APPENDIX N

TRANSPORT RISK ASSESSMENT

DANGEROUS GOODS TRANSPORT RISK ASSESSMENT

CHLORINE LIQUEFACTION PLANT

CHLORALKALI FACILITY

BOTANY INDUSTRIAL PARK

IXOM OPERATIONS PTY LTD

PREPARED FOR:	**Jamie Van Rooyen** Head of Projects and Technology
DOCUMENT NO:	**21838-RP-003**
REVISION:	**1**
DATE:	**28-Mar-2025**

Sherpa Consulting Pty Ltd (ABN 40 110 961 898)
Phone: 61 2 9412 4555
Web: www.sherpaconsulting.com.au

DOCUMENT REVISION RECORD

Rev	Date	Description	Prepared	Checked	Approved	Method of issue
A	28-Feb-2025	Issued to Client for comments	N. Barty	J. Polich	-	Email PDF
B	12-Mar-2025	Updated with comments	N. Barty	J. Polich	J. Polich	Email PDF
0	21-Mar-2025	For final review	J. Polich	G. Peach	G. Peach	Email PDF
1	28-Mar-2025	Final Issue	J. Polich	G. Peach	G. Peach	Email PDF

Title: **Dangerous Goods Transport Risk Assessment** **Chlorine Liquefaction Plant** **Chloralkali Facility** **Botany Industrial Park**	**QA verified:** K. Shen **Date:** 28-Mar-2025

CONTENTS

1. SUMMARY 1
1.1. Background 1
1.2. Scope 1
1.3. Results 2
2. INTRODUCTION 5
2.1. Project description 5
2.2. Background 5
2.3. Study objectives 5
2.4. Scope 5
2.5. Exclusions and limitations 6
3. CONTEXT AND CRITERIA 7
3.1. Location and surrounding land uses 7
3.2. Previous Denison St traffic risk assessments 7
3.3. Criteria 8
4. TRANSPORT RISK ASSESSMENT BASIS 9
4.1. Risk assessment approach 9
4.2. Release scenarios 9
4.3. DG transport release frequencies 10
4.4. Vehicle Movements 12
4.5. Transport risk assessment case definition 15
5. CONSEQUENCE ANALYSIS 18
5.1. Overview 18
5.2. Input assumptions 18
5.3. Results 19
6. FREQUENCY ANALYSIS 20
6.1. Overview 20
6.2. LOC frequencies 20
6.3. Ignition probability 21
7. RISK ANALYSIS AND EVALUATION 22
7.1. Overview 22
7.2. Risk analysis and evaluation 22

7.3. Key findings 22

7.4. Conclusion 23

APPENDIX A. ACCIDENT SUMMARY

APPENDIX B. METEOROLOGICAL CONDITIONS

APPENDIX C. CONSEQUENCE AND FREQUENCY ANALYSIS

APPENDIX D. REFERENCES

TABLES

Table 3.1: NSW HIPAP 4 individual fatality risk criteria 8
Table 4.1: DG transport release scenarios 9
Table 4.2: OGP LOC frequencies for LPG tankers, Ref [7] 10
Table 4.3: Flammable liquid road tanker leak LOC frequencies, Ref [7] 10
Table 4.4: Comparison of LOC rates for bulk tankers 11
Table 4.5: Frequency of mechanical failure related leaks, Ref [8] 11
Table 4.6: Summary of DG transport LOC frequencies 12
Table 4.7: Chlorine vehicle movements 14
Table 4.8: DG vehicle movements 15
Table 4.9: Transport risk assessment case definitions 16
Table 5.1: Consequence modelling input assumptions 18
Table 6.1: LOC frequencies for modelled scenarios 20
Table 7.1: Comparison of transport risk assessment cases against HIPAP 4 risk criteria 24

FIGURES

Figure 1.1: IFR for cases 1 & 2 – Current chlorine transport (left) and future chlorine transport (right) ... 3
Figure 1.2: IFR Existing risk profile compared with cumulative risk including future chlorine transport .. 4
Figure 3.1: Site location and surrounding land uses 7
Figure 7.1: IFR risk results for the 2016 Scott Lister study, Ref [1], (left) and case 3 – equivalent QRA risk model 27
Figure 7.2: IFR for cases 1 & 2 – Current chlorine transport (left) and future chlorine transport (right) . 28
Figure 7.3: IFR for cases 3 & 6 – Equivalent QRA risk model (Scott Lister 2016) (left) and Equivalent QRA risk model with increased class 2.3 DG traffic (right) 29
Figure 7.4: IFR for case 3 & 4 – Equivalent QRA risk model (left) and equivalent QRA risk model (reduced 2.1 tanker numbers) (right) 30
Figure 7.5: IFR case 7 & 4 – Equivalent QRA risk model (reduced 2.1 tanker numbers) with increased class 2.3 DG traffic (left) and equivalent QRA risk model (reduced 2.1 tanker numbers) (right) 31

ABBREVIATIONS

BIP	Botany Industrial Park
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOM	Bureau of Meteorology
CAP	Chlorakali Plant
Cl_2	Chlorine
CLP	Chlorine Liquefaction Plant
DG	Dangerous Good
DOT	(US) Department of Transport
DPHI	Department of Planning, Housing and Infrastructure
FMCSA	(US) Federal Motor Carrier Safety Administration
IFR	Individual Fatality Risk
LOC	Loss of Containment
LPG	Liquefied Petroleum Gas
NSW	New South Wales
OGP	International Association of Oil and Gas Producers
QRA	Quantitative Risk Assessment
SEARS	Secretary's Environmental Assessment Requirements
TfNSW	Transport for New South Wales
TRA	Transport Risk Assessment
US	United States of America
VCE	Vapour Cloud Explosion

1. SUMMARY

1.1. Background

Ixom is proposing to construct a Chlorine Liquefaction Plant (CLP) at the existing Chloralkali Plant (CAP) located in the Botany Industrial Park (BIP), New South Wales (NSW). As a result, there will be an increase in chlorine transport movements to and from the plant. Chlorine is a Class 2.3 (Toxic Gas) Dangerous Good (DG).

The Department of Planning, Housing and Infrastructure (DPHI) has issued the Secretary's Environmental Assessment Requirements (SEARS) for the project, which includes the following requirement for assessing DG transport risk:

Include a Transport Risk Assessment (TRA) to evaluate the potential impacts from Dangerous Good (DG) transport to and from the modified facility with comparison to the TRA findings from Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility).

The study that is referred to in the Secretary's Environmental Assessment Requirements (SEARS) is the *Vopak Port Botany Expansion – Denison St Transport QRA – July 2016 Update. Rev 4* prepared by Scott Lister (issued August 2016 doc ref: MC20160715, Ref [1]). The risk model used in the Scott Lister study is not publicly available and hence cannot be updated by Sherpa to reflect the change in DG transport. The study also does not directly report the number of vehicle movements transporting chlorine.

Therefore, as agreed with DPHI the approach for this TRA involved preparing a new model in Gexcon RISKCURVES (v12.4.0) retaining Scott Lister risk modelling assumptions where possible to produce an updated baseline risk. This model was then used to assess the change in cumulative transport risk resulting from the increase in class 2.3 DG transport movements associated with the CLP project and compare the results to the Individual Fatality Risk (IFR) criteria in Hazardous Industry Planning Advisory Paper No. 4 - *Risk Criteria for Land Use Safety Planning*, 2011 (HIPAP 4).

1.2. Scope

The scope of the TRA covers the change in chlorine transport risk for the following movements along Denison St resulting from the proposed CLP project:

- Flatbed trucks transport 920 kg chlorine drums and 70 kg cylinders in and out of the BIP site via the northern portion of Denison St between BIP Gate 3 and Wentworth Ave.
- Bulk tankers (13 tonne) travel in and out of the BIP site via the southern portion of Denison St between BIP Gate 3 and Beauchamp Rd.

The current CAP case is 4 road tankers per year and 484 drum trucks per year.

The CLP will have two operational modes:

- Normal case: During normal operation, the liquefaction plant will be operated at 10% of liquefaction capacity The produced chlorine will be used to fill bulk tankers to supply the liquid chlorine demand in the NSW region. This will result in a total of 156 road tankers per year and 484 drum trucks per year.
- Contingent case: During contingent operation, when the Ixom chlorine liquefaction plant at Laverton, Victoria is unavailable, the CLP will run at full capacity and facilitate tanker loading as well as chlorine drum and cylinder filling for export via flatbed trucks. This will result in a total of 187 road tankers per year and 520 drum trucks per year.

The contingent case is used for the TRA as this has the higher volume of chlorine transport movements.

1.3. Results

Figure 1.1 shows a comparison of individual fatality risk contours between the current chlorine transport case and the contingent case accounting for the CLP. This shows:

- The change in chlorine transport has minimal impact on the transport risk in the northern part of Denison St as the drum transport numbers have not increased significantly.
- An increase in risk associated with the chlorine tanker increase can be seen in the southern part of Denison St however this is at a low level i.e. below 1 x 10^{-6} per year.
- For chlorine transport only all relevant individual fatality risk criteria are met, i.e. the 1 x 10^{-6} per year IFR contour does not extend to residential land uses and the 0.5 x 10^{-6} per year IFR contour does not extend to sensitive land uses (the nearest is Matraville Public School approximately 400m for Denison St) for either the current CAP or post CLP case.

Figure 1.2 compares the existing cumulative transport risk along Denison St, as shown in the 2016 Scott Lister report prepared for Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility) with the cumulative risk including increased chlorine traffic (contingent case) associated with the CLP. This shows:

- The existing 1 x 10^{-6} per year IFR contour from the Scott Lister study extends into the residential area in the southern area of Denison St.
- The estimated IFR contour including the increase in volume of Class 2.3 DG transports (i.e. bulk tankers, flatbed trucks) resulting from the operation of the CLP shows a very similar cumulative risk profile to the Scott Lister study.

Overall, the TRA results demonstrate that the increased chlorine transport does not have a material effect on the cumulative IFR contours along Denison St when compared to the TRA findings from Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility).

Figure 1.1: IFR Current CAP chlorine transport (Case 1 left) and post CLP chlorine transport contingent case (Case 2 right)

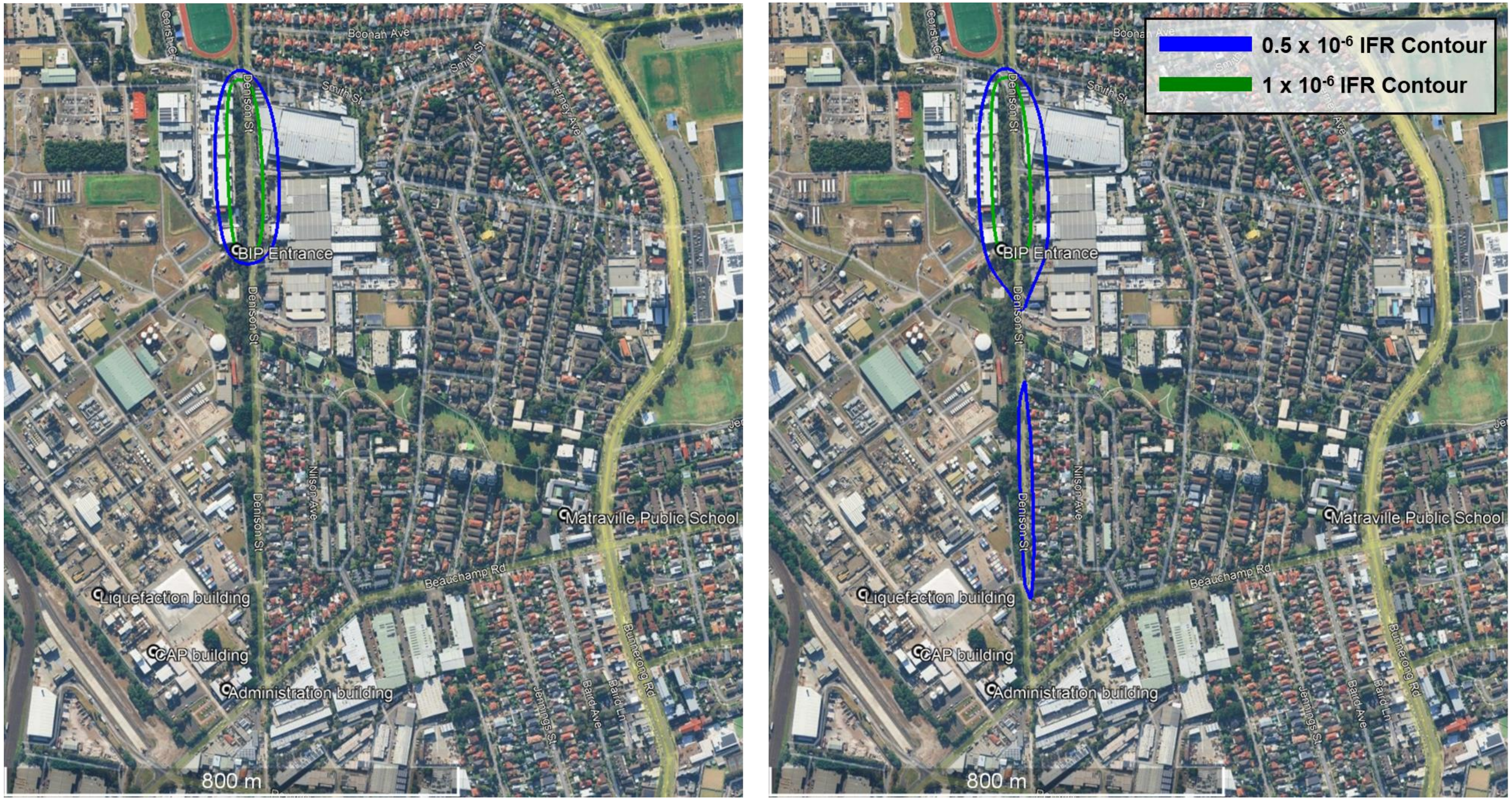
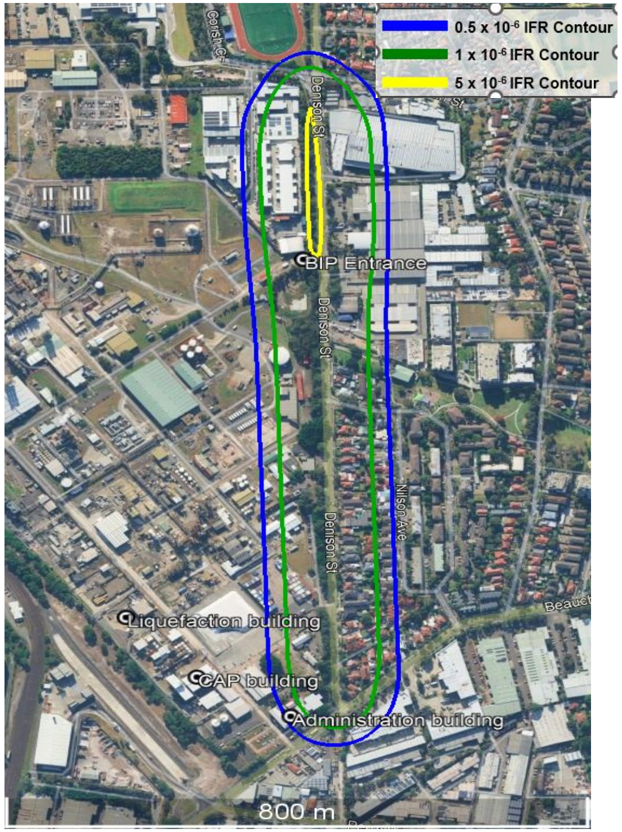


Figure 1.2: IFR Existing risk profile compared with cumulative risk including future chlorine transport

Risk Profile from Vopak Port Botany Expansion – Denison St Transport QRA – July 2016 Update. Rev 4, issued August 2016 doc ref: MC20160715	Equivalent QRA risk model with increased Class 2.3 DG traffic CLP contingent case
	

Comparison: this shows that the risk accounting for increase chlorine transport is similar to the 2016 Scott Lister results. Note that the map scale is not the same however in both cases the (non-intersection) $1x10^{-6}$ per year IFR contour extends approximately 60m from Denison St.

2. INTRODUCTION

2.1. Project description

Ixom is proposing to construct a Chlorine Liquefaction Plant (CLP) at the existing Chloralkali Plant (CAP) located in the Botany Industrial Park (BIP), New South Wales (NSW). As a result, there will be an increase in chlorine transport movements to and from the plant. Chlorine is a Class 2.3 (toxic gas) Dangerous Good (DG).

2.2. Background

The Department of Planning Housing, and Infrastructure (DPHI) has issued the Secretary's Environmental Assessment Requirements (SEARS) for the project, requiring Ixom to assess the onsite, offsite and transport risk.

The SEARS requirement for assessing DG transport risk is:

> *Include a Transport Risk Assessment (TRA) to evaluate the potential impacts from Dangerous Good (DG) transport to and from the modified facility with comparison to the TRA findings from Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility).*

This report is the TRA prepared to address the SEARS.

2.3. Study objectives

The overall objective of the TRA is to address the specific SEARS requirement for the evaluation of potential impacts from DG transport to and from the modified facility.

This is addressed by:

- Assessment of the impact on the current cumulative DG transport risk to and from the site as a result of increased Class 2.3 DG transport by comparing these findings against previous TRA studies for Denison St including for Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility).
- Assessment of the transport Individual Fatality Risk (IFR) against the risk criteria defined in the NSW DPHI Hazardous Industry Planning Advisory Paper No. 4 – *Risk Criteria for Land Use Planning Safety Planning* (HIPAP 4), Ref [2].

2.4. Scope

The scope of this study covers the change in chlorine transport risk for the following movements along Denison St resulting from the proposed CLP project only:

- Flatbed trucks transport 920 kg chlorine drums and 70 kg cylinders in and out of the BIP site via the northern portion of Denison St between Gate 3 and Wentworth Ave.
- Bulk tankers (13 tonne) travel in and out of the BIP site via the southern portion of Denison St between Gate 3 and Beauchamp Rd.

2.5. Exclusions and limitations

The exclusions, assumptions and limitations that apply to this study are summarised below:

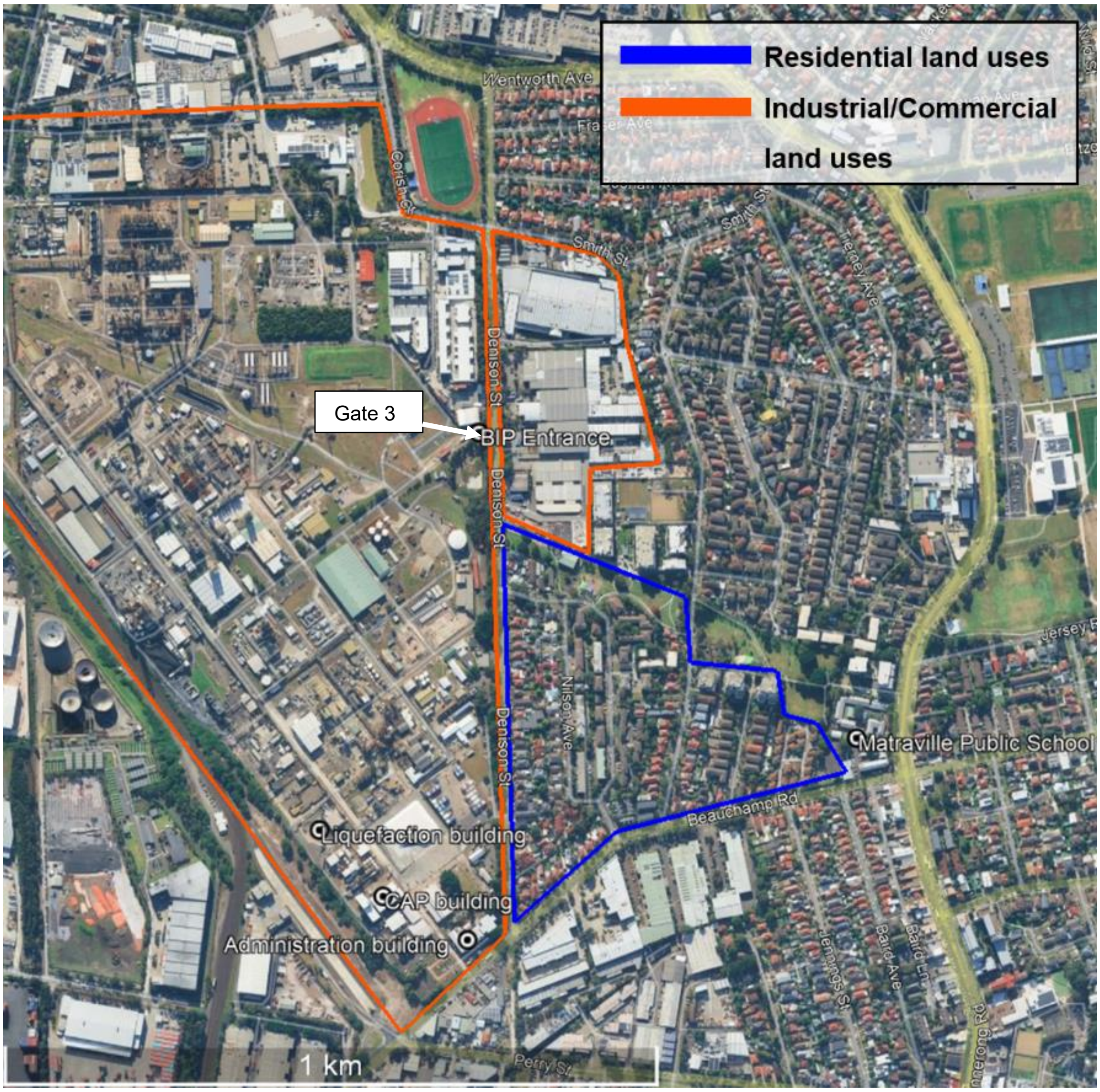
- There is no available traffic count data for current DG transport movements along Denison St. Traffic counts have not been undertaken for this study.
- Risk metrics other than individual risk criteria were not assessed (i.e. societal risk) as there are no defined societal risk criteria for transport.
- DGs associated with the CAP apart from chlorine are not assessed. Other DGs associated with the CAP are Class 8 corrosives and these have not been assessed quantitatively in previous transport risk assessments as a loss of containment during transport has localised environmental effects.
- The only other potentially hazardous DG apart from chlorine associated with the CLP is a small quantity of ammonia (< 200 kg) contained in the refrigeration system. Whilst there may be an occasional need for re-gassing of the refrigerant, there are no routine transport activities planned with this so ammonia is not included in the TRA.
- As per the scope of previous studies including for Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility), any sections of the transport route apart from the Denison St section are outside the scope of the study.
- Transport within the BIP boundary is also outside scope of the study.

3. CONTEXT AND CRITERIA

3.1. Location and surrounding land uses

The location of the proposed CLP and surrounding land uses are shown in Figure 3.1, with the nearest sensitive land use (Matraville Public School) also shown. The operation of the CLP will increase class 2.3 DG traffic volume along Denison St.

Figure 3.1: Site location and surrounding land uses



3.2. Previous Denison St traffic risk assessments

There is minimal information available regarding the overall volume of DG traffic in the Port Botany precinct and surrounding industrial areas.

Discussions between Sherpa and DPHI were held, and it was agreed that the methodology adopted in previous DG transport risk studies completed by Scott Lister for

Denison St could be broadly adopted and used as a baseline for risk assessment[1]. The DG transport Quantitative Risk Assessments (QRA) were commissioned by a Joint Regional Planning Panel (which included the DPE and City of Botany Bay Council) to assess the risk to a proposed Bunnings development in Denison St.

The relevant studies are:

- Scott Lister, Dangerous Goods Transport QRA, Denison St, Hillsdale Rev 3 Issued: 12 February, 2015, Ref [3].
- Scott Lister, *Addendum to Dangerous Goods transport QRA, Denison St, Hillsdale*. An update to the Dangerous Goods Transport QRA in the form of an Addendum was released in July 2015, Ref [4].
- Scott Lister, *Vopak Port Botany Expansion – Denison St Transport QRA – July 2016 Update. Rev 4*, issued August 2016 (doc ref: MC20160715), Ref [1]. Note: This study formed the basis for the TRA for the Major Project approval MP 06_0089 MOD 2, referred to in the SEARS requirements. The results in this study are the basis for comparison for individual fatality risk contours for Denison St transport risk. Refer to Figure 7.3, for cumulative risk contours.

3.3. Criteria

Individual fatality risk criteria used in this risk assessment are from NSW HIPAP 4 Ref [2], as shown in Table 3.1.

Table 3.1: NSW HIPAP 4 individual fatality risk criteria

Limit (per year)	Land use
0.5×10^{-6}	Hospitals, child-care facilities and old age housing developments
1×10^{-6}	Residential developments and places of continuous occupancy such as hotels and tourist resorts
5×10^{-6}	Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres
10×10^{-6}	Sporting complexes and active open space areas
50×10^{-6}	Industrial – as a target must not be exceeded any boundary adjacent to another industrial facility

[1] Email, D Yau (DPHI) to J Polich (Sherpa), 20 Feb 2025.

4. TRANSPORT RISK ASSESSMENT BASIS

4.1. Risk assessment approach

The previous Scott Lister TRAs (see Section 3.2) include chlorine transport risk, however they do not directly report the number of vehicle movements transporting chlorine. The model itself is also not available for use by Sherpa, making a direct update comparison not possible.

Therefore, as agreed with DPHI the approach for this TRA involved preparing a new model in Gexcon RISKCURVES (v12.4.0) retaining previous risk modelling assumptions as far as possible to produce an updated baseline risk. This model was then used to assess the change in cumulative transport risk resulting from the increase in class 2.3 DG transport movements associated with the CLP project.

4.2. Release scenarios

Table 4.1 summarises the release scenarios used for the transport risk assessment modelling. Scenarios from the 2016 Scott Lister study, Ref [1], were used for Class 3 and Class 2.1 transport aligning with the leak frequencies shown in Table 4.2.

Scenarios for chlorine transport are consistent with the CAP and CLP QRA loss of containment scenarios for chlorine drums and tankers.

Table 4.1: DG transport release scenarios

Scenario ID	Vehicle	Inventory	Release scenario
Class 2.1 flammable liquefied gases			
1.1	Liquefied Petroleum Gas (LPG) bulk tanker	10-tonnes, Ref [1]	Vapour space leak (50 mm), Ref [1]
1.2			Liquid space leak (50 mm), Ref [1]
1.3			Cold rupture (instantaneous release), Ref [1]
1.4			Boiling Liquid Expanding Vapour Explosion (BLEVE), Ref [1]
Class 2.3 toxic gases			
2.1	Chlorine bulk tanker	13-tonnes	Mechanical failure and leak liquid (13 mm), Ref [5]
2.2			Cold rupture (instantaneous release), Ref [1]
3.1	Chlorine flatbed truck	920 kg per drum	Mechanical failure (instantaneous release), Ref [6]
3.2			Drum rupture (instantaneous release), Ref [6]
3.3			Mechanical failure equivalent to drum valve leak (6 mm), Ref [6]
Class 3 flammable liquids			
4.1	Gasoline bulk tanker	20-tonnes, Ref [1]	Cold rupture (instantaneous release), Ref [1]

4.3. DG transport release frequencies

Typically Loss of Containment (LOC) during transport is due to:

- LOC as a result of vehicle accidents
- LOC as a result of a mechanical failure on-route.

There is very little information available regarding LOC during DG transport and it is not clear in some cases whether the data is 'all causes' or due to accidents only. A summary of data sources is discussed in the following sections with adopted values for the study provided in Table 4.6.

4.3.1. Class 2.1 loss of containment frequency

These frequencies are sourced from the International Association of Oil and Gas Producers (OGP) *Report No. 434-9: Land transport accident statistics*, Ref [7], and are for LPG tanker releases. In the previous Scott Lister reports, these frequencies were applied for all pressurised liquefied gases, including chlorine.

Table 4.2: OGP LOC frequencies for LPG tankers

Failure case	Frequency per km
BLEVE	2.70×10^{-12}
Cold rupture (instant release)	2.60×10^{-9}
Large liquid space leak 50 mm	1.80×10^{-8}
Large vapour space leak 50 mm	2.10×10^{-9}
Total LOC rate[(a)]	2.27×10^{-8}
Notes: Total LOC rate calculated as the sum of all release types excluding BLEVE as this is not credible for liquefied chlorine.	

4.3.2. Class 3 loss of containment frequency

The frequencies used for modelling Class 3 transport LOC scenarios were from the same OGP report as the LPG tanker frequencies in Table 4.2, Ref [7]. The modelled release scenario was loss of the contents from a bulk Class 3 transport (20-tonnes) corresponding to the frequency of a spill >1500 kg. as per Table 4.3.

Table 4.3: Flammable liquid road tanker leak LOC frequencies

Spill size	Frequency per km
5-15 kg	6.00×10^{-9}
15-150 kg	2.60×10^{-8}
150-1500 kg	7.00×10^{-9}
>1500 kg	2.10×10^{-8}
Total	$\mathbf{6.00 \times 10^{-8}}$

4.3.3. Comparison

The OGP data has been compared against data collected by the United States of America's (US) Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA) in Table 4.4.

The OGP frequency for LPG tanker LOC is broadly similar to the LOC frequency for Class 2.3 tankers therefore the OGP frequency was retained for chlorine transport in this study.

Table 4.4: Comparison of LOC rates for bulk tankers

Source	Frequency per km	Reference
OGP Report 434-09 LPG bulk tankers	2.27×10^{-8}	[7]
Report conducted for FMCSA by Abkowtiz et al., Class 2.3 bulk tankers.	2.47×10^{-8}	[8]

4.3.4. Mechanical failure frequency

To account for non-accident related releases that may occur enroute (i.e. mechanical failure) statistical data was obtained from a study conducted for the FMSCA, Ref [8], that quantified the frequency of incidents involving the transport of DGs in the US. Note that this scenario was not included in the Scott Lister studies (i.e. it is an additional frequency included in the QRA model for chlorine transport only).

Table 4.5: Frequency of mechanical failure related leaks

DG class	Mechanical failure enroute leak rate per km
Class 2.1 (i.e. LPG)	1.16×10^{-8}
Class 2.3 (i.e. chlorine)	6.17×10^{-8}
Average all DG classes)	$\mathbf{1.16 \times 10^{-7}}$

4.3.5. Denison St accident rate

A review of vehicle accident data, published by Transport for New South Wales (TfNSW), for Denison St over the period from 2016-2023, Ref [9], found that 16 accidents had occurred on Denison St. Out of the 16 accidents 1 involved a semi-trailer and 6 involved light trucks, with 1 fatality occurring due to a collision between a light truck and cyclist. The majority of accidents occurred at the intersection between Denison St. and Smith St. A summary of the identified accidents is provided in APPENDIX A.

This indicates that the accident rate for heavy vehicles along Denison St is very low and that there is no history of accidents of sufficient severity (e.g. high speed impact, rollover) that are likely to result in a DG release. Therefore, there is no attempt made to directly correlate accident rates with DG vehicle LOCs.

4.3.6. Summary of adopted frequencies

The frequencies adopted in the DG transport QRA model are summarised in Table 4.6 for all DGs included in the model.

Note that there are some differences between the present study and the Scott Lister studies in how the LOC frequency data is apportioned to the transport route:

- The Scott Lister studies apportioned the LOC frequency to some intersections along Denison St and some to the overall road length This approach excluded the intersections at the Bunnings hardware and at Smith St and the rational for the inclusion of some intersections only was not clear. Therefore for the present study the LOC frequencies were distributed evenly along the relevant route.
- The route in the present study is limited to the segment of Denison St adjacent to the BIP between Smith St (north) and Beauchamp Rd (south). The Scott Lister study also includes a further the segment from Smith St north to Wentworth Ave adjacent to the oval; however, this does not account for the split between Corish Circle and Denison St so has not been included.

Table 4.6: Summary of DG transport LOC frequencies

DG class	Source	Scenario	LOC per km	Comments
Class 2.1 (i.e. LPG)	Tanker	Rupture	2.60×10^{-9}	OGP (As per Scott Lister TRA, Ref [3])
		Leak liquid 50mm	1.80×10^{-8}	
		Leak vapour 50mm	2.10×10^{-9}	
		BLEVE	2.70×10^{-12}	
Class 3	Tanker	Rupture	2.10×10^{-8}	OGP (As per Scott Lister TRA, Ref [3])
Class 2.3 (i.e. chlorine)	Tanker	Mechanical failure on route	6.17×10^{-8}	FMSCA Additional scenario
		Rupture	2.60×10^{-9}	OGP
		Leak liquid 13mm	1.80×10^{-8}	OGP
	Drum	Mechanical failure enroute	6.17×10^{-8}	FMSCA Additional scenario
		Rupture	2.60×10^{-9}	OGP
		Leak liquid 6mm	1.80×10^{-8}	OGP

4.4. Vehicle movements

4.4.1. Chlorine

The CLP will have two operational modes:

- **Normal case:** During normal operation, the liquefaction plant is operated at a 10% of liquefaction capacity. The produced chlorine is primarily used to fill the bulk tankers to supply the liquid chlorine demand in the NSW region.

- **Contingent case:** During contingent operation, when the chlorine liquefaction plant at Laverton, Victoria is down, the CLP will run at full capacity and facilitate tanker loading as well as chlorine drum and cylinder filling for export via flatbed trucks.

The chlorine transport movements associated with these operational cases are summarised in Table 4.7.

Table 4.7: Chlorine vehicle movements

Vehicle	Inventory	Scenario – transport LOC	Current case (loaded vehicles per year)			Comments	Gemini - post liquefaction (loaded vehicles per year)						Comments
							Normal			Contingent			
			to BIP	from BIP	Total		to BIP	from BIP	Total	to BIP	from BIP	Total	
Chlorine (Cl2) bulk tanker	13 tonnes	LOC of complete tanker contents	0	0	**4**	There are no routine trips to/from Botany by bulk Cl2 tanker. Conditions of consent allow parking 1 full tanker 50% of time but this is very rarely on site - allow for a few trips in QRA – 4 times per year	0	156	156	0	187	**187**	<u>Normal:</u> Bulk tankers servicing NSW clients up to 3 per week in total <u>Contingent:</u> Would also need to take on Laverton filling, Botany would need to cover Melbourne Water (31 per year) in the contingent case
Cl2 flatbed truck	70 kg cylinder 920 kg drum	LOC of complete drum contents	104	380 (280 metro deliveries and 100 regional deliveries)	**484**	2 flatbeds per week from Laverton to Botany, each carrying up to 26 drums and 48 cylinders (4 crates of 12) From site - Approximately 380 truck movements from Botany for container deliveries to NSW customers, consisting of approximately 280 metro deliveries and 100 regional deliveries.	104	380 (280 metro deliveries and 100 regional deliveries)	484	0	520	**520**	<u>Normal:</u> No drum /cylinder filling all delivered from Laverton <u>Contingent:</u> Botany would continue servicing NSW customers (380 trucks) Would also need to take on Laverton filling = additional 105 to 140 trucks per year + (2-3 per week)

4.4.2. Other hazardous materials

There is minimal information publicly available regarding the overall volume of DG traffic in the Port Botany precinct and surrounding industrial areas. Therefore, for consistency, vehicle movement numbers have been sourced from previous Scott Lister studies and operational information made available to Sherpa by Ixom.

The previous Scott Lister study, Ref [1], demonstrated that transport risk was dominated by Class 2.1 LPG tankers. With the closure of the Qenos BIP facility, it is expected that there will be a reduction in the number of LPG tankers moving to and from the BIP. To account for this change, a sensitivity study for traffic volume for Class 2.1 vehicles was carried out. The base value of 4,521 Class 2.1 tankers per year was sourced from the previous Scott Lister study, Ref [1]. The reduced number of 1,500 vehicles per year represents an estimate of Class 2.1 traffic from Port Botany that is not associated with the Qenos BIP facility and hence will not be affected by the facility's closure.

The values used in risk calculations for the total number of vehicles (current and future cases) transporting DGs entering and exiting the site are summarised in Table 4.8. Note that for chlorine transport the contingent mode is adopted which has the highest number of chlorine transport movements. Current/future cases were only applicable for chlorine transport, accounting for the additional traffic volume generated by operation of the CLP.

Table 4.8: DG vehicle movements

Vehicle	Inventory	Total number of loaded vehicle movements (to/from BIP) per year		Reference
		Current	Future/reduced	
Class 2.1 flammable liquefied gases				
LPG bulk tanker	10 tonnes	4,521	1,500	[10]
Class 2.3 Toxic gases				
Chlorine bulk tanker	13 tonnes	4 (a)	187	Ixom operational information
Chlorine flatbed truck	920 kg per drum	484	520 (b)	
Class 3 Flammable liquids				
Gasoline bulk tanker	20 tonnes	7,712	7,712 (no change)	[10]

Notes:

This value is nominal for parked tankers only to and from the site only, with no filling occurring.

This value allows for the contingent mode of operation when drum filling is occurrent at the site, as this results in the highest chlorine transport throughput.

4.5. Transport risk assessment case definition

A range of transport risk assessment cases were developed to allow for comparison against the HIPAP 4 risk criteria, these cases are summarised in Table 4.9.

Table 4.9: Transport risk assessment case definitions

Case ID	Case definition	Class 2.1	Class 2.3		Class 3	Objective
			Current	Future		
1	Current chlorine transport	✗	✓	✗	✗	Demonstrate current risk due to the transport of liquefied chlorine only to and from the CAP.
2	Future chlorine transport	✗	✗	✓	✗	Demonstrate any additional risk generated due to the increased volume of liquefied chlorine transport to and from the CAP as a result of the operation of the CLP.
3	Equivalent QRA risk model (Scott Lister 2016) (New baseline)	✓	✓	✗	✓	Demonstrate the current transport risk along Denison St. by replicating the risk assessment methodology as far as possible that was applied in previous Scott Lister studies. Forms new baseline.
4	Equivalent QRA risk model (Scott Lister 2016) – reduced Class 2.1 tanker numbers	✓ (reduced)	✓	✗	✓	Demonstrate the change in cumulative transport risk as result of the closure of the Qenos BIP facility by reducing traffic volume for class 2.1 vehicles from 4,521 to 1,500.
5	Equivalent QRA risk model (Scott Lister 2016) – no Class 2.1 tankers	✗	✓	✗	✓	Demonstrate the effect of cessation of all Class 2.1 transport, i.e. shutdown of Qenos BIP facility, Origin operations and Elgas at Port Botany also shuts down by reducing traffic volume for class 2.1 vehicles from 4,521 to 0. NOTE this is not a real case as Elgas at Port Botany remains operational
6	Equivalent QRA risk model (Scott Lister 2016) and future chlorine transport	✓	✗	✓	✓	Demonstrate the contribution the increase in chlorine transport will make to the current transport risk profile.

Case ID	Case definition	Class 2.1	Class 2.3		Class 3	Objective
			Current	Future		
7	Equivalent QRA risk model (Scott Lister 2016) – reduced Class 2.1 tanker numbers and future chlorine transport	✓ (reduced)	×	✓	✓	Demonstrate the contribution the increase in chlorine transport will make to the current transport risk profile also allowing for the expected reduction Class 2.1 traffic by reducing traffic volume for Class 2.1 vehicles from 4,521 to 1,500.

5. CONSEQUENCE ANALYSIS

5.1. Overview

Consequence analysis was undertaken for the release scenarios summarised in Section 4.2, based on the input assumptions and release conditions previously outlined in the Scott Lister report, Ref [1].

For the present risk model Gexcon RISKCURVES (v12.4.0) was used to model the consequences for the release scenarios. Inputs for each release are summarised in Section 4.2

5.2. Input assumptions

The key model input assumptions are summarised in Table 5.1. For scenarios involving pool fires (scenario 4.1), it was assumed that the pool diameter would be constrained by the road gutters, i.e. equivalent to the road diameter which was estimated to be approximately 15 m.

Other key inputs such as meteorological data were also carried forward from the previous Scott Lister report, Ref [1]. The meteorological distribution used is summarised in APPENDIX B.

Table 5.1: Consequence modelling input assumptions

<table>
<tr><th>Scenario ID</th><th>Material</th><th>Inventory (m³)</th><th>Temperature (ºC)</th><th>Leak size (mm)</th><th>Consequence modelled</th></tr>
<tr><td colspan="6">Class 2.1 flammable liquefied gases</td></tr>
<tr><td>1.1</td><td rowspan="4">Propane</td><td rowspan="4">25</td><td rowspan="4">25</td><td>50</td><td>Jet fire, flash fire (with Vapour cloud explosion [VCE])</td></tr>
<tr><td>1.2</td><td>50</td><td>Jet fire, flash fire (with VCE)</td></tr>
<tr><td>1.3</td><td>Rupture</td><td>Flash fire (with VCE)</td></tr>
<tr><td>1.4</td><td>BLEVE</td><td>BLEVE</td></tr>
<tr><td colspan="6">Class 2.3 toxic gases</td></tr>
<tr><td>2.1</td><td rowspan="2">Chlorine</td><td rowspan="2">9.2</td><td rowspan="2">25</td><td>50</td><td>Toxic cloud</td></tr>
<tr><td>2.2</td><td>Rupture</td><td>Toxic cloud</td></tr>
<tr><td>3.1</td><td rowspan="3">Chlorine</td><td rowspan="3">0.65</td><td rowspan="3">25</td><td>Rupture</td><td>Toxic cloud</td></tr>
<tr><td>3.2</td><td>Rupture</td><td>Toxic cloud</td></tr>
<tr><td>3.3</td><td>6</td><td>Toxic cloud</td></tr>
<tr><td colspan="6">Class 3 flammable liquids</td></tr>
<tr><td>4.1</td><td>Gasoline</td><td>25</td><td>25</td><td>50</td><td>Pool fire, flash fire (with VCE)</td></tr>
</table>

5.3. Results

The previous Scott Lister report, Ref [1], did not provide detail on effect distances. A direct comparison between the consequence results is therefore not possible.

Consequence results for the distance to 1% fatality for all release scenarios in the model have been included in APPENDIX C.

6. FREQUENCY ANALYSIS

6.1. Overview

The frequency for each release scenario was estimated by determining a base frequency of LOC during transport per km travelled for each scenario (see Section 4.3). This base frequency was then modified by the number of DG specific vehicle movements. For release scenarios involving flammables (DG Class 2.1 and 3), an ignition probability was applied to account for the likelihood of a release resulting in an explosion and/or a sustained fire.

6.2. LOC frequencies

The base frequencies for LOC during DG transport and modified frequencies (based on number of vehicle movements) used in the assessment of transport risk for the identified scenarios, are summarised in Table 6.1.

Table 6.1: LOC frequencies for modelled scenarios

Scenario ID	Base Frequency (per km)	No. of vehicle movements		Modified frequency (per km)		Reference
		Current	Future/ reduced	Current	Future/ reduced	
Class 2.1 flammable liquefied gases						
1.1	2.10×10^{-9}	4,521	1,500	9.49×10^{-6}	3.15×10^{-6}	[7]
1.2	1.80×10^{-8}	4,521	1,500	8.41×10^{-5}	2.70×10^{-5}	[7]
1.3	2.60×10^{-9}	4,521	1,500	1.18×10^{-5}	3.90×10^{-6}	[7]
1.4	2.70×10^{-12}	4,521	1,500	1.22×10^{-8}	4.05×10^{-9}	[7]
Class 2.3 toxic gases						
2.1	6.17×10^{-8}	4	187	2.47×10^{-7}	1.15×10^{-5}	[8]
2.2	2.60×10^{-9}	4	187	1.04×10^{-8}	4.86×10^{-7}	[7]
3.1	6.17×10^{-8}	484	520	2.99×10^{-5}	3.21×10^{-5}	[8]
3.2	2.60×10^{-9}	484	520	1.26×10^{-6}	1.35×10^{-6}	[7]
3.3[(a)]	2.01×10^{-8}	484	520	9.73×10^{-6}	1.05×10^{-5}	[7]
Class 3 flammable liquids						
4.1	2.10×10^{-8}	7,712	7712[(b)]	1.62 x 10-4	1.62 x 10-4	[7]
Notes: Scenario considers release from vapour and liquid space of the storage drum, as such the base frequency is the summation of the OGP frequencies for vapour and liquid leaks.						

No changes for Class 3.

6.3. Ignition probability

For consistency, ignition probabilities for this study were based on the values used in the previous Scott Lister report, Ref [1]. For immediate ignition a probability of 30% was used and for delayed ignition a value of 20% was used.

7. RISK ANALYSIS AND EVALUATION

7.1. Overview

Risk analysis was performed using Gexcon RISKCURVES (v12.4.0), which combines the consequences and frequencies of the identified release scenarios. Assessment of the risk results against relevant risk criteria was then conducted. Risk results were also compared against results from previous Scott Lister transport studies to determine the impact that the additional DG transport movements attributed to the operation of the CLP will have on the existing risk profile.

7.2. Risk analysis and evaluation

Fatality risk results were reported as IFR contours, which are overlaid on a map of Denison St. and the surrounding area.

Figure 7.1 compares the cumulative DG transport risk along Denison St for Case 3 (the new baseline) to the 2016 Scott Lister study, Ref [1]. From this comparison it can be seen that the IFR contours for the equivalent QRA risk model (case 3) are approximately the same along Denison St. as the 2016 Scott Lister study, with the 1 x 10^{-6} per year IFR contour extending into the residential zone along the south end of Denison St.

Table 7.1 provides a comparison of the IFR assessed for all transport risk assessment cases against the individual fatality risk criteria specified by Table 3.1, as well as a discussion on the effect that the increase in volume of Class 2.3 DG transports will have on the current cumulative transport risk along Denison St.

7.3. Key findings

The conclusions from the evaluation of IFR for all specified transport risk assessment cases were as follows:

- In the 2026 SL report the 1 x 10^{-6} per year risk contour extended approximately 60 m from Denison St and out to approximately 90 m around the intersections, reaching the residential areas.
- A new baseline model using equivalent assumptions where possible to the 2016 Scott Lister study was developed. As per Figure 7.1, the results are broadly comparable in that the 1 x 10^{-6} per year IFR contours extends approximately 60 m (i.e. into residential areas in the south end of Denison St as per the 2016 SL study), and the at the risk is dominated by Class 2.1 tankers. The overall conclusion with respect to risk criteria is the same as the SL report.
- As per Figure 7.2, both the CAP current case and the CLP chlorine contingent transport case (see Section 2.1) for chlorine (Class 2.3 DG) transport traffic volume only comply with all relevant HIPAP 4 risk criteria

- As per Figure 7.3 (which compares the new baseline model with the baseline changed to reflect the modified facility CLP contingent operation case), the change will not have a material effect on the existing cumulative transport risk along Denison St as presented in the TRA findings from Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility.
- The effect of reducing Class 2.1 numbers due to Qenos closure on the baseline model is shown in Figure 7.4 and reduces the extent of the risk contours in the south part of Denison St however the HIPAP4 criterion for residential land use is not met.

7.4. Conclusion

A TRA has been completed to evaluate the potential impacts from DG transport to and from the modified facility (i.e. the CAP and CLP cumulative operations) with comparison to the TRA findings from Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility).

The TRA demonstrates that the modified facility does not materially increase the risk level. Conclusions with respect to HIPAP 4 risk criteria compliance remain unchanged, specifically that the residential risk criterion is exceeded in the southern part of Denison St.

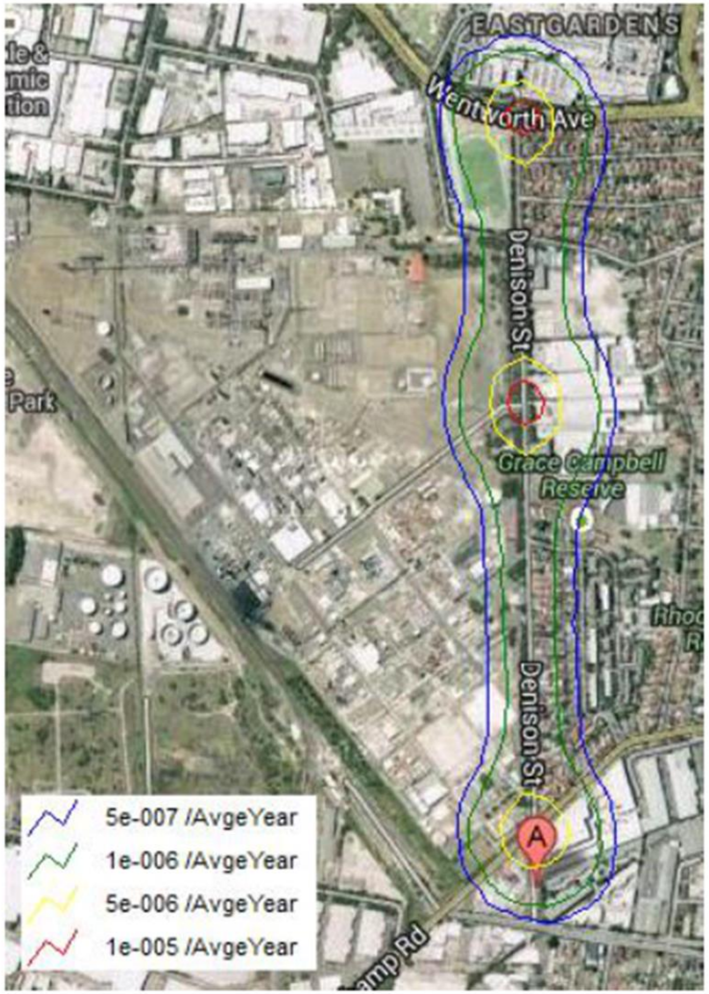
Table 7.1: Comparison of transport risk assessment cases against HIPAP 4 risk criteria

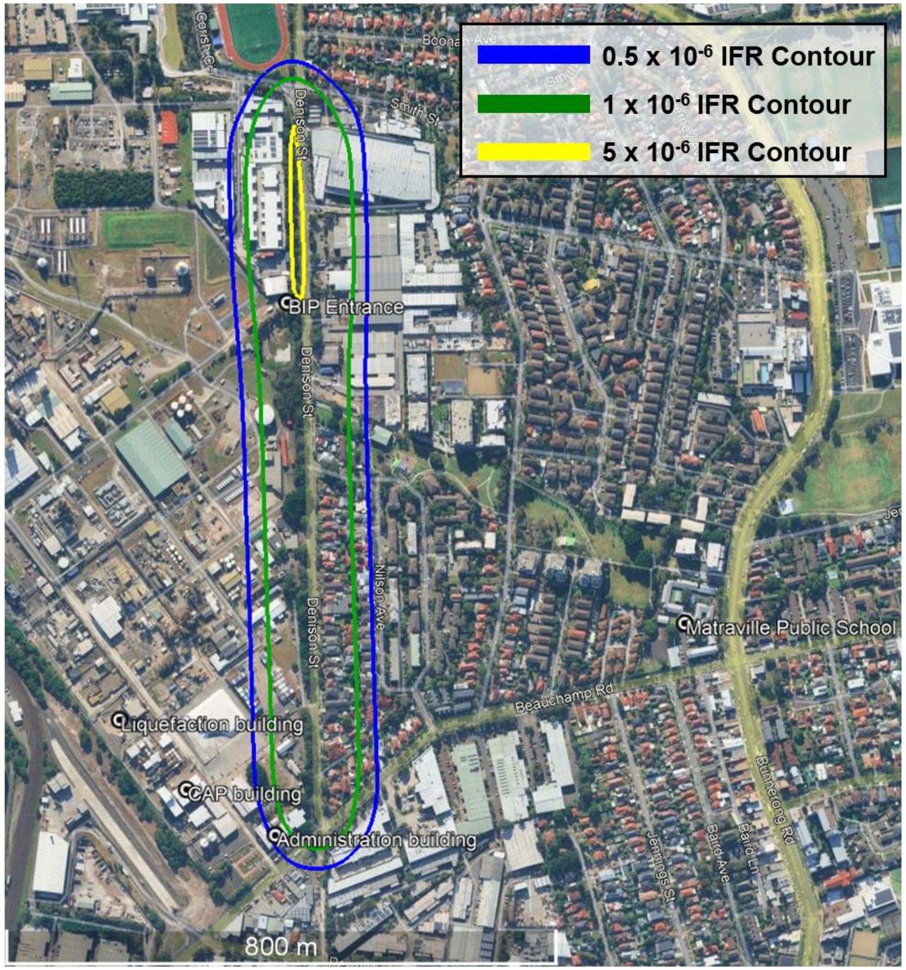
Case ID	Case definition	Met criteria (Y/N)[(a)]			Comments
		5×10^{-6}	1×10^{-6}	0.5×10^{-6}	
SL	Scott Lister report	No	No	Yes	• From Figure 7.1 risk meets the HIPAP 4 risk criteria for sensitive land uses as the cumulative 0.5×10^{-6} per year IFR contour does not reach any sensitive land uses (i.e. Matraville Public School). • The cumulative 1×10^{-6} per year IFR contour reaches the residential zone along the south of Denison St (extends about 20 m). • The 5×10^{-6} per year IFR contour does not reach the business/zone Bunnings commercial land uses in the centre of Denison St so does not meet this criteria.
1	Current chlorine transport only	Yes	Yes	Yes	• From Figure 7.2, currently the risk due to the transport of chlorine to and from the CAP along Denison St. meets all relevant risk criteria, as the 1×10^{-6} per year IFR contour is only present at the northern section of Denison St. which is zoned industrial and does not reach a residential area. • No 5×10^{-6} per year IFR contour was generated, so this criterion was met.
2	Future chlorine transport only	Yes	Yes	Yes	• From Figure 7.2, the increase in chlorine transport due to the operation of the CLP will increase the risk along Denison St., however it will still meet the relevant HIPAP 4 risk criteria, as the 1×10^{-6} and 0.5×10^{-6} per year IFR contours do not reach residential zones or sensitive land uses (i.e. Matraville Public School), respectively. • No 5×10^{-6} per year IFR contour was generated, so this criterion was met.
3	Equivalent QRA risk model (Scott Lister 2016)	Yes	No	Yes	• From Figure 7.3, it can be seen that the equivalent QRA risk model (case 3) meets the HIPAP 4 risk criteria for sensitive land uses as the cumulative 0.5×10^{-6} per year IFR contour does not reach any sensitive land uses (i.e. Matraville Public School). • The cumulative 1×10^{-6} per year IFR contour does reach the residential zone along the south of Denison St. This is consistent with the results presented in the 2016 Scott Lister study. The 5×10^{-6} per year IFR contour does not reach any commercial land uses, so this criterion is met.

Case ID	Case definition	Met criteria (Y/N)[(a)]			Comments
		5×10^{-6}	1×10^{-6}	0.5×10^{-6}	
4	Equivalent QRA risk model (Scott Lister 2016) – reduced Class 2.1 tanker numbers	Yes	No	Yes	• From Figure 7.4, it can be seen that a reduction in the LPG tanker numbers (to exclude transport to and from the Qenos BIP facility), results in some risk reduction along Denison St. when compared against the baseline QRA model. It can be seen that the chlorine drum transport occurring at the north of Denison St. is the primary contributor to the 1 x10^{-6} per year IFR risk contour. • The 1 x 10^{-6} per year IFR risk contour is now restricted to the road and does not extend into the residential area along the south of Denison St., as such this case meets the HIPAP 4 risk criteria for residential land uses. • As per case 3, case 4 also meets the HIPAP 4 risk criteria for commercial and sensitive land uses.
5	Equivalent QRA risk model (Scott Lister 2016) – no Class 2.1 tankers	Yes	No	Yes	• Not a credible case, as even with the closing of the Qenos BIP facility, there is still additional class 2.1 LPG tanker traffic from the surrounding port area (Elgas only as Origin at Port Botany has closed). • NOTE Retained as this case was agreed with DPHI.
6	Equivalent QRA risk model (Scott Lister 2016) and future chlorine transport	Yes	No	Yes	• From Figure 7.3, it can be seen that the increase in the volume of Class 2.3 DG transports resulting from the operation of the CLP will not have an effect on the cumulative 0.5 x 10^{-6} per year IFR contour and will slightly increase the reach of the cumulative 1 x 10^{-6} per year IFR contour along the south section of the Denison St. This is consistent with the results presented in the 2016 Scott Lister study. As such, the increased volume of Class 2.3 DG transports will not have a material effect on the current transport cumulative risk along Denison St. • The 5 x 10^{-6} per year IFR contour does not reach any commercial land uses, so this criterion was met.

Case ID	Case definition	Met criteria (Y/N)[(a)]			Comments
		5×10^{-6}	1×10^{-6}	0.5×10^{-6}	
7	Equivalent QRA risk model (Scott Lister 2016) – reduced Class 2.1 tanker numbers and future chlorine transport	Yes	No	Yes	• From Figure 7.5, it can be seen that the inclusion of the contingent chlorine transport case slightly increases the cumulative 0.5×10^{-6} and 1×10^{-6} per year IFR contour along the south section of Denison St when reduced Class 2.1 tankers are accounted for. • No 5×10^{-6} per year IFR contour was generated, so this criterion was met.
Notes: The HIPAP 4 criteria for sporting complexes/active open spaces (10×10^{-6}) and industrial sites (50×10^{-6}) were met as the IFR generated was not high enough to produce these contours.					

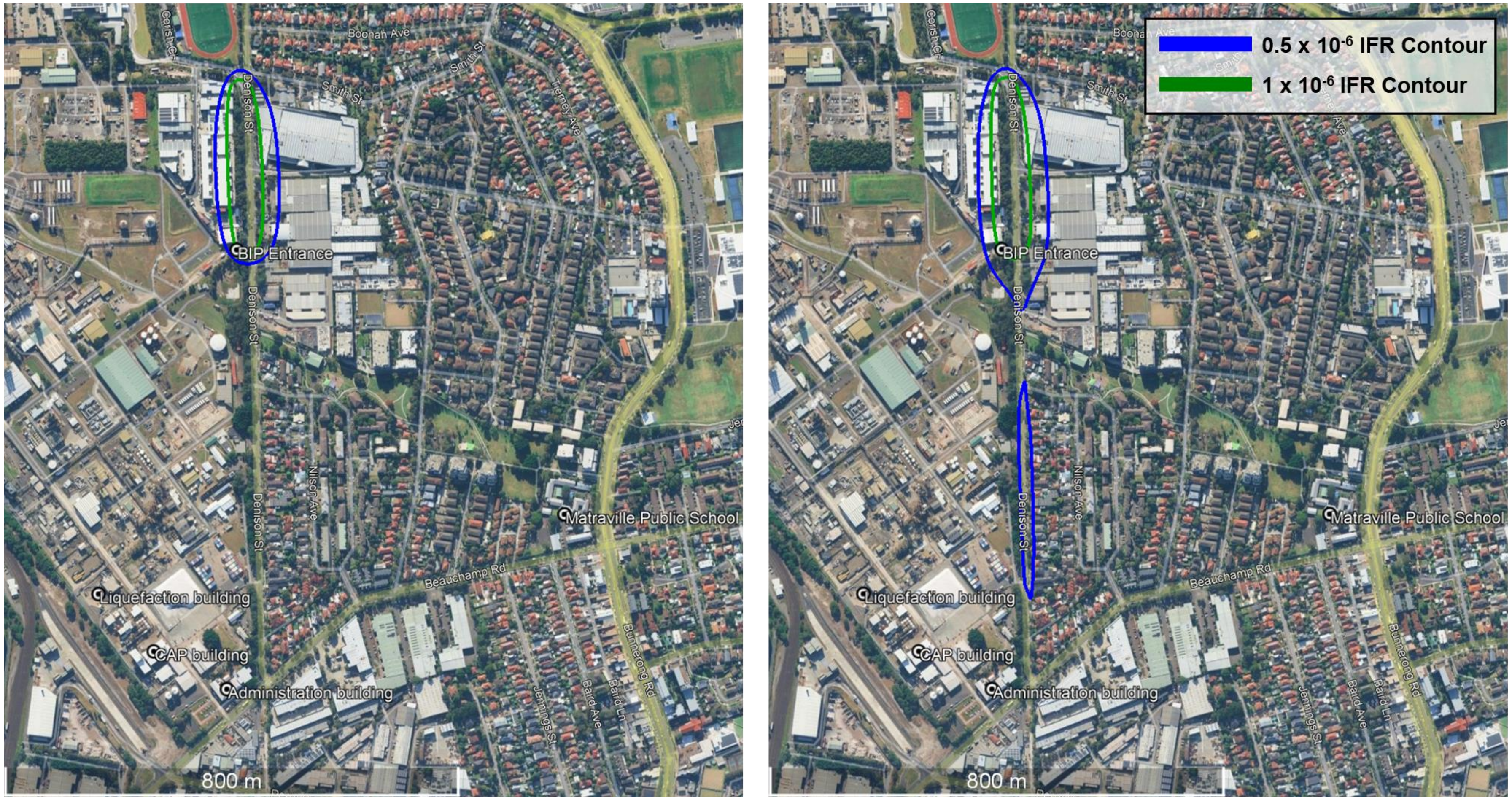
Figure 7.1: IFR risk results for the 2016 Scott Lister study, Ref [1], (left) and case 3 – equivalent QRA risk model





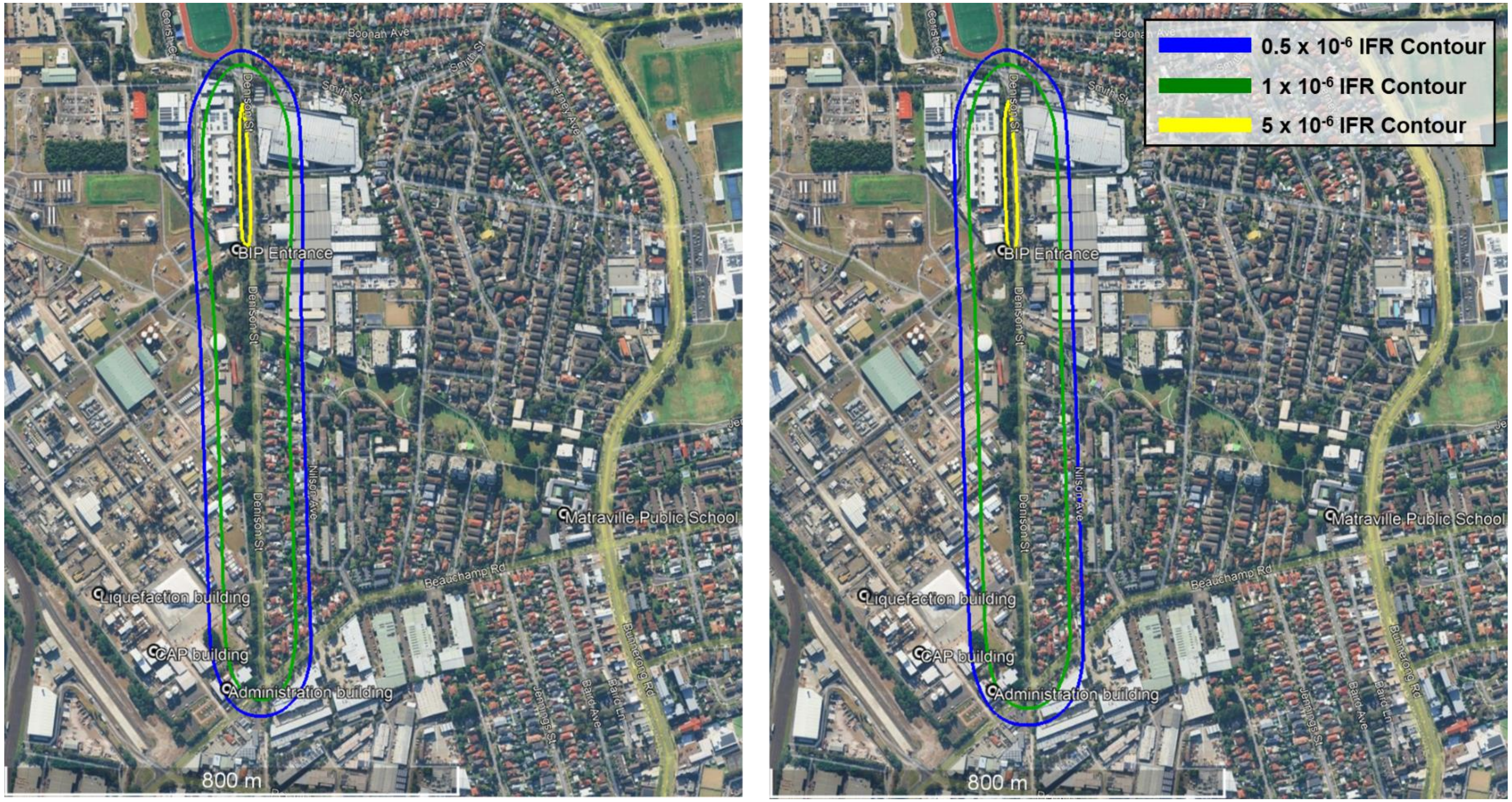
Comparison: this shows that the new baseline risk model is similar to the 2016 Scott Lister model. Note that the map scale is not the same however in both cases the (non-intersection) $1x10^{-6}$ per year IFR contour extends approximately 60m from Denison St

Figure 7.2: IFR for cases 1 & 2 – Current chlorine transport (left) and future chlorine transport (right)



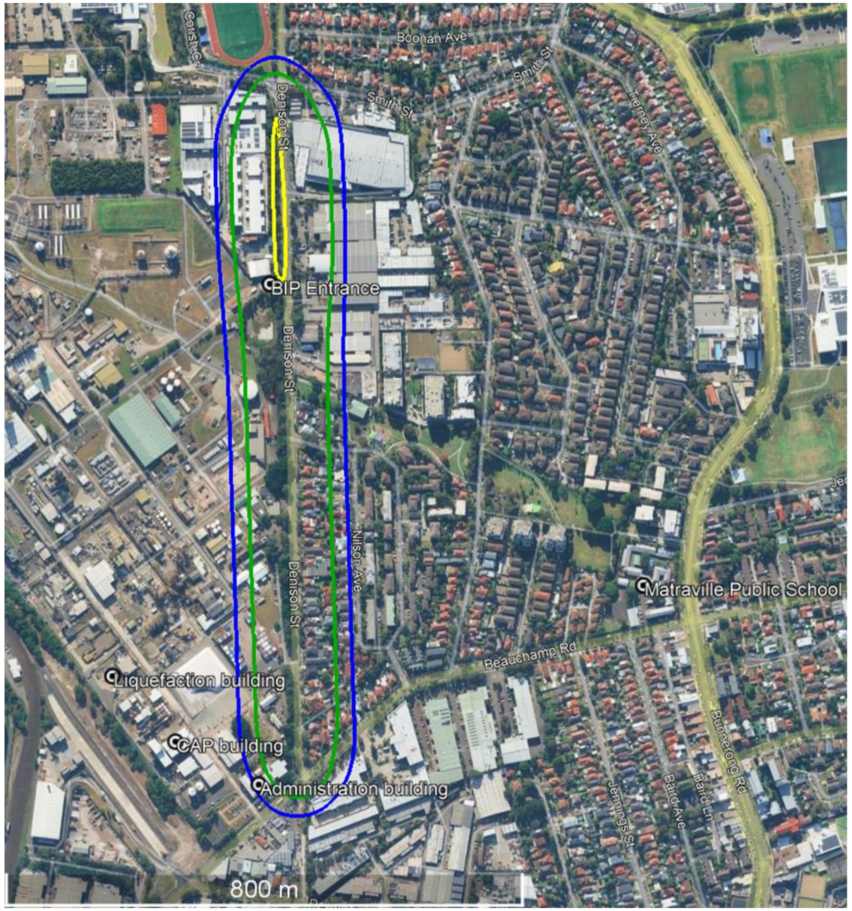
Comparison: this shows that the increase in chlorine transport has minimal impact on the transport risk in the northern part of Denison St as the drum numbers have not increased significantly. An increase in risk associated with the chlorine tanker increase can be seen in the southern part of Denison St however this is at a low level i.e. below 1 x10^{-6} per year and all relevant individual fatality risk criteria are met.

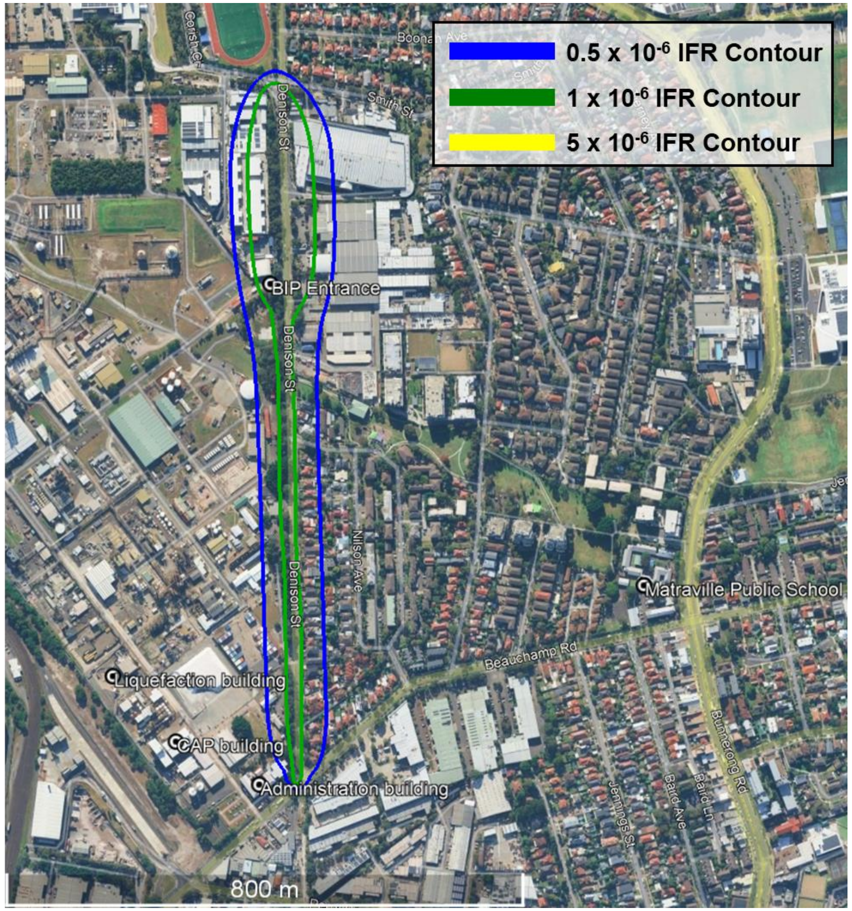
Figure 7.3: IFR for cases 3 & 6 – Equivalent QRA risk model (Scott Lister 2016) (left) and Equivalent QRA risk model with increased class 2.3 DG traffic (right)



Comparison: this shows minimal increase in cumulative risk including the effect of increased chlorine transport compared to the current baseline risk, i.e. cumulative risk remains similar to that in the 2016 risk profile in the TRA for the *Major Project approval MP 06_0089 MOD 2 (Vopak Bulk Liquids Storage Facility.*

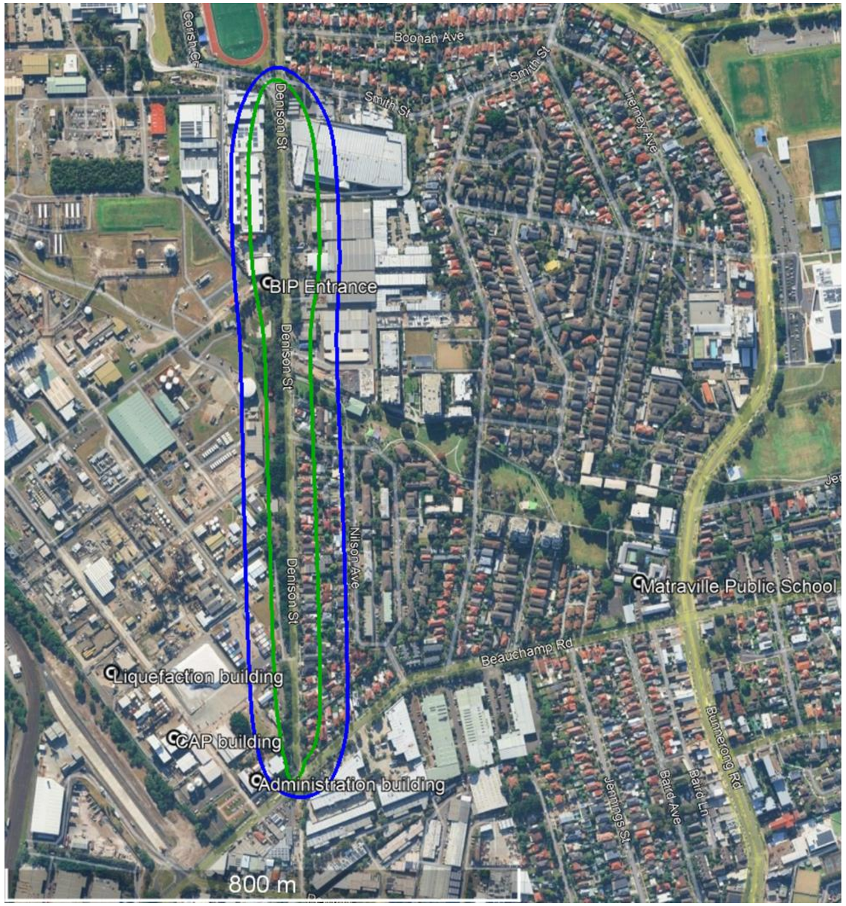
Figure 7.4: IFR for case 3 & 4 – Equivalent QRA risk model (left) and equivalent QRA risk model (reduced 2.1 tanker numbers) (right)

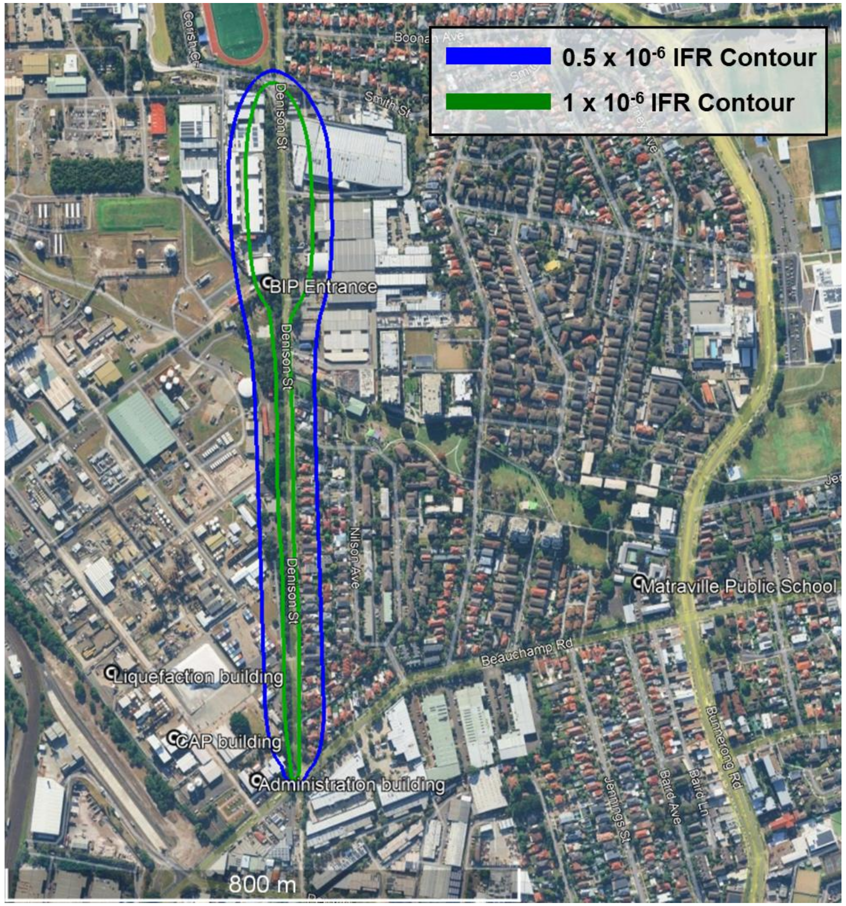




Comparison: this shows the effect of reducing Class 2.1 tankers which is the dominant DG transport risk contributor. The 1 x10^{-6} per year contour still extends into residential areas in the southern part of Denison St.

Figure 7.5: IFR case 7 & 4 – Equivalent QRA risk model (reduced 2.1 tanker numbers) with increased class 2.3 DG traffic (left) and equivalent QRA risk model (reduced 2.1 tanker numbers) (right)





Comparison: this shows the effect of increased chlorine transport and also accounts for reduced Class 2.1 tankers. The 1 $\times 10^{-6}$ per year contour extends slightly further into residential areas in the southern part of Denison St due to increased chorine tanker volumes and there is no material change in the northern part of Denison St.

APPENDIX A. ACCIDENT SUMMARY

Table A.1: Summary of accidents on Denison St. over the period of 2016-2023, Ref [9]

Crash ID	Degree of crash	Year of crash	First impact type	Key vehicle type	Secondary vehicle type	Number of fatalities	Number of serious injuries
1112459	Non-casualty (towaway)	2016	Right angle	Car (sedan/hatch)	4-wheel drive	0	0
1118040	Serious Injury	2016	Other angle	4-wheel drive	Motorcycle	0	1
1132434	Non-casualty (towaway)	2017	Rear end	Station wagon	Car (sedan/hatch)	0	0
1134499	Fatal	2017	Rear end	Light truck	Pedal cycle	1	0
1155510	Moderate Injury	2017	Other angle	Car (sedan/hatch)	Light truck	0	0
1156826	Minor/Other Injury	2017	Other angle	Car (sedan/hatch)	Light truck	0	0
1184572	Minor/Other Injury	2018	Head-on	Light truck	Semi-trailer	0	0
1188950	Serious Injury	2018	Right angle	Passenger van	Motor scooter	0	1
1272109	Non-casualty (towaway)	2021	Other angle	Light truck	4-wheel drive	0	0
1276301	Non-casualty (towaway)	2021	Head-on	Car (sedan/hatch)	Semi-trailer	0	0
1311457	Minor/Other Injury	2023	Rear end	4-wheel drive	Car (sedan/hatch)	0	0
1330596	Non-casualty (towaway)	2023	Other angle	4-wheel drive	Car (sedan/hatch)	0	0
1335563	Non-casualty (towaway)	2023	Other angle	4-wheel drive	Car (sedan/hatch)	0	0
1338437	Moderate Injury	2023	Other angle	4-wheel drive	Motorcycle	0	0
					Total	**1**	**2**

APPENDIX B. METEOROLOGICAL CONDITIONS

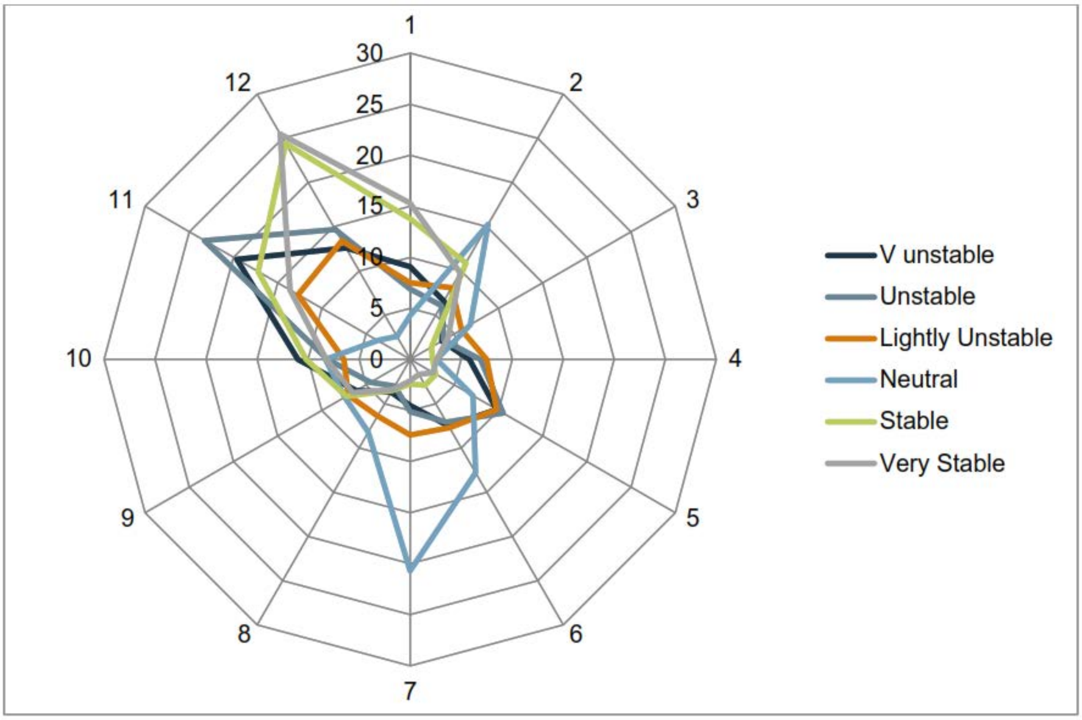
B1. Weather conditions

To ensure consistency the meteorological data used in this study is the same as the data used in the 2016 Scott Lister study. This study used meteorological data from the Bureau of Meteorology (BOM) for Sydney Airport over the period of 1999-2004 and was categorised by wind speed and Pasquill stability class. The descriptions for each Pasquill stability class are summarised in Table B.1 and a wind rose taken from the 2016 Scott Lister study is shown in

Table B.1: Pasquill atmospheric stability classes

Class	Type	Description
A	Very unstable	Daytime – sunny, light winds
B	Unstable	Daytime – moderately sunny, light to moderate winds
C	Lightly unstable	Daytime – moderate winds, overcast or windy and sunny
D	Neutral	Daytime – windy and overcast or Night-time – windy
E	Stable	Night-time – moderate winds with little cloud or light winds with more clouds
F	Very stable	Night-time – light wind, little cloud

Figure B.1: Wind direction probabilities for selected atmospheric stability conditions, Ref [1]



APPENDIX C. CONSEQUENCE AND FREQUENCY ANALYSIS

C1. Overview

Table C.1summarises the maximum distances to 1% fatality for each scenario as well as the frequencies for each scenario.

Table C.1: Maximum distance to 1% fatality for modelling scenarios

Scenarios	Frequency (per year)	Max. distance to 1% fatality (m)
Class 2.1 Traffic Vopak Expansion Case (reduced tanker numbers)		
1.1 - 50mm Vapour	3.15×10^{-6}	41
1.2 - 50mm Liquid	2.70×10^{-5}	168
1.3 - Catastrophic Rupture	3.90×10^{-6}	226
1.4 - T1.1 LPG Tanker BLEVE	4.05×10^{-9}	164
Class 2.1 Traffic Vopak Expansion Case		
1.1 - 50mm Vapour	9.49×10^{-6}	41
1.2 - 50mm Liquid	8.14×10^{-5}	168
1.3 - Catastrophic Rupture	1.18×10^{-5}	226
1.4 - BLEVE	1.22×10^{-8}	164
Class 3 Traffic Vopak Expansion Case		
4.1 - Rupture	1.62×10^{-4}	21
CURRENT Denison St North (drum transport only)		
3.1 - Release from Filled Drums - Mechanical Failure	2.99×10^{-5}	494
3.2 - Release from Filled Drums - Rupture	1.26×10^{-6}	494
3.3 - Release from Filled Drums - 6mm valve	9.73×10^{-6}	515
CURRENT Denison St South (bulk tanker transport only)		
2.1 - Chlorine Storage Tank - Mechanical Leak (13 mm)	2.47×10^{-7}	1,305
2.2 - Chlorine Storage Tank - Rupture	1.04×10^{-8}	2,024
FUTURE Denison St North (drum transport only)		
3.1 - Release from Filled Drums - Mechanical Failure	3.21×10^{-5}	494
3.2 - Release from Filled Drums - Rupture	1.35×10^{-6}	463
3.3 - Release from Filled Drums - 6mm valve	1.05×10^{-5}	515
FUTURE Denison St South (bulk tanker transport only)		
2.1 - Chlorine Storage Tank - Mechanical Leak (13 mm)	1.15×10^{-5}	1,305
2.2 - Chlorine Storage Tank - Rupture	4.86×10^{-7}	2,024

APPENDIX D. REFERENCES

[1] Systra, Scott Lister, "Vopak Port Botany Expansion - Denison St Transport QRA - July 2016 Update. Rev 4," 2016.

[2] NSW Department of Planning, "Hazardous Industry Planning Advisory Paper No. 4 - Risk Criteria for Land Use Safety Planning," 2011.

[3] Scott Lister, "Dangerous Goods transport QRA, Denison St, Hillsdale Rev 3," 2015.

[4] Scott Lister, "Addendum to Dangerous Goods transport QRA, Denison St, Hillsdale," 2015.

[5] Imperial Chemical Industries (ICI) PLC (UK), "ICI Engineering Department, Process Safety Guide 14 - Reliability Data," 1992.

[6] Ixom Operations Pty Ltd (formerly Orica), "Drum failure frequency data for chlorine risk assessment, Rev C".

[7] International Association of Oil & Gas Producers, "Report No. 434-9: Land transport accident statistics," OGP, 2010.

[8] M. Abkowitz, J. Delorenzo, R. Duych and A. Greenberg, "Comparative risk assessment of hazmat and non-hazmat truck shipments," *Transportation Research Record,* pp. 1-15, 2000.

[9] TfNSW, "NSW Road Crash Data - 2016-2023," 2024. [Online]. Available: https://opendata.transport.nsw.gov.au/data/dataset/nsw-crash-data.

[10] Sherpa Consulting Pty Ltd, "Vopak Terminals Australia: Site B proposed throughput increase - Dangerous Goods road transport risk assessment," 2016.