted to below 10% ethanol in water to avoid flammable envelope.

2.2. Ethanol Explosion Hazards

The Buncefield event in the UK showed that large scale vapour cloud explosion events involving gasoline spills were possible. As part of the incident investigation other materials were also investigated. Significant amounts of vapour for alcohols were not predicted for overfill / spill type scenarios due to higher boiling point, ie. Absence of the "light" fractions in gasoline. Vapour cloud explosions due to spills of ambient temperature ethanol are therefore not regarded as credible. (Ref 4).

2.3. Firefighting techniques

Tests have shown that the only successful means of extinguishing ethanol fires is with Alcohol Resistent (AR) foam using a gentle application (Type 2) technique.

The literature review indicated that there are few examples of large ethanol fires and that there have been no successful extinguishments of large ethanol fires. The well known 2004 tank fire at Manildra, Port Kembla lasted for 20 hours and was extinguished only once the ethanol in the tank was diluted to below 10%.

3. SITE DETAILS

3.1. Layout and tank sizes

The site layout showing tank capacity, dimensions and locations is in APPENDIX C.

3.2. Fire Protection

Extensive fire protection systems are provided at Site B as follows:

- Cooling water to all bulk storage tank shells and roofs.
- Foam solution to all bulk storage tank foam pourers.
- Foam deluge in the pump bays.
- Oscillating cooling water monitors for the slops and additives tanks.
- Road tanker loading area fixed foam deluge
- Fixed foam monitor to the east of the road tanker unloading bay.

All fire water and foam deluge systems include a deluge valve that can be operated:

- Locally at the deluge valve with a manual release valve.
- Remotely from the FIP.
- Remotely from the SCADA system

Tank surface foam injection systems are provided on all tanks at Vopak. The fire fighting foam type (Ansulite 3%) and available application rate at Vopak is suitable for alcohol as shown in APPENDIX B. In tank foam pourers are a gentle application technique. The systems at Site B are therefore consistent with the literature review summary results with regards to the most effective ethanol fire fighting methods.

The risk of bund fires is low, therefore fixed firefighting equipment is not provided. There is a pressurised foam main complete with hydrants, hoses and monitors as well as two medium expansion foam carts for manually fighting bund fires from an upwibd position. All foam is Ansulite 3% and compatible with alcohol.

This approach to bund fire protection is unchanged by the storage of ethanol.

4. RESULTS

4.1. Heat Radiation Modeling Methodology

Relevant scenarios are:

- Tank top fires
- Intermediate bund fires

The proprietary modelling package Shell FRED (Fire, Release, Explosion, Dispersion) Version 6.0 has been used to assess the heat radiation impact distances. Fire sizes were estimated using bund dimensions (from drawing no 5510-81-001 Rev A) and calculating an equivalent diameter for a circular fire. The surface area for most bund fire scenarios is assumed to be that bounded by the 600mm internal bund dividing walls rather than the entire compound surface area.

Modeling also assumed the following parameters:

Temperature: 20oC

Relative Humidity: 70%

Materials: gasoline or ethanol

Windspeed: 5m/s

4.2. Heat Radiation Impacts

The following heat radiation levels are of interest:

- 4.7 kW/m^2 maximum intensity to which a suitably-clothed fire-fighter could approach a fire to, for example, operate a hydrant/ monitor
- 12.5 kW/m^2 significant chance of fatality
- 23 kW/m^2 minimum incident intensity at which escalation to equipment in the vicinity of a fire could occur. Unprotected steel will reach thermal stress temperatures sufficient to cause failure.

4.3. Results

A tabular summary of the distances to the heat radiation levels of interest for the tank and intermediate bund fire scenarios is given in Table 4.1. Impacts at the control room are given in Table 4.2.

Overlays of consequence distances onto an aerial photo are given in APPENDIX C.

In summary:

- Heat radiation levels of 23kW/m^2 and 12.5 kW/m^2 from both tank top and intermediate bund fires extend offsite for ethanol storage in TK0624, TK0101 (not currently proposed) and TK-0943 (not currently proposed).

Maximum extent of 12.5kW/m^2 contour from site boundary is around 45m. Maximum extent of 23kW/m^2 contour from site boundary is around 30m.

- Heat radiation levels of 4.7kW/m^2 (injury level) for both tank top and intermediate bund fires extend offsite for most scenarios.
- Heat radiation levels at the control room will be higher than originally predicted for gasoline fires in TK0624 area with levels well above 4kW/m^2 which will damage glass. However these levels are similar to those from gasoline fires in the TK0940 bund on the other side of the control room (less separation distance) The control room design already includes protection against heat radiation with fire rated walls and roof, toughened glass windows with water sprays. Egress from both sides of the building is provided (providing shielding from a fire on the opposite side of the building. The existing design is already adequate.

TABLE 4.1: HEAT RADIATION IMPACT DISTANCES

Item No.	Scenario		Material	Relevant dimensions				SEP (kW/m2)	Flame dimensions			Distance to heat radiation level from the centre of pool/tank		
	Tank No	Fire type		Diameter (m)	Height (m)	Bund area (if applicable) (m2)	Equiv diameter (m)		Height (m)	Length (m)	Tilt (deg from vertical)	4.7 kW/m2	12.5 kW/m2	23 kw/m2
1	Tank 0730	Tank top	Ethanol	16.5	24		16.5	69	-	-	48			
2	Tank 0730	Interm. Bund	Ethanol				39	50	-	46	30			
3	Tank 0624	Tank top	Ethanol	19.1	24		19.1	59	29	42	47	68	52	47
4	Tank 0624	Tank top	Gasoline	19.1	24		19.1	38	18	25	44	45	35	31
5	Tank 0624	Interm. Bund	Ethanol			1070	37	49	52	66	39	104	78	69
6	Tank 0624	Interm. Bund	Gasoline			1070	37	23	32	39	36	62	49	None
7	Tank 0625	Tank top	Ethanol	15	18		15	79	23	35	50	61	47	42
8	Tank 0625	Interm. Bund	Ethanol			1464	43	48	59	74	37	116	86	75
9	Tank 0624 + 0625	Interm. Bund	Ethanol			2534	57	49	75	90	33	143	104	89
10	Tank 0207	Tank top	Ethanol	28	18		28	52	41	55	42	86	66	59
11	Tank 0207	Tank top	Gasoline	28	18		28	27	25	32	40	54	42	39
12	Tank 0207	Interm. Bund	Ethanol			2073.6	51	49	68	83	35	131	96	83
13	Tank 0207	Interm. Bund	Gasoline			2074.6	51	21	42	49	32	76	59	None
14	Tank 0101	Tank top	Ethanol	36	18		36	49	51	65	39	102	76	68
15	Tank 0101	Interm. Bund	Ethanol			2956.8	61	49	79	94	32	150	109	93
	ADD TANK 0924	Tank top	Ethanol	35.9	24		35.9	49	50	65	39	102	76	68
		Interm. Bund	Ethanol			3139	63	50	82	96	32	154	111	95
Actual	Manildra fire	Tank top	Ethanol	32	5				50		0		>50	
FRED	Manildra fire	Tank top	Ethanol	32	5				60	60	0		43	

TABLE 4.2: HEAT FLUXES AT CONTROL ROOM BUILDING

Item No.	Scenario	Material	ApproxSurface area (m^2)	Equiv / actual. diam (m)	SEP, (kW/m^2)	Flame tilt (deg from vertical)	Separation distance to control room (m) (Note 2)	Max heat flux at control room (kW/m2) (Note 1,4)		
						at 5m/s (Note 5)		1.5m elevation	4m elevation	10m elevation
1	Tank top fire (TK0940)	Gasoline	1120	37.8	23	36	36	>12.5 (Note 6)	>12.5 (Note 6)	>12.5 (Note 6)
2	Intermediate bund (TK0940)	Gasoline	2100	50	21	32	21	5	6	9
3	Full B3B bund surface area fire	Gasoline	8600	105 (Note 3)	20		21	9.5	10	12
4	Tank top fire (TK0624)	Gasoline	300	19.1	47	48	36	<4.7	<4.7	<4.7
4a	Tank top fire (TK0624)	Ethanol	300	19.1			36	7	10	>12.5 (Note 6)
5	TK0624 Bund Fire (Note 7)	Gasoline	4400	75	20	27	25	4.7	5	6
5a	TK0624 Bund Fire (TK0624)	Ethanol	4400	75			25	>12.5 (Note 6)	>12.5 (Note 6)	>12.5 (Note 6)

NOTES:

1. Distance is from edge of tank or edge of bund to nearest point of control room building
2. 1st storey and 2nd storey and potential 3rd storey
3. The results for the B3A bund (118m equivalent diameter) have been used. B3B is similar size.
4. These results assume wind blowing towards the control room building. If wind direction is away, heat radiation would be lower.
5. 5m/s is representative of wind conditions as per the B3 FSS. On some occasion wind speeds may be higher, causing greater flame tilt.
6. Shell has revised guidance on the interpretation of radiation levels downwind of a tank fire. To account for the flame being drawn into the tank Shell advise that the radiation levels are projected down to grade and no benefit is taken for being located underneath the radiation contours.
7. A fire filling the southern end of the bund was modelled, assessing the entire bund and converting to an equivalent diameter would have been overly conservative
8. New scenarios for ethanol

4.4. Effect on Risk

4.4.1. Risk Criteria

The relevant land use risk criteria are from NSW DoP guideline HIPAP 4 (Ref 5) highlighted in red bold. The other criteria are for land uses too far away to be affected by the heat radiation from fires as can be seen from the consequence modeling results. The nearest residential areas are more than 1 km away. Explosions involving spills of ambient temperature ethanol are not credible as per Section 2.2, hence there is no risk associated with overpressures.

TABLE 4.3: NSW RISK CRITERIA, NEW PLANTS

Description	Risk Criteria (per year)
Individual Fatality Risk	
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6}
Fatality risk to residential and hotels	1×10^{-6}
Fatality risk to commercial areas, including offices, retail centres, warehouses	**5×10^{-6}**
Fatality risk to sporting complexes and active open spaces	10×10^{-6}
Fatality risk to be contained within the boundary of an industrial site	**50×10^{-6}**
Injury / Irritation	
Fire/Explosion Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6}
Toxic Injury - 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	10×10^{-6}
Toxic Irritation - 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	50×10^{-6}

TABLE 4.4: NSW ESCALATION RISK CRITERIA, NEW PLANTS

Description	Risk Criteria (per year)
Escalation	
Incident heat flux radiation at neighbouring potentially hazardous installations or land zoned to accommodate such use should not exceed a risk of 50 per million per year for the 23 kW/m^2 heat flux contour	**50×10^{-6}**
Overpressure at neighbouring potentially hazardous installations or the nearest public building should not exceed a risk of 50 per million per year for the 14 kPa overpressure contour	50×10^{-6}

4.5. Site B Risk Contours

The risk contours for Site B from the Site B approval (FHA, Ref 2) and updated contours prepared for expansion to the Elgas site (but not yet released, Ref 3) are given in APPENDIX D.

The following conclusions can be drawn:

- Boundary individual fatality risk associated with the bulk storage will not exceed 50x10-6 per year. The total event frequencies with potential to have an offsite effect are unaffected by the change from gasoline to ethanol and the total is below 50x10-6 per year. Note that this does not account for wind direction so the risk in a particular direction would be lower than the total event frequencies.
- The maximum extent of the offsite fatality consequence is around 50m from the site boundary (TK0101 intermediate bund fire and combined TK0624 and 0625 bund fire). This is around 25m more than the equivalent gasoline results. This is the maximum extent of any change that could occur in the fatality risk contours, i.e at worst the 1 x10-6 per year contour could extend by another 25m. However this does not take into account probabilities of wind direction or that only some tanks would be in ethanol service, so the actual increase in risk contour size would be much smaller.
- Escalation risk (i.e. frequency of exceeding 23kWm2) associated with the bulk storage will not exceed 50x10-6 per year. The total event frequencies with potential to have offsite heat radiation level exceeding 23kW/m2 are unaffected by the change from gasoline to ethanol and the total is below 50x10-6 per year. Note that this does not account for wind direction so the risk in a particular direction would be lower than the total event frequencies.

Overall a minor increase in the fatality risk contours would be expected however the HIPAP4 criteria will still be compiled with.

4.6. Port Botany Land Use Study

To determine the potential impact on the Port Botany area, the risk contours reported in the Port Botany Land Use Safety Study (Department of Planning, 1996) have been reviewed. Figure 8 of the Land Use Safety Study shows risk contours for residential (1 x 10-6 per year) and industrial land use criteria (50 x 10-6 per year) and is given in APPENDIX D.

These contours were developed taking into account the then proposed (now constructed and operating) Vopak Stage B1 site and also included additional proposed storage towards Molineux Point to the south (which was not developed and has since been developed into container handing facilities, ie no hazardous materials). Vopak Site B2 and B3 do not appear to be included.

The 1 x 10^{-6} per year risk contour extends about 200 m from the centre of the site on Figure 8 of the land use safety study (Refer to Ref 1).

- The consequence distance for a bund or tank top fire (about 100 m maximum) does not extend that far and hence additional combustible storage will have no impact on the overall risk contour (1 x 10^{-6} per year)
- The 50 x 10^{-6} per year risk contour will be within the Vopak site boundary hence will not impact the cumulative Port Botany 50 x 10-6 per year risk contour which is outside the Vopak Site B boundary (just outside the roadways).

Hence there will be no significant effect on the cumulative risk as shown in the *Port Botany Land Use Safety Study* future use case.

5. CONCLUSIONS

Overall the risk review indicates that:

- Higher heat radiation levels are expected from ethanol compared to gasoline for equivalent fire scenarios hence the consequence distances are larger for ethanol.
- Best practice fire protection for ethanol fires is AR foam using a gentle application technique. This is achieved by the in-tank foam pourers in the Site B tanks.
- Higher heat radiation levels may occur at the control room than originally predicted for gasoline fires, however this is already protected against heat radiation with fire rated walls and roof, toughened glass with water sprays, and egress on both sides (i.e. shielded from fire occurring on either side).
- The size of the overall fatality risk contours for Site B would increase slightly (depending on proportion of site converted to ethanol) however these will have no effect on the overall cumulative risk in the Port Botany area as the consequence distances (hence risk) is well within the location of the cumulative risk contours shown in the DoP Port Botany Land Use Planning study.
- HIPAP 4 criteria for Site B would still be met as follows:
  - The 50×10^{-6} per year individual risk contour will remain within the Site B boundary as the total predicted frequency for events with offsite effects is below this value.
  - The 1×10^{-6} per year individual risk contour will not extend to any residential areas (which are more than 1 km away).
  - The 50×10^{-6} per year contour for exceedance of $23 kW/m^2$ (escalation risk) will remain within the Site B boundary as the total predicted frequency events with offsite effects is below this value.

APPENDIX A. LITERATURE REVIEW OF ETHANOL TANK FIRES

A1. Introduction

With increasing demand for ethanol in blended fuels, there has been a greater need to store ethanol in large tanks. It is therefore important to identify the heat radiation impact of large scale ethanol tank fires to determine likely effects on firefighting requirements. However, this area of study has been relatively unexplored and limited fire test data are available. This appendix summarises prior studies and impacts due to heat radiation from large scale ethanol fires as established via a literature search

A2. Characteristics of Ethanol and Gasoline

Physical properties of ethanol and gasoline are summarized in the table below. Key points are that:

- Ethanol is water miscible, gasoline is not.
- Pure ethanol is within its flammable range at temperatures between 12 and 40 deg C inside a fixed roof storage tank (Ref 6). Gasoline is above its Upper Explosive Limit (UEL) at ambient temperatures (and down to -20 deg C). Ignition of an ethanol tank vapour space is therefore more likely

	Gasoline	Ethanol
DG Class	Flammable Class 3 PGII	Flammable Class 3 PGII
Boiling Point (°C)	25-250	78.5
Flashpoint (°C)	-37.8	12.8
LFL (vol%)	1.4	3.3
UFL (vol%)	7.6	19
Auto ignition temperature (°C)	250 to 280	363
Heat of combustion (kJ/kg)	Approx. 43,500	26,800
Vapour pressure(kPa at 38°C)	36	9
Approximate temperature range in which equilibrium vapour/air mixture is in the explosive range	-50 to 0	10 to 33
Other comments		Burns with a colourless flame Soluble in water

The burning behaviour of ethanol is different to that of gasoline in that while it has lower heat of combustion than gasoline, ethanol typically burns more efficiently than gasoline. In large scale gasoline pool fires, large amounts of smoke are generated that tend to shield the visible parts of the flames to receivers, thereby reducing the heat radiation (Ref 7).

Figure 5.1 shows a large ethanol storage tank fire, burning intensely and with little smoke, while the large gasoline storage tank fire is less intense and accompanied with heavy smoke. It should be noted that firefighters are able to stand relatively closer to the tank in the gasoline fire.

FIGURE 5.1: LARGE ETHANOL TANK FIRE (LEFT) LARGE GASOLINE TANK FIRE (RIGHT)

A3. Heat Radiation from Ethanol Tank Fires

A3.1. 2004 Ethanol Tank Fire at Manildra Park

In 2004, a major ethanol tank fire occurred at Manildra Park Petroleum near Port Kembla, NSW. It started when the tank roof was blown off and firefighters spent more than 20 hours trying to extinguish the flames, which was not achieved until the ethanol was diluted to about 10%.

By determining the wind conditions and tank and flame characteristics, it is possible to extrapolate the heat radiation over a specified distance. It would also necessary to identify the effects on receivers at a certain distance away from the ethanol fire. The following lists the discussed requirements:

By determining the wind conditions and tank and flame characteristics, it is possible to extrapolate the heat radiation over a specified distance. It would also necessary to identify the effects on receivers at a certain distance away from the ethanol fire. The following lists the discussed requirements:

- An explosion in the tank blew off the roof which landed around 20m away and damaged site fire protection equipment.
- Tank storage of 4,000 m^3 ethanol concentrate (Ref 3)
- 32 m tank diameter (Ref 2)
- Flames were 50 m into the air (Ref 8)

- Plastic fixtures on cars over 50 m away from the tank had melted and buckled (Ref 3). Plastic melts at a radiation intensity of approximately 12 kW/m2 (Ref 9)
- There was no wind for the majority of the fire (Ref 10)
- Hundreds of workers were evacuated from around the site of the fire and a 500 m exclusion zone was set up (Ref 11).

A3.2. Other Incidents

Since 2000, there have been at least 26 major fires in the U.S. involving polar solvents, of which 14 were ethanol plant fires and three were ethanol tanker fires (Ref 12). No details of these incidents could be found. Apart from the Port Kembla fire no other details of ethanol tank or spill fire incident examples were found.

A3.3. Project Etankfire

Project Etankfire aims to determine the large scale burning behaviour of ethanol fuels but is currently at the project planning stage. Although there are no results from this study at present, experts from the project have shared their knowledge and previous work on tank fires to infer the effect of burning ethanol. The following is a summary of their inferences and comparisons to gasoline fires:

- Based on theoretical calculations, ethanol tank fires would result in a heat flux between 35% and 50% higher than gasoline (Ref 1)
- A small-scale test was conducted using a 1.7 m^2 pan for a spill scenario. Gasoline flames reached 7 m in height while a mixture of 85% ethanol and 15% acetone (E85) was less severe. Heat release measurements taken at 3 m distances were higher for gasoline than E85. However, up-scaling the experiment produced very different results. E85 flames and radiant heat were much higher. Figure 5.2 compares the heat radiation from burning gasoline and E85. However the same effect is unknown for pure ethanol (Ref 1)
- A modeling program predicts flame height of 40 m for ethanol in comparison with 25 m for gasoline under the same conditions (Ref 1)
- Fire tests in a 200 m^2 pool fire indicate that the heat flux from the acetone/ethanol fire is approximately twice that of gasoline. The reason for this is probably that, as the scale increases, petrol fires generate increasingly large amounts of smoke that tend to block the visible parts of the flames thereby reducing the heat radiation (Ref 13).

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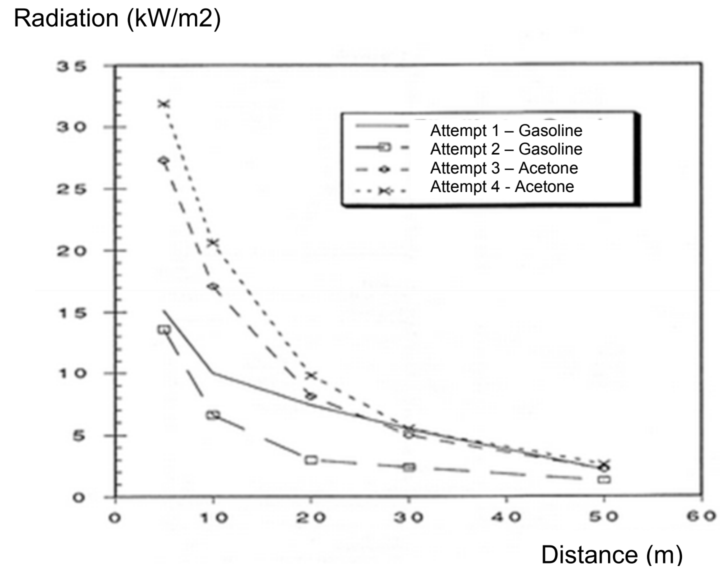
FIGURE 5.1: HEAT RADIATION FROM GASOLINE AND ACETONE/ETHANOL (REF 1)



A3.4. Firefighting Methods

The number of known ethanol tank fires to date is presently low. Those few tank fires that have occurred have resulted in burn out rather than extinguishment (Ref 13).

Testing has been conducted in the US to establish the foam requirements for spill fire scenarios, i.e. relatively thin fuel layers with short pre-burn times. This cannot be immediately extrapolated to tank fire scenarios. A tank fire will present a more severe situation compared to a spill fire due to the large fuel depth and consequently, the dilution effect from the firefighting foam will be limited. In most situations, the pre-burn time will also be longer than that expected in a spill fire, thereby increasing the temperature of the fuel and creating hot steel surfaces making extinguishment even more difficult.

However the general conclusion from the various large scale tests and standard test methods, is that the use of alcohol resistant (AR) foams is a fundamental requirement to obtain extinguishment of water miscible fuels (Ref 13). However, the tests have also shown that even AR foams will fail unless gentle foam application onto the burning fuel surface can be achieved. As tank fires are usually extinguished using large capacity foam monitors, gentle application is not possible and therefore extinguishment cannot be expected using this technique (Ref 13).

A4. Conclusion

Project Etankfire aims to study the burning behaviour of these fires, but results are not yet available. Fire tests for larger pools conducted using acetone/ethanol mixtures show that the heat flux is approximately twice that of gasoline at an equivalent distance. Pure ethanol pool fires are expected to have similar results. The impact of the ethanol tank fire at Manildra Park in 2004 to the surrounding environment can be used to infer the heat radiation effects from a large tank top fire.

APPENDIX B. FIRE PROTECTION AT SITE B

ANSULITE® 3x3 LOW-VISCOSITY AR-AFFF CONCENTRATE

Data/Specifications

ANSUL®

DESCRIPTION

ANSULITE® 3x3 Low-Viscosity AR-AFFF (Alcohol-Resistant Aqueous Film-Forming Foam) Concentrate is formulated using a newly patented and proprietary technology. The foam concentrate has a dramatically reduced viscosity as compared to other listed polar-solvent type AR-AFFF concentrates on the market. This reduced viscosity enhances performance in all types of foam proportioning equipment including in-line eductors, balanced pressure systems, and built-in systems aboard CFR vehicles.

Additionally, the fire fighting performance of ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is superior to other 3% foam concentrates. This includes the blended gasoline additive Methyl Tertiary Butyl Ether (MTBE) which is being used worldwide as an oxygenate to make gasoline cleaner burning.

ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate offers many distinct advantages for ease of use and represents a continued commitment to quality by improving the first agent listed by Underwriters Laboratories for use as a 3% concentrate on both polar solvent and hydrocarbon fuels.

ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is formulated from special fluorochemical and hydrocarbon surfactants, a high molecular weight polymer, and solvents. It is transported and stored as a concentrate to provide ease of use and considerable savings in weight and volume.

It is intended for use as a 3% proportioned solution on both polar solvent and hydrocarbon fuels in fresh, salt or hard water. It may also be stored and used as a premixed solution in fresh water only.

There are three fire extinguishing mechanisms in effect when using ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate on either a conventional Class B hydrocarbon fuel such as gasoline, diesel fuel, etc., or a Class B polar solvent (water miscible fuel) such as methyl alcohol, acetone, etc. First, an aqueous film is formed in the case of a conventional hydrocarbon fuel, or a polymeric membrane in the case of a polar solvent fuel. This film or membrane forms a barrier to help prevent the release of fuel vapor. Second, regardless of the fuel type, a foam blanket is formed which excludes oxygen and from which drains the liquids that form the film or the polymeric membrane. Third, the water content of the foam produces a cooling effect.

Typical Physiochemical Properties at 77 °F (25 °C)

Appearance	Colorless to Pale Yellow Gelled Liquid
Density	1.020 g/ml ± 0.020
pH	7.0 – 8.5
Refractive Index	1.3565 ± 0.0020
Surface Tension (3% Solution)	18 ± 1 dynes/cm
Viscosity	1500 ± 500 cps*

*Brookfield Viscometer Spindle #4, Speed 30

ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is a non-Newtonian fluid that is both pseudoplastic and thixotropic. Because of these properties, dynamic viscosity will decrease as shear increases.

APPLICATION

ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is unique among the ANSULITE AFFF agents in that it can be used on either conventional Class B fuel or the polar solvent type Class B fuels. Its excellent wetting characteristics make it useful in combating Class A fires as well.

Because of the low energy required to make foam, it can be used with both aspirating and nonaspirating discharge devices.

To provide even greater fire protection capability, it may be used with dry chemical extinguishing agents without regard to the order of application. Due to the velocity of the dry chemical discharge, care must be taken not to submerge the polymeric membrane below the fuel surface.

A unique application for ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is vapor mitigation for hazardous fuming compounds including fuming acids. Recent tests on oleum and chlorosulfonic acids conducted in conjunction with DuPont at a DOE testing facility in Nevada found the foam to be very effective when applied through medium expansion nozzles such as the ANSUL® Model KR-M2 and KR-M4. In addition, the concentrate is ideally suited for situations involving flammable liquid spills where prolonged vapor suppression is desirable in advance of the spill clean up.

APPLICATION RATES

Application Rates using UL 162 Standard 50 ft^2 Fire Test on representative hydrocarbon and polar solvent fuels are listed below.

U.L. Type II Application(1) – Polar Solvents

Fuel Group	Concentration	Minimum Recommended Application Rate gpm/ft^2	(Lpm /m^2)
Alcohols			
Methanol (MeOH)	3%	0.10	(4.1)
Ethanol (EtOH)	3%	0.10	(4.1)
Isopropanol (IPA)	3%	0.15	(6.1)
Tertiary Butyl Alcohol (TBA)	3%	0.19	(7.7)
Ketones			
Methyl Ethyl Ketone (MEK)	3%	0.10	(4.1)
Acetone	3%	0.15	(6.1)
Methyl Isobutyl Ketone (MIBK)	3%	0.15	(6.1)
Amines			
Ethylene Diamene	3%	0.10	(4.1)
Ethers			
Methyl Tertiary Butyl Ether (MTBE)	3%	0.13	(5.3)
MTBE Blended Gasoline(2)	3%	0.10	(4.1)
Ethyl Tertiary Butyl Ether	3%	0.14	(5.7)
Tetrahydrofuran (THF)	3%	0.20	(8.2)

U.L. Type III Application(3) – Hydrocarbons

Heptane	3%	0.10	(4.1)

(1) TYPE II DISCHARGE OUTLET – A device that delivers foam onto the burning liquid and partially submerges the foam or procedures restricted agitation of the surface as described in UL 162.

(2) MTBE (17.8%)/Regular Unleaded Gasoline (82.2%) Blend

(3) TYPE III DISCHARGE OUTLET – A device that delivers the foam directly onto the burning liquid as described in UL 162.

PERFORMANCE

Fire Performance – The fire performance of ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is measured primarily against Underwriters Laboratories Standard 162.

Foaming Properties – When used with fresh, salt or hard water at the correct dilution with most conventional foam making equipment, the expansion will vary depending on the performance characteristics of the equipment. Aspirating discharge devices produce expansion ratios of 5:1 to 10:1 depending primarily on type of aspirating device and flow rate. Nonaspirating devices such as handline water fog/stream nozzles or standard sprinkler heads give expansion ratios of 2:1 to 4:1. Medium expansion discharge devices produce typical expansion ratios between 20:1 to 60:1 depending primarily upon type of device and operating conditions.

Proportioning – ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate can be easily proportioned (at the correct dilution) using most conventional proportioning equipment such as:

1. Balanced pressure and in-line balanced pressure pump proportioning equipment
2. Balanced pressure bladder tank proportioner
3. Around-the-pump proportioners
4. Fixed or portable (in-line) venturi proportioners
5. Handline nozzles with fixed induction/pickup tubes

The minimum and maximum usable temperature for ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate in this equipment is 35 °F (2 °C) to 120 °F (49 °C) respectively.

Storage/Shelf Life – When stored in the packaging supplied (polyethylene drums or pails) or in equipment recommended by the manufacturer and within the temperature limits specified, the shelf life of ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is about 20-25 years. The factors affecting shelf life and stability for ANSULITE AFFF agents are discussed in detail in Ansul Technical Bulletin No. 54. Freezing of the product should be avoided. If, however, the product is frozen during transport or storage, it must be thawed and inspected for signs of separation. If separation has occurred, the product must be mechanically mixed until homogeneous.

When the concentrate is to be stored in an atmospheric storage tank, a 1/4 in. (6 mm) layer of mineral oil should be added to seal the concentrate and minimize the effects of evaporation.

Compatibility – Since ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is a unique blend of surfactants, high molecular weight polymers, and solvents; it is recommended that ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate should not be mixed with any other foam concentrates. Consult Ansul Incorporated with any questions of compatibility.

Materials of Construction Compatibility – Tests have been performed with ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate verifying its compatibility with standard carbon steel "black" pipe and pipe manufactured from various stainless steel or brass compounds. Alternative pipe, plastic fittings, and valves may be used in some cases if acceptable to the customer and/or the authority having jurisdiction. Refer to Ansul Technical Bulletin No. 59, Form No. F-90109, addressing acceptable materials of construction for use with ANSUL foam concentrates.

Galvanized pipe and fittings must not be used in areas where undiluted concentrate will contact them since corrosion will result.

Please **first** consult Ansul Incorporated for specific guidelines concerning materials of construction.

Inspection – As with any fire extinguishing agent, ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate, whether in the concentrate or pre-mixed form, should be inspected periodically. NFPA 11 "Standard for Low Expansion Foam and Combined Agent Systems" requires that foam concentrate samples be submitted to the manufacturer or other qualified laboratory for quality condition testing at least annually. Contact ANSUL for further information on annual inspection.

APPROVALS AND LISTINGS

Underwriters Laboratories successfully tested ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate to the requirements contained in UL Standard 162, "Standard for Air-Foam Equipment and Liquid Concentrates." To receive the UL listing, the following tests had to be performed successfully:

1. Foam Quality Tests
2. Class B Hydrocarbon Fuel Fire Tests
3. Class B Polar Solvent Fuel Fire Tests
4. Foam Identification Tests
5. Tests of Shipping Containers
6. Class B Hydrocarbon and Polar Solvent Fuel Sprinkler Tests (Standard type both upright and pendent)

Besides determining agent characteristics, Underwriters Laboratories lists ANSULITE 3x3 Low-Viscosity Concentrate for use with specific hardware components that also carry the UL listing. To obtain these listings, ANSUL selected various hardware components from the major U.S. manufacturers of foam hardware.

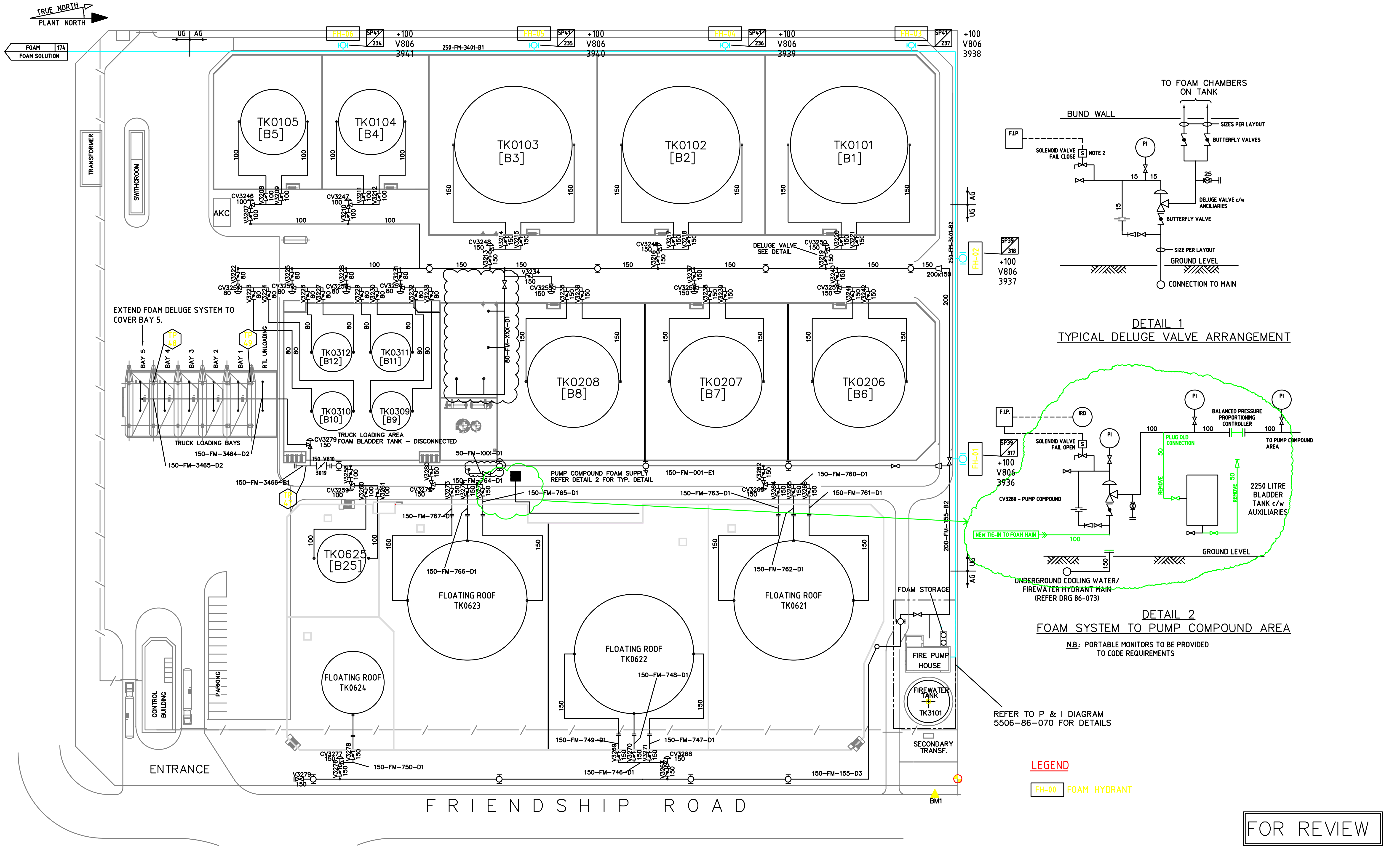
ORDERING INFORMATION

ANSULITE 3x3 Low-Viscosity AR-AFFF Concentrate is available in pails, drums, totes, or bulk shipment.

Part No. 416493	5 gallon pail
Part No. 416495	55 gallon drum
Part No. 429741	265 gallon tote
Part No. 416607	Bulk (contact ANSUL about domestic truckload delivery)

Shipping Weight:
- 5 gal (19 L) pail – 45 lb (20.4 kg)
- 55 gal (208.2 L) drum – 495 lb (224.5 kg)
- 265 gal (1000 L) tote – 2465 lb (1118 kg)

Cube:
- 5 gal (19 L) pail – 1.25 ft^3 (0.0354 m^3)
- 55 gal (208.2 L) drum – 11.83 ft^3 (0.3350 m^3)
- 265 gal (1000 L) tote – 50.05 ft^3 (1.42 m^3)



FOR REVIEW

NOTE
1. DRAWING IS REFERENCED FROM VOPAK 5506-86-072
2. CLOUDED SECTIONS SHOW PROPOSED FOAM PIPING

No.	DATE	REVISION	INITIAL	APP'D
B	25-8-10	FOAM DELUGE FOR JET & CTP PUMPS	PZ	
A	20-7-10	REVISED DWG 5506-86-072 RevF	PZ	ES

SCALE	NTS
DATE	20-7-10
DRAWN	PZ
CHECKED	

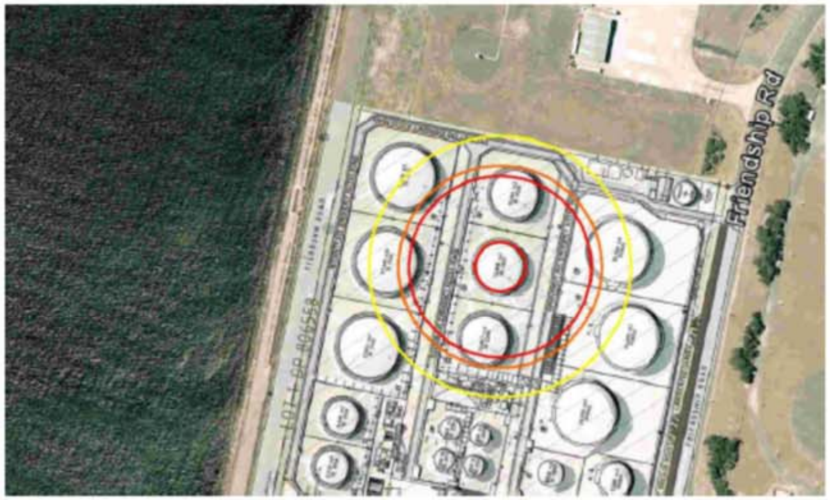
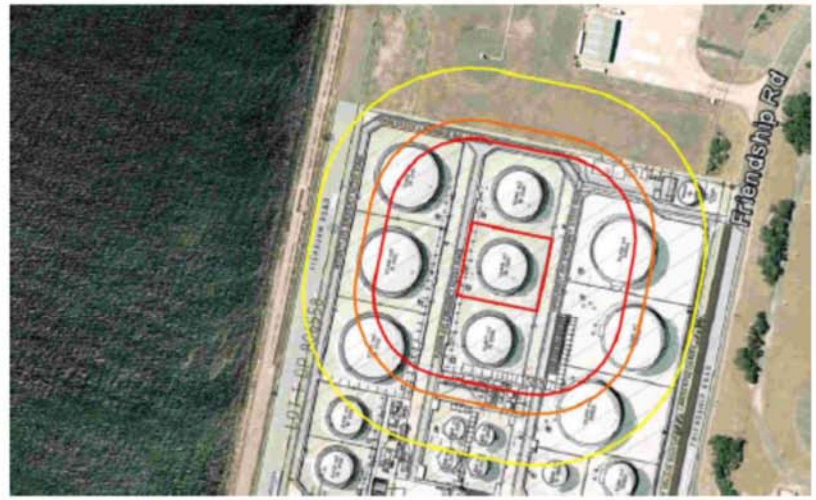
TITLE
VOPAK TERMINALS SYDNEY
P & ID - FIRE FIGHTING SYSTEM - Modified

Vopak

APPROVED

ENGINEERING	OPERATIONS	Q.C.T.	DRAWING No.	REV.
E. STRAUTINS			5640-86-072	B

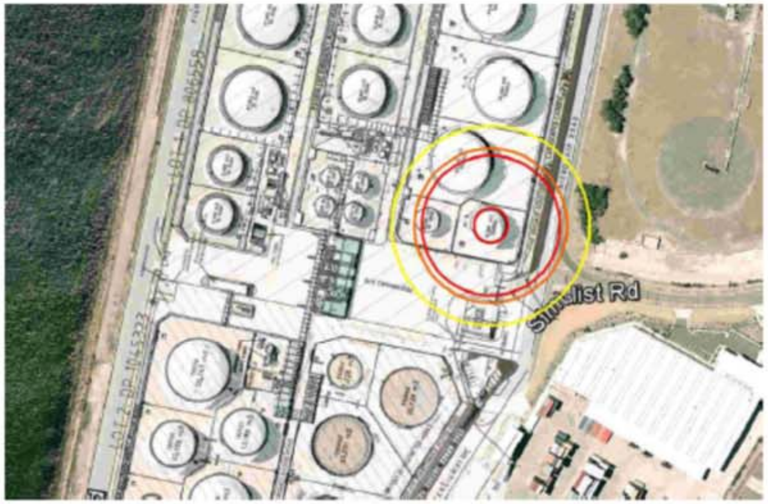
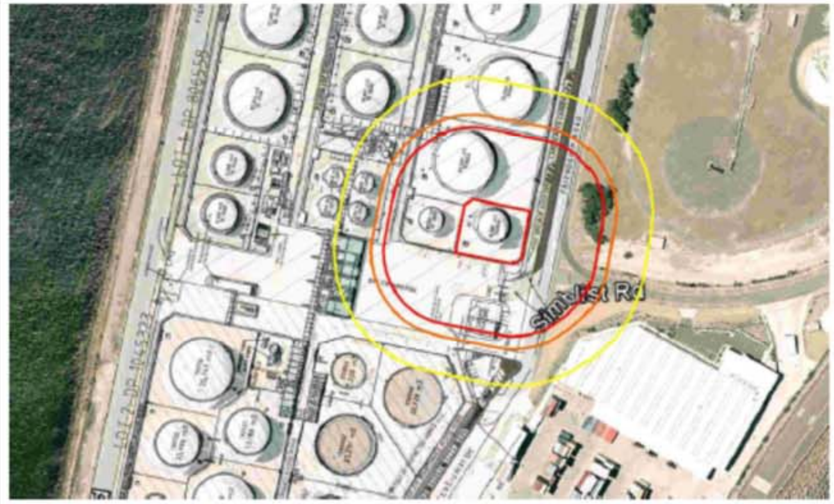
APPENDIX C. CONSEQUENCE OVERLAYS

TK0207 Tank top fire – Ethanol	TK0207 Intermediate bund fire – Ethanol
	
Analysis: 23kW/m² does not extend offsite 12.5 kW/m² does not extend offsite 4.7 kW/m² very marginally extends offsite No impact of offsite risk	Analysis: 23kW/m² does not extend offsite 12.5 kW/m² marginally extends offsite 4.7 kW/m² extends offsite for about 30m Minimal impact on offsite risk

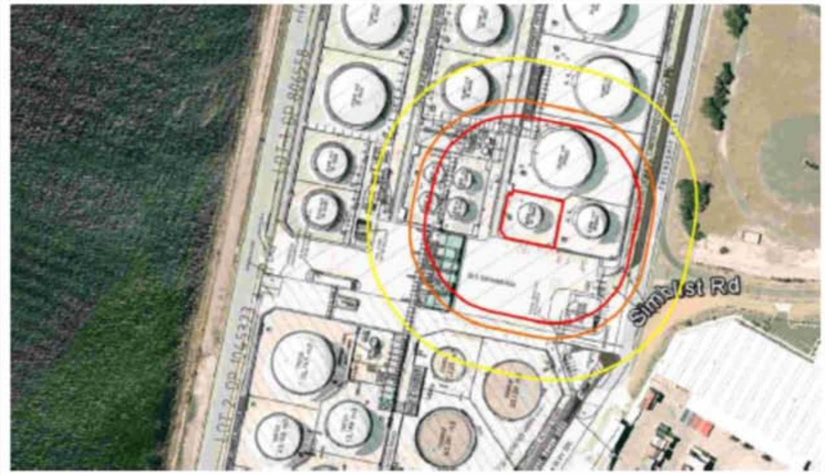
-------- 23 kW/m²

-------- 12.5 kW/m²

-------- 4.7kW/m²

TK0624 Tank top fire - Ethanol	TK0624 Intermediate bund fire - Ethanol
	
Analysis: 23kW/m² extends offsite 12.5 kW/m² extends offsite 4.7 kW/m² extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity	Analysis: 23kW/m² extends offsite 12.5 kW/m² extends offsite 4.7 kW/m² extends offsite for about 30m Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity

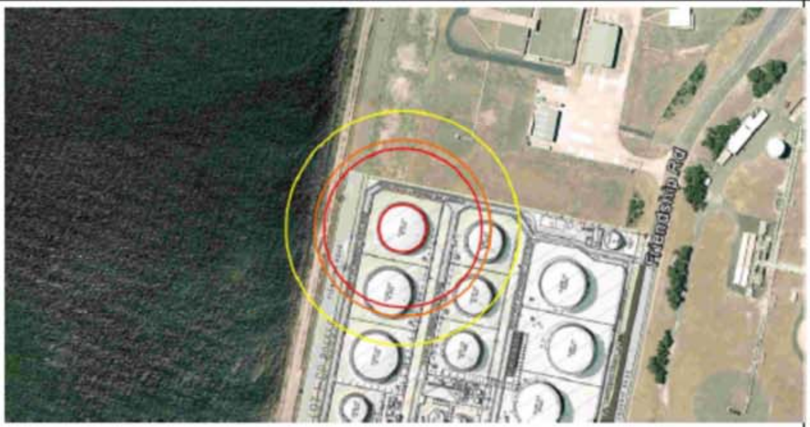
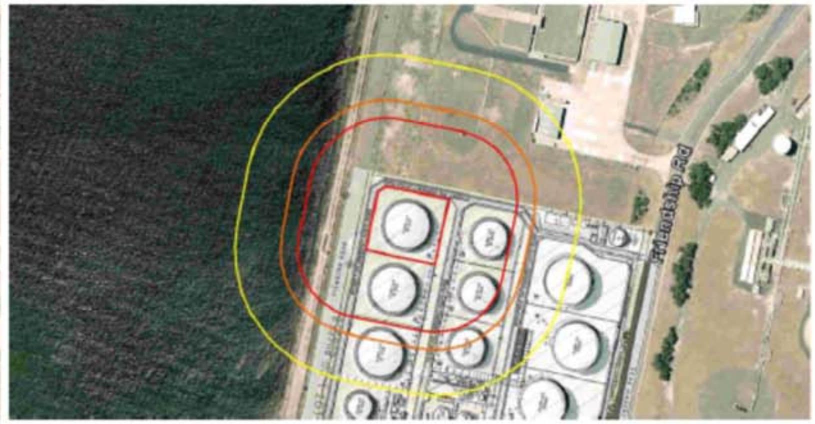
-------- (red)	23 kW/m²
-------- (orange)	12.5 kW/m²
-------- (yellow)	4.7kW/m²

TK0625 Tank top fire - Ethanol	TK0625 Intermediate bund fire - Ethanol
	
Analysis: 23kW/m² does not extend offsite 12.5 kW/m² does not extend offsite 4.7 kW/m² does not extend offsite No impact on offsite risk	Analysis: 23kW/m² does not extend offsite 12.5 kW/m² marginally extends offsite 4.7 kW/m² extends offsite for about 20m Minimal impact on offsite fatality risk

-------- 23 kW/m²

-------- 12.5 kW/m²

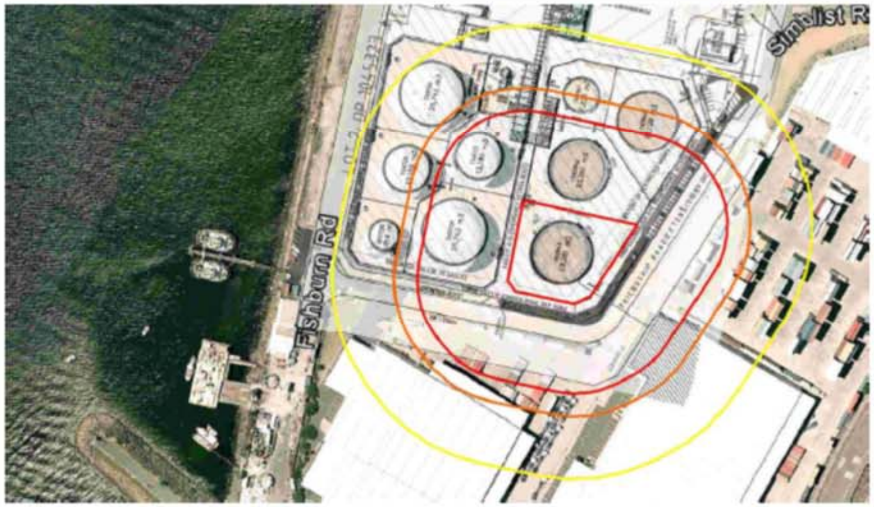
-------- 4.7kW/m²

TK0101 Tank top fire - Ethanol	TK0101 Intermediate bund fire - Ethanol
	
Analysis: $23 kW/m^2$ extends offsite $12.5 kW/m^2$ extends offsite $4.7 kW/m^2$ extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity	Analysis: $23 kW/m^2$ extends offsite $12.5 kW/m^2$ extends offsite $4.7 kW/m^2$ extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity

$23 kW/m^2$

$12.5 kW/m^2$

$4.7 kW/m^2$

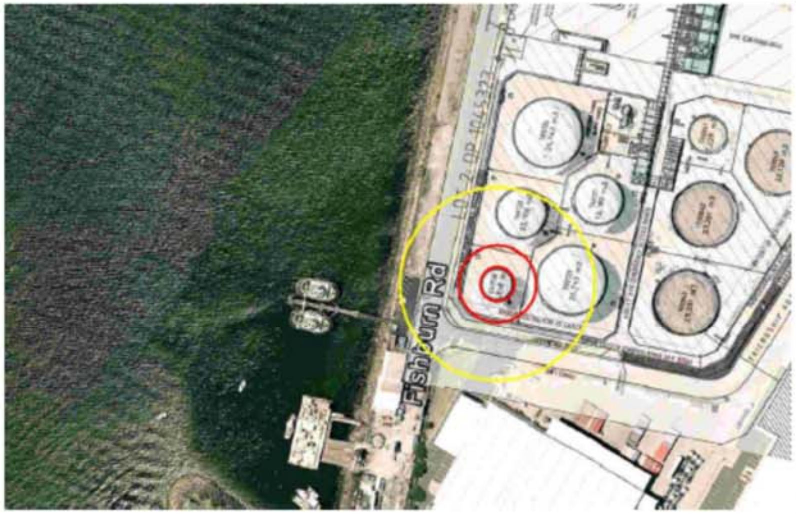
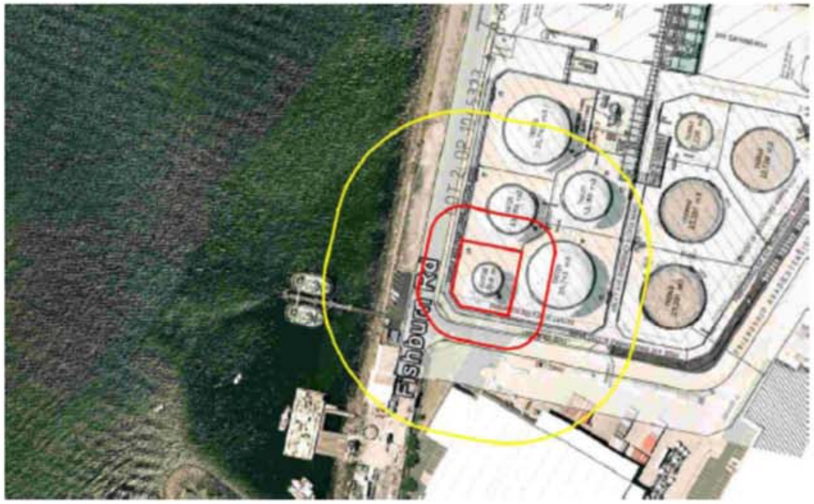
TK0943 Tank top fire - Ethanol	TK0943 Intermediate bund fire - Ethanol
	
Analysis: 23kW/m² extends offsite 12.5 kW/m² extends offsite 4.7 kW/m² extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity	Analysis: 23kW/m² extends offsite 12.5 kW/m² extends offsite 4.7 kW/m² extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity

-------- 23 kW/m²

-------- 12.5 kW/m²

-------- 4.7kW/m²

sherpa consulting

TK0730 Tank top fire - Ethanol	TK0720 Intermediate bund fire - Ethanol
	
Analysis: 23kW/m² does not extend offsite 12.5 kW/m² does not extend offsite 4.7 kW/m² extends offsite No impact on offsite risk, no escalation potential – no hazardous inventories in vicinity	Analysis: 23kW/m² extends offsite 12.5 kW/m² extends offsite 4.7 kW/m² extends offsite Minor impact on offsite risk, no escalation potential – no hazardous inventories in vicinity

-------- 23 kW/m²

-------- 12.5 kW/m² (not shown – results from previous FSS)

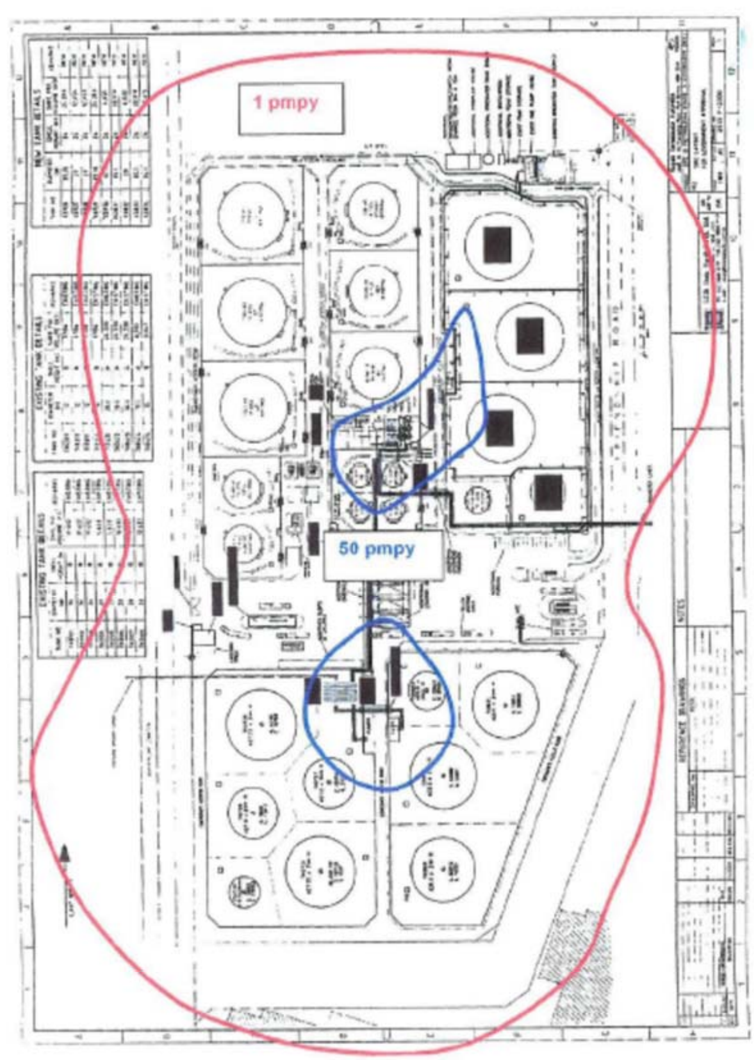
-------- 4.7kW/m²

APPENDIX D. RISK CONTOURS

D1. Risk Contours from FHA (Ref 2)

Pinnacle Risk Management

Figure 3 – Individual Fatality Risk Contour



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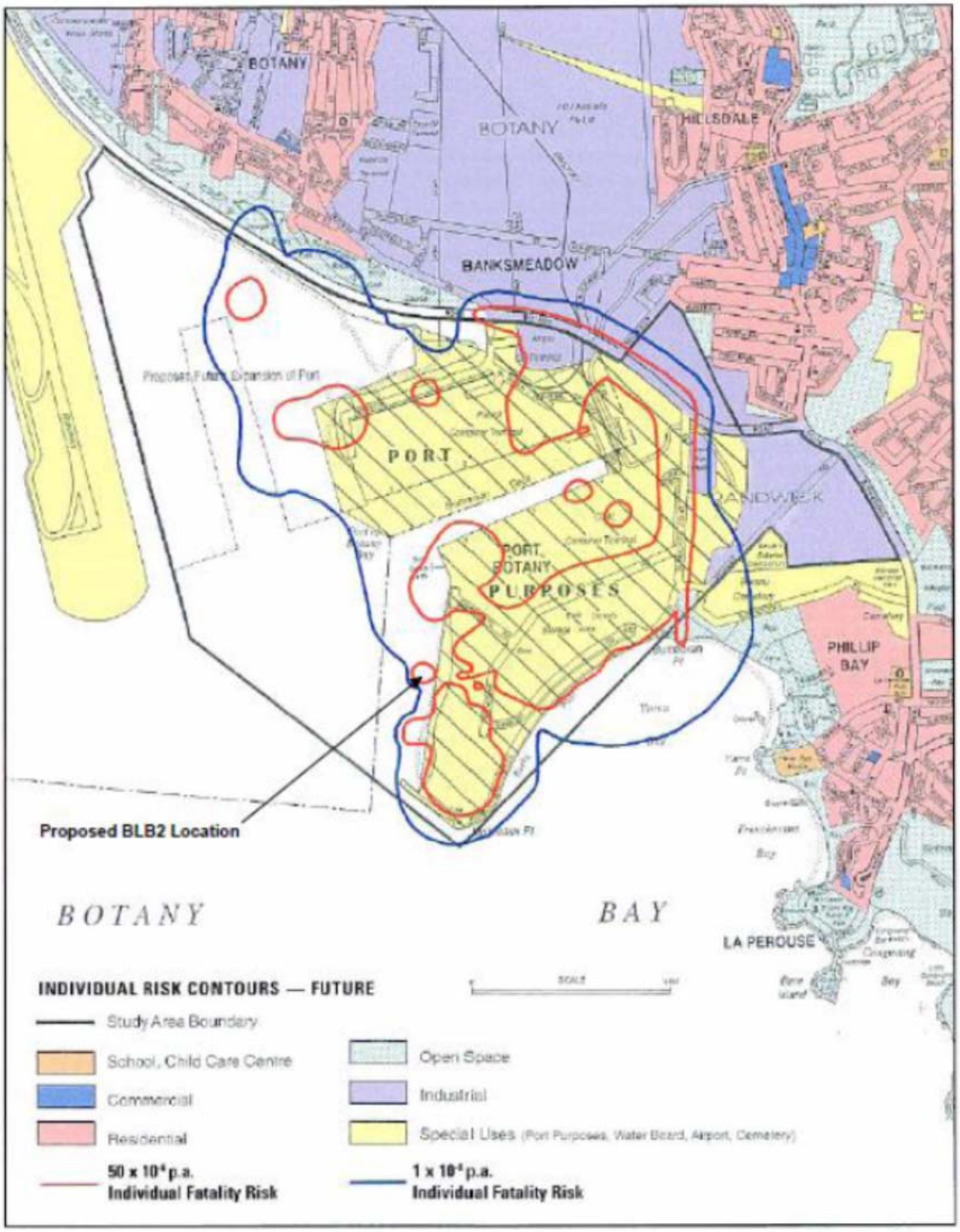
D2. Risk Contours from Combined Vopak / Elgas QRA (Ref 3)

Figure 8-1 Cumulative Individual Fatality Risk Contours for Existing (B1, B2 and B3) and Proposed (B4A and B4B) Facilities– Vopak Site B

D3. Risk Contours from Port Botany Land Use Study (Ref 1)



APPENDIX E. REFERENCES

1 NSW Department of Planning 1996 *Port Botany Land Use Safety Study Overview Report*

2 Pinnacle Risk Management (Oct 2007) *Final Hazard Analysis Vopak Site B*

3 Lloyds Register, 10 June 2011 *Quantitative Risk Assessment Vopak Site B and Elgas LPG Caverns* Rev 1

4 UK HSE (2008) *The Buncefield Incident 11 December 2005 The final report of the Major Incident Investigation Board Volumes 1, 2A, 2B*

5 NSW Department of Planning (2011) *Hazardous Industry Planning Advisory Paper (HIPAP) No 4 Risk Criteria for Land Use Planning*

6 Industrial Fire Journal – Fire & Rescue, 2011, *Project Etankfire*, http://hemmingfire.com/news/printpage.php/aid/1317/Project_ETANKFIRE.html

7 Asia Pacific Fire Magazine, 2011, *Ethanol – Providing Answers to New Firefighting Challenges*, http://www.mdmpublishing.com/mdmmagazines/magazineapf/newsview/178/ethanol-providing-answers-to-new-firefighting-challenges

8 Fire News, 2004, *Major Ethanol Tank Fire, p2*, http://www.fire.nsw.gov.au/gallery/files/pdf/fire_news/firenews_2004_mar.pdf

9 The Netherlands Organisation of Applied Scientific Research, 1992, *Methods for the determination of possible damage CPR 16E*, Chapter 7 – Material Damages due to heat radiation

10 Baden S, 2004, *Investigation launched into Kembla blaze*, *The Age*

11 Kamper A, 2004, *Ethanol inferno extinguished*, *The Daily Telegraph*

12 Industrial Fire World Jan 2007, David White, *The Trouble with Ethanol* http://www.fireworld.com/ifw_articles/ethanol_07.php

13 Persson H, McNamee M and Rosen F, 2011, *Ethanol Tank Firefighting to be presented at a workshop*, http://www.fireproductsearch.com/news/ethanol-tank-fire-fighting/

APPENDIX F. WEATHER DATA AND ANALYSIS

F1. Data Source

Historical meteorological weather data for the Vopak Site B terminal was obtained from the Bureau of Meteorology (BOM). The acquired data sets were based readings from the Automatic Weather Station (AWS) at Sydney Airport (AWS 066037) and Kurnell (AWS 066043) over the period of July 2000 – June 2008 (Ref. 10).

As advised by the BOM, local effects will mean there are differences between Kurnell and the Port Botany Terminal. In particular, Kurnell is across the Bay, on a long jetty off a north-facing shore; the northern side of the Bay is much more complex. This could mean that sea breezes in particular may come from a different direction or speed.

F2. Pasquill Stability Class

Gifford (Ref.16) defines the conditions for different stability classes as summarised in Table F.1.

TABLE F.1: METEOROLOGICAL CONDITIONS DEFINING THE PASQUILL-GIFFORD STABILITY CLASSES

Surface wind speed, m/s	Daytime insolation			Night time conditions	
	Strong	Moderate	Slight	Thin overcast or >4/8 low cloud	≥ 3/8 cloudiness
<2	A	A-B	B	F	F
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D	E
4-6	C	C-D	D	D	D
>6	C	C	D	D	D

A1. Representative Stability Class and Wind Speed

The representative stability classes and wind speed data sets for Port Botany are provided in Table F.2 (All Times), Table F.3 (Day Time) and Table F.4 (Night Time).

The values presented in these tables are percentage of observations in the given grouping at the indicated time. In these tables, the wind is shown as the direction blowing to. Thus, a wind in the *030 – 060* category is blowing to the northeast (from the southwest).

For the purpose of the study, the data were consolidated into three different representative weather conditions which are:

- Pasquill Stability Class: D; wind speed 6 m/s (D6)
- Pasquill Stability Class: E; wind speed 4 m/s (E4)
- Pasquill Stability Class: F; wind speed 2 m/s (F2).

TABLE F.2: PORT BOTANY – REPRESENTATIVE GROUPING 'ALL TIMES'

	Wind speed (m/s) and stability class					
Direction wind *toward* (degrees true)	**3.2 C**	**3.8 D**	**6.5 D**	**9.7 D**	**3.8 E**	**2.1 F**
000 - 030	2.4	6.5	14.6	26.9	3.6	6.1
030 - 060	3.0	7.5	6.3	5.2	7.8	10.4
060 - 090	4.1	7.6	9.5	10.3	11.8	14.3
090 - 120	22.4	9.4	9.5	8.2	14.7	11.8
120 - 150	35.0	12.8	5.3	3.0	19.6	12.1
150 - 180	10.2	6.6	3.3	1.5	12.2	9.2
180 - 210	4.3	6.2	8.7	9.2	11.1	8.1
210 - 240	3.7	6.8	10.9	16.5	7.0	8.2
240 - 270	5.9	8.8	6.3	2.1	3.0	6.5
270 - 300	4.4	11.2	3.9	0.9	3.2	4.8
300 - 330	3.0	12.0	11.0	2.6	3.9	4.6
330 - 360	1.6	4.8	10.9	13.7	2.1	4.0
Number of cases	2269	10937	20894	14098	8809	4721
Percentage of total	3.2	15.6	29.8	20.1	12.6	6.7

TABLE F.3: PORT BOTANY – REPRESENTATIVE GROUPING 'DAY TIME'

	Wind speed (m/s) and stability class					
Direction wind *toward* (degrees true)	**3.0 B**	**2.3 C**	**4.6 C**	**3.8 D**	**6.5 D**	**9.8 D**
000 - 030	2.6	2.8	4.3	5.6	16.0	27.4
030 - 060	2.1	3.3	2.6	5.4	4.9	5.1
060 - 090	4.9	6.8	3.6	6.6	7.0	9.7
090 - 120	16.2	22.6	14.8	11.7	9.0	7.8
120 - 150	24.1	31.4	19.7	18.1	5.5	2.9
150 - 180	11.4	10.9	6.0	6.7	2.6	1.5
180 - 210	7.4	5.3	3.7	4.7	4.7	6.9
210 - 240	8.5	5.0	7.1	6.0	12.4	20.2
240 - 270	10.2	5.5	15.6	9.8	9.7	2.5
270 - 300	5.3	2.5	9.1	11.0	5.3	0.6
300 - 330	5.1	2.4	9.4	10.0	12.1	2.9
330 - 360	2.3	1.5	4.2	4.5	10.8	12.6
Number of cases	1953	1023	5123	5231	10480	8607
Percentage of total	5.6	2.9	14.6	14.9	29.9	24.6

TABLE F.4: PORT BOTANY – REPRESENTATIVE GROUPING ‘NIGHT TIME’

	Wind speed (m/s) and stability class					
Direction wind *toward* (degrees true)	**3.1 D**	**5.6 D**	**8.7 D**	**2.6 E**	**3.9 E**	**2.1 F**
000 - 030	6.3	11.0	22.3	5.6	3.4	6.0
030 - 060	10.1	8.4	5.9	9.1	7.9	10.6
060 - 090	9.7	10.7	11.8	13.8	11.8	14.4
090 - 120	8.6	8.8	9.1	10.1	14.9	12.0
120 - 150	9.4	5.5	3.2	10.5	20.0	12.1
150 - 180	7.4	4.7	1.9	7.5	12.9	9.4
180 - 210	7.1	11.6	12.6	6.9	11.7	8.2
210 - 240	6.4	9.3	10.3	7.3	6.8	8.1
240 - 270	8.0	4.2	1.8	7.8	2.5	6.3
270 - 300	12.1	4.5	1.5	9.2	2.6	4.7
300 - 330	10.5	12.4	4.5	6.8	3.6	4.4
330 - 360	4.5	9.0	15.0	5.3	1.8	3.7
Number of cases	3610	9718	8134	769	7595	4580
Percentage of total	10.3	27.8	23.3	2.2	21.7	13.1

APPENDIX G. REFERENCES

1 Pinnacle Risk Management Pty Ltd (2007): *Final Hazard Analysis, Site B Petroleum – Stage 3 Project, Vopak Terminals Australia Pty Ltd, Port Botany, NSW*, Rev B.

2 Vopak Terminals Australia (2012): *MHF Safety Case – Vopak Terminal Sydney – Site B, MHF No.: 10075, Rev A.*

3 NSW Department of Planning (2011): *Hazardous Industry Planning Advisory Paper No. 6 – Hazard Analysis.*

4 NSW Department of Planning (2011): *Hazardous Industry Planning Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning*.

5 NSW Department of Planning (1996): *Port Botany Land Use Safety Study Overview Report.*

6 Vopak Terminals Australia (2015): *Berth Occupancy Study, Rev G.*

7 TNO Institute of Environmental Sciences (1997): *Yellow Book: Method for the calculation of physical effects due to releases of hazardous materials*, Third Edition.

8 TNO Institute of Environmental Sciences (1992): *Green Book: Methods for the determination of possible damage to people and objects resulting from release of hazardous materials,* First Edition.

9 Fire and Blast Information Group (2013): *Technical Note 12 – Vapour Cloud Development in over-filling Incidents*, April 2013.

10 Bureau of Meteorology (2008): *Meteorological Data for Port Botany Terminal.*

11 Oil & Gas Producers (OGP) (2010): *Risk Assessment Data Directory, Process Release Frequencies, Report No. 434 - 1.OGP process release*

12 Lastfire Project Update (2012): *Large Atmospheric Storage Tank Fire Project, Incident Survey for 1984-2011, 2012 Edition*.

13 Cox Lees and Ang (1992), *Classification of Hazardous Areas*.

14 State of New South Wales (2014): *State Environmental Planning Policy (Port Botany and Port Kembla) Amendment (Port of Newcastle) 2014 (under the Environmental Planning and Assessment Act 1979)*.

15 Mannan, S. (2005): *Lee's Loss Prevention in the Process Industries,* 3rd ed., Elsevier Butterworth-Heinemann, Table 14.15.

16 Gifford, F.A (1961): *Turbulent Diffusion-Typing Schemes: A Review*, Nucl Saf, Vol.17, No. 1, Jan/Feb, 1961, pp.68-86.