



APPENDIX D

QUANTITATIVE RISK ASSESSMENT

QUANTITATIVE RISK ASSESSMENT REPORT

PROPOSED CHLORINE LIQUEFACTION PLANT

MODIFICATION TO CHLORALKALI FACILITY

BOTANY INDUSTRIAL PARK

IXOM

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CONTENTS

1.	SUMMARY	9
	1.1. Overview	9
	1.2. Objectives	9
	1.3. Scope	10
	1.4. Methodology	10
	1.5. Results	11
	1.6. Recommendations	13
2.	INTRODUCTION	19
	2.1. Background	19
	2.2. Objectives	19
	2.3. Scope	19
	2.4. Study approach	20
	2.5. Links to MHF regulatory requirements	20
	2.6. Exclusions and limitations	21
3.	FACILITY DESCRIPTION	24
	3.1. Location	24
	3.2. Surrounding land use	24
	3.3. CLP capacity and operating modes	24
	3.4. Plant layout	26
	3.5. Chlorine liquefaction plant details	26
	3.6. Process description	26
	3.7. Chlorine liquefaction plant building	27
	3.8. CLP interface with CAP	31
	3.9. Risk minimisation	35
	3.10. Abnormal event control philosophy	38
4.	STUDY BASIS AND ASSUMPTIONS	39
	4.1. Overview	39
	4.2. Inventory and throughputs	39
	4.3. Meteorological data	40
	4.4. Population data	41
	4.5. Toxicity effects	41

4.6. Offsite risk criteria	42
4.7. Software.....	44
5. HAZARD IDENTIFICATION	45
5.1. Overview.....	45
5.2. Hazardous material	45
5.3. Hazard identification	46
6. CONSEQUENCE ANALYSIS.....	47
6.1. Consequence results	47
6.2. Worst-case consequences	47
6.3. Storage tank bund impact.....	47
7. FREQUENCY ANALYSIS	48
7.1. Release frequencies	48
7.2. Control measures	48
8. RISK ASSESSMENT.....	49
8.1. Modelled cases.....	49
8.2. Individual fatality risk results.....	50
8.3. Injury and irritation risk	55
8.4. Risk contributors	58
8.5. Societal risk	58
8.6. Onsite risk.....	61
9. CONCLUSION.....	62
9.1. Main findings.....	62
9.2. Recommendations.....	64

- APPENDIX A. SEARS CROSS REFERENCES
- APPENDIX B. ASSUMPTION REGISTER
- APPENDIX C. DRAWINGS
- APPENDIX D. METEOROLOGICAL DATA
- APPENDIX E. POPULATION DATA
- APPENDIX F. LIQUEFACTION BUILDING AND SCRUBBER DESIGN
- APPENDIX G. HAZARD IDENTIFICATION

APPENDIX H. CONSEQUENCE RESULTS

APPENDIX I. FREQUENCY ANALYSIS

APPENDIX J. RISK CONTRIBUTORS

APPENDIX K. ONSITE RISK BASIS

APPENDIX L. BOTANY/RANDWICK SAFETY STUDY RECOMMENDATIONS (2001)

APPENDIX M. REFERENCES

TABLES

Table 1.1: Onsite risk.....	13
Table 1.2: Compliance with HIPAP 4 risk criteria.....	16
Table 2.1: Exclusions and limitations	21
Table 3.1: Chlorine usage and production rate of the Botany plant.....	25
Table 3.2: Design choices to minimise risk	36
Table 3.3: Scrubber design summary	38
Table 4.1: Chlorine inventory QRA basis	39
Table 4.2: CLP chlorine throughputs QRA basis.....	40
Table 4.3: Meteorological data summary	41
Table 4.4: Toxic fatality, injury and irritation criteria	41
Table 4.5: NSW HIPAP 4 risk criteria	42
Table 8.1: Sensitivity cases	49
Table 8.2: Onsite risk as day time individual fatality risk per annum (IRPA).....	61
Table 9.1: Comparison against HIPAP 4 quantitative risk criteria.....	65
Table 9.2: Comparison against HIPAP 4 qualitative risk criteria	67

FIGURES

Figure 1.1: Individual Fatality Risk results.....	15
Figure 1.2: Societal risk – Population includes additional 40/hectare former BIP operations.....	18
Figure 3.1: Isometric view of the Chlorine Liquefaction Plant building.....	28
Figure 3.2: Site location.....	32
Figure 3.3: CLP block diagram	33
Figure 3.4: CLP building layout	34
Figure 4.1: Indicative societal risk criteria from Figure 3, HIPAP 4 (2011)	44
Figure 8.1: IFR contours – CLP only	51
Figure 8.2: IFR contours – cumulative risk (normal case).....	52
Figure 8.3: IFR contours – cumulative risk (contingent case).....	53
Figure 8.4: CLP impact on future risk.....	54
Figure 8.5: Toxic injury contour (AEGL 3 equivalent toxic dose, 10×10^{-6} per year contour).....	56
Figure 8.6: Toxic irritation contour (AEGL 2 equivalent toxic dose, 50×10^{-6} per year contour).....	57
Figure 8.7: Societal risk – Population 1 (additional 40 people/hectare on former BIP operations).....	60

ABBREVIATIONS

ABS	Australian Bureau of Statistics
ADG	Australian Dangerous Goods (Code)
AEGL	Acute Emergency Guideline Level
ALARP	As Low As Reasonably Practicable
AS	Australian Standard
AWS	Automatic Weather Station
BIP	Botany Industrial Park
BoM	Bureau of Meteorology
CAP	Chloralkali Plant
Cl ₂	Chlorine
CLP	Chlorine Liquefaction Plant
DA	Development Application
DCS	Distributed Control System
DG	Dangerous Good
DPHI	Department of Planning, Housing and Infrastructure ¹
FHA	Final Hazard Analysis
HAZID	Hazard Identification
HCl	Hydrogen Chloride
HIPAP	Hazardous Industry Planning Advisory Paper
HS	Hazard Studies
HSE	(UK) Health and Safety Executive
IFR	Individual Fatality Risk (offsite)
IRPA	(worker) Individual Fatality Risk per annum
LBS	Liquefaction Building Scrubber
LCP	Local Control Panel
LOC	Loss of Containment
JRPP	Joint Regional Planning Panel
MHF	Major Hazard Facility
MI	Major Incident
NaOH	Sodium hydroxide (caustic soda)
NCI ₃	Nitrogen chloride
NH ₃	Ammonia
NSW	New South Wales
PFD	Process Flow Diagram
PFDAvg	Probability of Failure on Demand
PID	Piping and Instrumentation Diagram
ppm	parts per million
PPE	Personal Protective Equipment
QRA	Quantitative Risk Assessment

¹ This acronym covers all previous forms of the same authority e.g. DPIE, DUAP, DPE, DoP.

R2P2	Reducing Risks, Protecting People
SA	Statistical Area
SEARs	Secretary's Environmental Assessment Requirements
SEE	Statement of Environmental Effects
SERM	State and Emergency Rescue Management (Act)
SFARP	So Far As Reasonably Practicable
SIL	Safety Integrity Level
SMS	Safety Management System
TfNSW	Transport for NSW
TRA	Transport Risk Assessment
TZ	Travel Zone

1. SUMMARY

1.1. Overview

IXOM is proposing to construct a Chlorine Liquefaction Plant (CLP) at the existing Chloralkali Plant (CAP) located on the Botany Industrial Park (BIP), New South Wales (NSW). The CAP is an existing Major Hazard Facility (MHF) which manufactures gaseous chlorine and caustic soda and then uses the chlorine to make hydrochloric acid, ferric chloride, and sodium hypochlorite in downstream product plants. Liquid chlorine (from IXOM's Laverton plant in Victoria) is also stored in drums, cylinders and a parked road tanker in an outdoor storage area at the CAP.

The CLP will be located within a containment building fitted with a Liquefaction Building Scrubber (LBS) to treat chlorine leaks. Bulk liquid chlorine will be stored in pressure vessels under refrigerated conditions and atmospheric pressure within the building. The existing outdoor chlorine drum, cylinder storage and parked tanker associated with the CAP will be relocated to within the containment building.

The NSW Department of Planning, Housing and Infrastructure (DPHI) has issued Secretary's Environmental Assessment Requirements (SEARs) for the project which require IXOM to assess the offsite, onsite and Dangerous Goods (DG) transport risk. IXOM retained Sherpa Consulting Pty Ltd (Sherpa) to carry out the risk study.

1.2. Objectives

The overall objective of this study is to undertake a Quantitative Risk Assessment (QRA) in accordance with the Hazardous Industry Planning Advisory Paper No. 6 *Hazard Analysis* (HIPAP 6) to determine if the cumulative risk from the existing CAP and proposed CLP complies with qualitative and quantitative HIPAP 4 *Risk Criteria for Land Use Safety Planning*. The criteria for individual fatality risk, toxic injury and irritation risk and societal risk have been included in the study.

All specific requirements of the SEARs in relation to hazard and risk and the location in the report where they are addressed are summarised in APPENDIX A.

Note that the QRA has been prepared in the context that the Qenos and Indorama operations on the BIP have been shut down, hazardous materials removed and these no longer present a source of risk. These areas have been assessed as potential additional industrial populations in the societal risk assessment.

1.3. Scope

The study covers the proposed CLP facility. The CLP will have two operational modes:

- Normal case: During normal operation, the CLP is operated at 10% of total 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 is unavailable, the CLP will run at full capacity and facilitate bulk tanker loading as well as chlorine drum and cylinder filling for export via flatbed trucks.

Both operational cases for the CLP are covered in the QRA.

The existing CAP and associated downstream product plants are also included in the cumulative risk assessment.

Results for both offsite risk and onsite risk are included in this report. Transport risk is not covered in this report as it is addressed separately.

1.4. Methodology

The QRA included the following steps:

1. Consultation with DPHI and SafeWork to discuss key assumptions and reporting requirements.
2. Hazard Identification (HAZID) for the CLP was undertaken based on experience with chlorine plants, review of similar IXOM operations and the project hazard studies (HS) completed for the CLP. This included review of the MHF Major Incidents (MIs) at the IXOM Laverton liquefaction plant in Victoria and was also generally informed by Chlorine Institute and Euro Chlor industry guidance.
3. Frequencies of potential hazardous incidents were estimated from industry statistical data bases together with event trees and operational input.
4. Quantitative consequence modelling and risk calculations were completed using commercially available software, Gexcon Effects and Riskcurves v12.5 to generate individual risk contours (fatality, toxic injury and irritation) and a societal risk (FN curve) for comparison against the HIPAP 4 risk criteria.
5. Onsite risk to IXOM operators was estimated quantitatively using the QRA model as a basis and compared to UK HSE worker risk criteria.
6. This QRA report was prepared for inclusion in the planning submission to the NSW DPHI.

1.5. Results

1.5.1. Qualitative criteria

MI scenarios associated with the CLP are typically chlorine releases. The overall intent of the CLP design with respect to risk was to:

- ensure that the cumulative offsite individual risk for the overall modified CAP (i.e. including the CAP and the CLP) is not materially higher than from the current CAP operations, and
- ensure that the worst-case consequence is not larger than from the current CAP operations.

This approach is consistent with ensuring the risk from a major hazard is reduced where practicable, irrespective of the numerical value of the cumulative risk. The project design decisions have been progressed in accordance with inherent safety principles and best practices for chlorine liquefaction with key control measures relevant at the design stage summarised below. Note that the QRA does not form an overall demonstration that the overall risk is reduced So Far As Reasonably Practicable (SFARP). This demonstration is required to be made as part of an update to the MHF Safety Case prior to any operations commencing.

1.5.2. Quantitative assessment

Key findings of this study are provided below:

1. Maximum consequence: No scenarios associated with the CLP were identified to have a greater consequence impact to the 1% fatality level than the existing CAP scenarios. The scenario with the largest impact remains a release from a 13-tonne chlorine road tanker at ambient conditions.
2. Control measures: High level design choices that minimise risk include:
 - Selection of the 'Block L' site within the BIP maximises the distance to residential areas along Denison St and minimises the extension of the pressurised chlorine vapour piping from the CAP to the CLP that cannot be located within the containment building. This also maximises the distance to onsite occupied areas such as the existing CAP control room and administration building.
 - Refrigerated storage conditions (i.e. atmospheric pressure and a temperature of approximately -34°C) limit the release rate and associated evaporation rate of chlorine allowing containment within a building and treatment by a scrubber at manageable rates.
 - Minimising the bund surface area for the storage tanks and other liquid chlorine handling areas significantly reduces spill evaporation rate. Hence, consequence impact of major release scenarios from refrigerated storage at atmospheric pressure such as storage tank failure.

- Containment building large enough to carry out all liquid storage and handling activities and sized to contain flash fraction of liquid chlorine scenarios including filled road tanker after warming up in combination with the scrubber system is an effective risk reduction measure for the CLP. The QRA has estimated a 5% 'unavailability' of the containment building and scrubbing system. This will be verified as achievable as part of detailed design as per the recommendations.

3. Offsite risk:

- All individual fatality risk criteria are met for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) as per Figure 1.1 and as summarised in Table 1.2. This is consistent with the existing CAP as per Table 1.2.
- Due to the effect of the containment building there is only a small difference in offsite risk between the normal and contingent cases as can be seen in the comparative risk contours in Figure 8.4.
- The toxic injury contour (see Figure 8.5) for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) does not reach the residential area hence meets the toxic injury criterion as per the current CAP case.
- The toxic irritation contour (see Figure 8.6) for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) does not reach the residential area and hence, meets the toxic irritation criterion as per the current CAP case.
- Societal risk is in the negligible region for both the normal and contingent cases as per Figure 1.2. The assessment assumes a population of 40 people/hectare on the Qenos and Indorama areas of the BIP.
- Due to the containment building, the individual and societal risk profile does not materially increase compared to the existing CAP plant risk profile.
- The overall extent of the individual fatality risk contours offsite is slightly reduced for the normal case compared to the current CAP due to the opportunity to relocate the existing liquid chlorine storages (drums, cylinder, parked road tanker) from the outdoor location to inside the containment building. The contingent case is slightly increased except to the north where it is decreased. (refer to Figure 8.4 for a comparative risk contour).
- The toxic injury and irritation risk contours are reduced for the normal and contingent cases due to the opportunity to relocate the existing liquid chlorine storages (drums, cylinder, parked road tanker) from the outdoor location to inside the containment building (refer to Figure 8.5 and Figure 8.6 for comparative risk contours).

4. Onsite risk (exposure mitigation not included): The purpose of the planning stage onsite risk calculation is to show that the worker risk can meet tolerability criteria. These results are not intended to demonstrate that worker risk is reduced SFARP as this demonstration will be undertaken as part of the MHF safety assessment. Onsite risk was estimated for typical roles for both the normal and contingent cases including CAP plus the future CLP operations using the QRA model. The risk estimate included adjustments for occupancy to calculate worker individual fatality risk per annum (IRPA). Mitigation factors relevant to reducing exposure of workers (e.g. self-escape, Personal Protective Equipment (PPE), localised ventilation) are not accounted for hence the calculations are conservative. As the IRPA without accounting for mitigation is below the UK Health and Safety Executive (HSE) ‘intolerable’ risk of 1×10^{-3} per year, the risk is tolerable for all worker roles including the effect of the CLP as summarised in Table 1.1.

Table 1.1: Onsite risk

Role	Day time IRPA – Modified facility CAP & CLP	
	Normal case	Contingent case
Day Plant Operator	3.65×10^{-5}	7.15×10^{-4}
Engineers/Planners	4.69×10^{-6}	1.17×10^{-5}
Technical/Quality	5.42×10^{-6}	1.43×10^{-5}
Operations	5.16×10^{-6}	1.24×10^{-5}
Admin staff	1.02×10^{-6}	2.65×10^{-6}

5. Risk contributors associated with operation of the modified facility are chlorine releases. There are small quantities of ammonia present in the CLP for the refrigeration system however ammonia risk contributions are not material due to the small inventory. The dominant risk contributors to the offsite individual fatality risk are liquid chlorine releases due to hose failures or piping failures in pumped liquid piping, i.e. for tanker loading for the normal case, and for drum and cylinder filling as well as tanker loading for the contingent case. These scenarios have been modelled conservatively for the QRA i.e. generic hose failure rates have been adopted, and the probability of failure of isolation and time to isolation has been selected conservatively for the planning stage QRA. These assumptions may be refined in detailed design stage further reducing the estimated risk.

1.6. Recommendations

The QRA is based on the design stage of the CLP. The key control that ensures the risk does not materially increase compared to current levels is the CLP containment building and scrubber. The dominant residual risk contributors are related to failures in equipment for transferring liquid chlorine between storages and tankers, drums or cylinders.

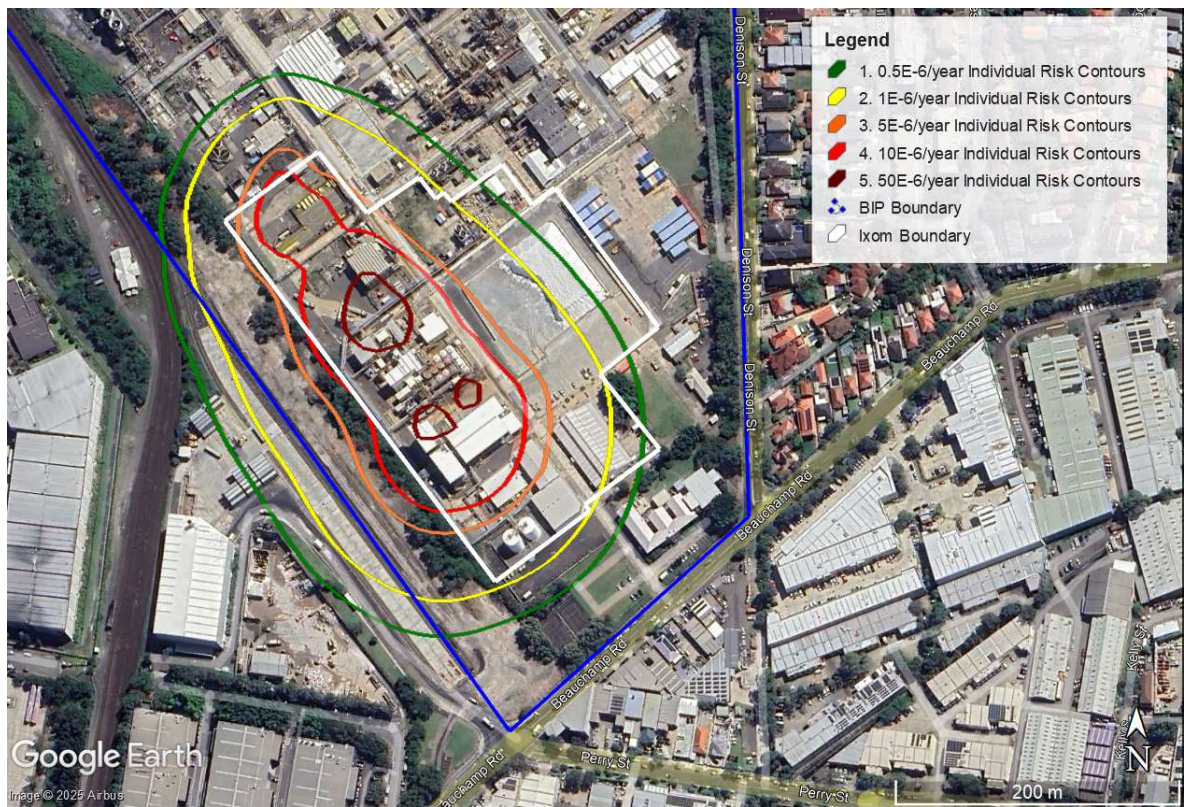
Recommendation 1: *It is recommended that as part of detailed design, the containment building and scrubber design should be verified to ensure that the estimated*

unavailability of no more than 5% is achieved. It is anticipated that this can be carried out as part of a Final Hazard Analysis (FHA) if project consent is received.

Recommendation 2: *The QRA has conservatively assessed the probability of failure on demand (PFDavg) of automatic detection and isolation (PFDavg = 0.1) and time to isolation (up to 3 minutes) for isolatable chlorine leak scenarios. It is recommended that as part of detailed design, automatic detection and isolation time and probability of failure on demand for detection and isolation of chlorine leaks from hoses and pumped liquid systems be more accurately assessed to confirm whether greater risk reduction is achievable for the residual risk contributors.*

Figure 1.1: Individual Fatality Risk results

Modified facility CAP & CLP – Normal case (Case SC1C)



Modified facility CAP & CLP – Contingent case (Case SC2C)

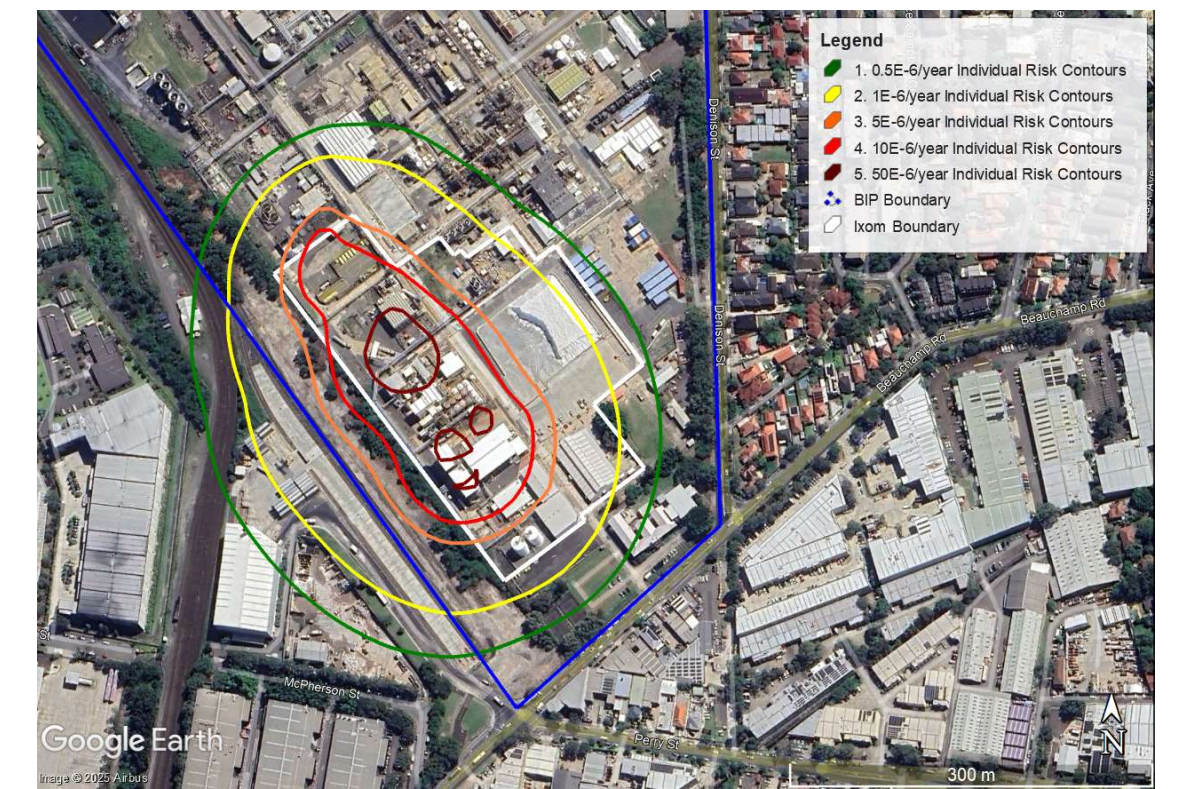
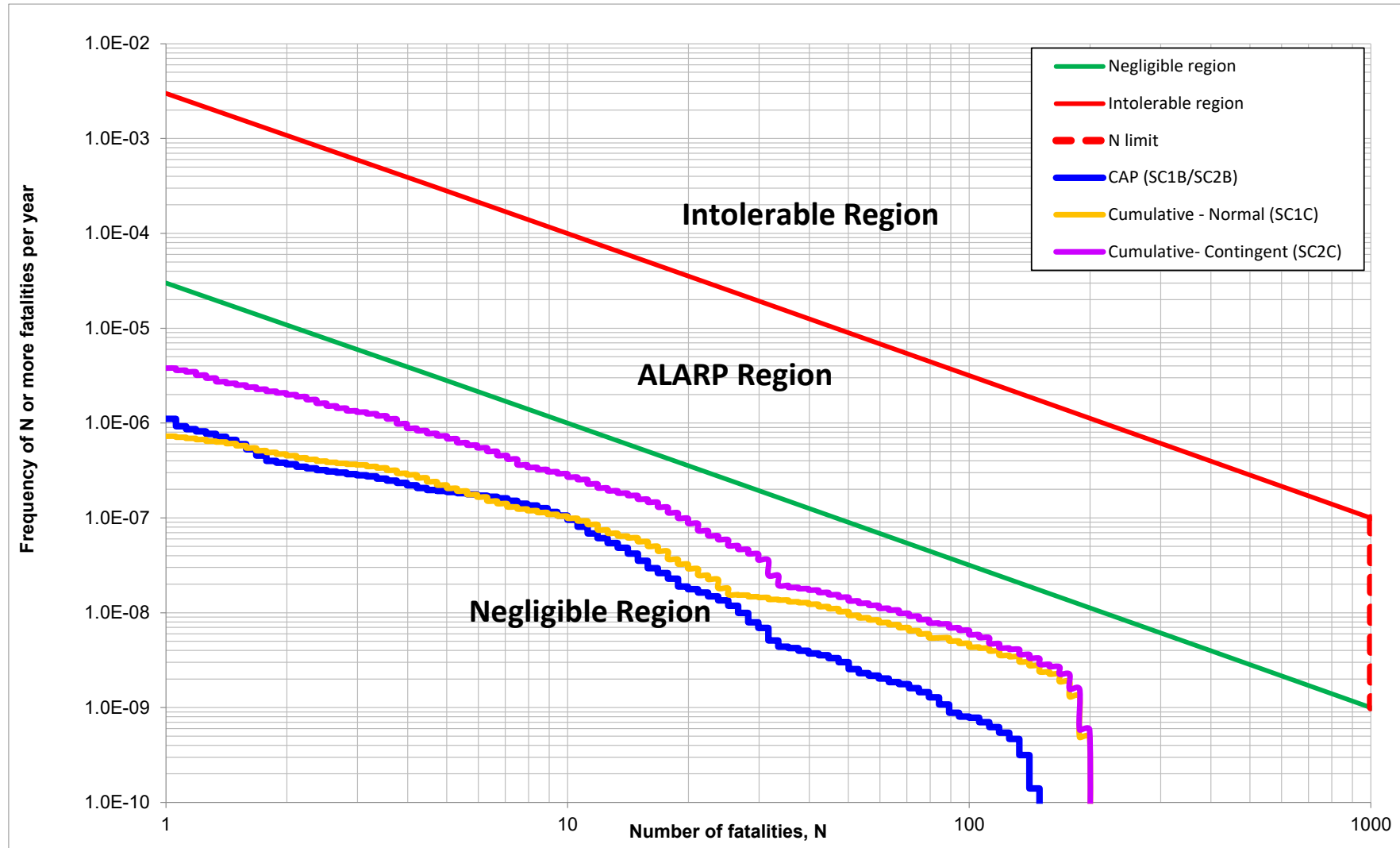


Table 1.2: Compliance with HIPAP 4 risk criteria

Description	Risk criterion (per year)	Risk criteria met?		Comments
		Existing CAP only	Modified facility CAP & CLP – normal and contingent cases (SC1C/SC2C)	
Individual Fatality Risk				
Sensitive uses, including hospitals, schools, aged care	0.5×10^{-6}	Yes	Yes	Contour extends past IXOM boundary but does not extend to any sensitive uses Matrville Botany Public School (Beauchamp Rd). Complies with criteria.
Residential areas and hotels	1×10^{-6}	Yes.	Yes.	Contour extends past IXOM boundary but does not extend to any residential land uses (Denison St). Complies with criteria.
Commercial areas, including offices, retail centres, warehouses	5×10^{-6}	Yes	Yes	Does not reach any commercial uses. Complies with criteria.
Sporting complexes and active open spaces	10×10^{-6}	Yes	Yes	Does not reach any open space uses. Complies with criteria.
Contained within the boundary of an industrial site	50×10^{-6}	Yes	Yes	Contour remains within IXOM boundary Complies with criteria.
Injury/Irritation Risk				
Injury (residential areas only)	10×10^{-6}	Yes	Yes	Contour extends past IXOM boundary to the south and west but does not extend to any residential or sensitive uses Matrville Botany Public School (Beauchamp Rd) to the east. Complies with criteria.

Description	Risk criterion (per year)	Risk criteria met?		Comments
		Existing CAP only	Modified facility CAP & CLP – normal and contingent cases (SC1C/SC2C)	
Irritation (residential areas only)	50 x10 ⁻⁶	Yes	Yes	Contour extends past IXOM boundary to the south and west but does not extend to any residential or sensitive uses Matraville Botany Public School (Beauchamp Rd) to the east. Complies with criteria.
Societal Risk				
Populations external to IXOM site	HIPAP 4 (2011) criteria	Yes	Yes	Max N < 1000. Results curve within negligible area for all cases.

Figure 1.2: Societal risk – Population includes additional 40/hectare former BIP operations



2. INTRODUCTION

2.1. Background

IXOM operates a Chloralkali Facility located at the Botany Industrial Park (BIP). Chlorine and caustic soda are currently manufactured in the Chloralkali Plant (CAP) and all chlorine is used in downstream product plants. These plants plus various storages comprise the Chloralkali Facility. The Chloralkali Facility is a Major Hazards Facility (MHF) under New South Wales (NSW) regulations.

IXOM is proposing to construct a Chlorine Liquefaction Plant (CLP) at the existing Chloralkali Facility which will liquefy a portion of the overall chlorine produced by the CAP for filling into road tankers, drums or cylinders.

The NSW Department of Planning, Housing and Infrastructure (DPHI) has issued Secretary's Environmental Assessment Requirements (SEARs) for the project which require IXOM to assess the offsite, onsite and transport risk associated with the CLP project. IXOM retained Sherpa Consulting Pty Ltd (Sherpa) to carry out the risk analysis study.

This report documents the Quantitative Risk Analysis (QRA) inputs and results.

2.2. Objectives

A requirement of the SEARs is to perform a QRA in accordance with HIPAP 6 to determine if the cumulative risk from the existing CAP and proposed CLP complies with qualitative and quantitative HIPAP 4 risk criteria as follows.

'Include a Quantitative Risk Analysis (QRA) in accordance with the Department's Hazardous Industry Planning Advisory Paper No. 6, 'Hazard Analysis' demonstrating that the existing chloralkali plant (CAP) with the proposed chlorine liquefaction plant (CLP) ('the modified facility' up to DA 35/98-Mod-6) complies with both the qualitative criteria, in particular the consideration of site location and technology, and the quantitative criteria in the Department's Hazardous Industry Planning Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning'.

This QRA report aims to address the 'Hazards and Risks' component of the SEARs. Additional details of specific SEARs requirements in relation to hazard and risk and the location in this report where they are addressed is provided in APPENDIX A.

2.3. Scope

The study covers the proposed CLP operations and new equipment associated with the CLP including:

- new compressed chlorine vapour piping from CAP to CLP
- CLP process equipment including:
 - chlorine liquefier and liquid chlorine separator,

- two chlorine storage tanks (one is a standby tank kept empty for use in an emergency),
- chlorine treatment facility including degas reactor and chlorine scrubber, and
- loading operations (chlorine tanker loading, cylinder and drum filling).

The existing CAP and downstream product plants are included in the cumulative risk assessment.

Results for both offsite risk and onsite risk are included in this report.

2.4. Study approach

The QRA has been conducted and reported in accordance with the NSW DPHI Hazardous Industry Planning Advisory Paper No. 6 *Hazard Analysis 2011* (HIPAP 6), Ref [1]. The key stages of the study are as follows:

- Potential hazardous incidents were identified based on proposed facility and operations.
- Quantitative consequence modelling for toxic releases was carried out.
- Frequencies of potential hazardous incidents were estimated from industry statistical data bases supplemented by event tree analysis as required.
- Quantitative risk calculations were completed, using the identified hazardous incident scenarios and recent meteorological and population data as inputs.
- Individual risk contours (fatality, toxic injury and irritation) and a societal risk (FN curve) were generated from the risk model and compared against the risk criteria in HIPAP 4 *Risk Criteria for Land Use Safety Planning*, Ref [2].
- Onsite risk to the IXOM operators was estimated quantitatively using the QRA model as a basis and compared to UK Health and Safety Executive (HSE) worker risk tolerability criteria suggested in *Reducing Risks, Protecting People – HSE’s Decision-Making Process* (R2P2), Ref [3].
- Other SEARs requirements related to hazards and risks were addressed.
- A QRA report was prepared for submission to the NSW DPHI as part of the overall planning application.

2.5. Links to MHF regulatory requirements

As an MHF, IXOM submits a periodic Safety Case report for the CAP to SafeWork NSW with the latest MHF licence renewal application occurring in 2024.

The objective of the MHF Safety Case is to demonstrate that the risks associated with an MHF have been eliminated, or if this is not achievable, adequate controls must be implemented to reduce the risk ‘So Far As Reasonably Practicable’ (SFARP). A Safety

Management System (SMS) must be in place that ensures the effectiveness and reliability of the controls that reduce the risk SFARP.

The QRA report is not intended to meet the full requirements of an update to the MHF safety assessment and is not intended as a demonstration the risk have been reduced SFARP. However, the QRA has been developed taking into account the hazard studies carried out as part of the project as applicable to the stage of the project to develop the QRA scenarios for modelling and account for control measures applicable at the design stage.

An update to safety assessment included in the MHF Safety Case will be required prior to the commissioning phase of the CLP. Aspects of the QRA (for example consequence modelling, cumulative risk assessment) will also be used to inform updates to the MHF safety assessment included in the MHF Safety Case at the relevant time in the project schedule.

2.6. Exclusions and limitations

The exclusions and limitations that apply to this report are summarised in Table 2.1.

Table 2.1: Exclusions and limitations

Item	Scope area	Exclusion/limitation
1	Offsite risk – boundary	The risk from the facility has been assessed against the IXOM boundary (not the BIP boundary).
2	Onsite risk	The study only assesses the risk to IXOM operators. Populations on the other areas of the BIP are treated as ‘offsite’ hence part of societal risk assessment
3	Transport risk	The Denison St Dangerous Goods (DG) transport risk results are not included in this report. Transport risk associated with the CLP project is provided in a separate report (Sherpa document reference 21838-RP-003).
4	Consultation outcomes	This report does not include the consultation outcomes with relevant bodies in relation to the QRA or other aspects relating to hazard and risk. A consultation summary is reported as part of the overall planning application.
5	Escalation	No potential events in the existing plants on the BIP were identified as affecting the CAP or CLP. Genos and Indorama, which previously posed explosion hazards, have now been shut down and hazardous inventories removed.
6	External events	External events include earthquakes, plane crashes, floods etc. Even allowing for the airport a few kilometres away, these are very low frequency events in the Botany area. These are not quantified in the QRA.

Item	Scope area	Exclusion/limitation
7	IXOM existing CAP facility	<p>The scenarios associated with the existing plants within the Chloralkali Facility were initially based on the most recent QRA prepared to comply with the CAP conditions of consent (Condition 11 DA 35/98 consolidated consent Mods 1 to 4) and submitted to DPHI in December 2024, Ref [4]. Various updates have been made to the modelling inputs or risk assessment methodology for the CAP in consultation with DPHI up to June 2025, Ref [5], and an updated CAP report (CAP QRA 2025) will be submitted to DPHI in July 2025 to close out comments.</p> <p>Note that the CAP QRA report itself is not in the public domain as it is not part of a planning application.</p>
8	Environmental risk	<p>The main concern relating to environmental risk from accident events is generally with effects on whole systems or populations. Whereas any adverse effect on the environment is obviously undesirable, there are no materials handled at the chlorine and product plants or proposed CLP with persistent toxicity or bioaccumulation issues. Environmental risk is excluded from the scope of the QRA.</p>
9	MHF considerations (including: SFARP demonstration, control measure adequacy)	<p>A description of relevant project design decisions and engineering control measures included in the design to date is included in the QRA report as per Table 3.2 and APPENDIX G. However, the QRA does not include detailed adequacy assessments of control measures or details of assurance of their integrity via the relevant facility operator's SMS. This will be covered as part of the overall update to the MHF Safety Assessment at the relevant time in the project schedule.</p>
10	SMS	<p>IXOM operates under an SMS that covers the elements of HIPAP 9 <i>Safety Management Systems</i> and has been reviewed as part of the MHF Safety Case and by various internal and external audits. The QRA does not attempt to quantitatively account for the quality of the SMS. This is because data used to estimate event frequencies in a QRA is based on historical information from a variety of plants and processes with different standards and designs. It is assumed that these generic failure frequencies apply to installations which have safety management systems corresponding to 'industry practice'. This assumption is believed to be conservative in that it will overstate the risk from modern, well-managed installations.</p>
11	Emergency planning	<p>The QRA does not provide details of emergency response to a chlorine release. A detailed emergency plan will be required to meet regulatory obligations prior to commissioning.</p>

Item	Scope area	Exclusion/limitation
12	Cessation of Indorama and Qenos operations 2024	<p>In 2024, Qenos and Indorama shut down operations at the BIP and have confirmed that hazardous materials have been removed with demolition commencing (see https://botanyindustrialpark.com.au/updates/alerts/)</p> <p>This means:</p> <ul style="list-style-type: none"> • The overall BIP QRA risk contours last submitted to DPHI in Nov 2024 under BIP DA 30/98 are no longer relevant and are not used as a basis of comparison in this QRA report. • Escalation effects due to potential explosions at these facilities are no longer relevant to IXOM facilities and have not been assessed. <p>Note that future potential land uses (i.e. non-hazardous industrial warehousing) have been assessed in the QRA as a societal risk sensitivity case as per Section 8.4 of this report.</p>

3. FACILITY DESCRIPTION

3.1. Location

The location of the CLP building is in the 'Block L' within the IXOM boundary, in the western area of the BIP, and to the north of the existing CAP as shown in Figure 3.2 and APPENDIX C. This location was selected as:

- separation distance to the residential area to the east along Denison St is maximised
- separation distance to the IXOM Main Admin building and existing CAP control room is maximised
- the additional extension of compressed chlorine piping from the existing CAP to the CLP is minimised
- the plot provides adequate space for the CLP within IXOM's existing leased land
- the location provides for current and future traffic flow through the overall BIP site.

3.2. Surrounding land use

The BIP site is bounded to the north by Corish Circle, the east by Denison St, the south by Beauchamp Rd and to the west by the Botany Goods railway line easement. The land around most of the BIP site perimeter is zoned commercial and industrial. The rail easement is adjacent to the CAP process area, with the BIP/rail easement fence line approximately 15 m away from the edge of the nearest process area.

The exception is land adjacent to part of the eastern boundary of the BIP, which is zoned residential, with significant residential areas along Denison Street. The nearest residential site along Denison St is approximately 200 m to the east from the main CAP chlorine process areas (lower hazard areas such as the salt heap, bulk Class 8 chemical storage tanks and some utilities are closer). On the western side, there are residential areas extending west from Stephen Rd. Banksmeadow Public School is located near Stephen Rd, about 650 m southwest of the nearest BIP boundary.

The nearest known sensitive land use is Matraville Public School, approximately 400 m to the east of the Denison St BIP boundary.

The area around Corish Circle at the northeast corner of the BIP is zoned recreational (Hensley Athletic Field), and beyond this to the north is the large commercial Eastgardens shopping complex.

The BIP land is industrial. There is no change to the BIP zoning proposed as part of the Qenos/Indorama shutdown, i.e. for the purposes of the QRA the BIP remains industrial.

3.3. CLP capacity and operating modes

The CLP will have a maximum production capacity of 50 tonnes per day but will typically operate at its turndown rate to supply liquefied chlorine in 13-tonne tankers to the NSW region.

There are two operating modes:

- **Normal operations case:** During normal operation, the CLP is operated at a 10:1 turndown (i.e. at 10% of liquefaction capacity). The produced chlorine is primarily used to fill road tanker to supply the liquid chlorine demand in the NSW region.
- **Contingent operations case:** During contingent operation, when the chlorine liquefaction plant at the Laverton, Victoria is unavailable, the Botany CLP will run at full capacity and facilitate tanker loading as well as chlorine drum and cylinder filling.

The CLP will not have a significant impact on chlorine derivative product volumes produced under normal operation as shown in Table 3.1.

Table 3.1: Chlorine usage and production rate of the Botany plant

Chlorine usage/ production rate	CAP*	HCL*	HYPO*	FERRIC*	LIQUEFACTION
Maximum, t/d	97	50	34	18	50
Minimum, t/d	40	15	6	5	5

During normal operation, the CLP will be continually monitored from the control room. It will be unattended except when:

- a tanker is being moved to or from the building,
- a tanker is being connected or disconnected,
- during routine inspection, or
- during maintenance or for handling of chlorine drums and cylinders.

Neither the operator nor the driver is expected to be in attendance for the duration of the filling of a tanker.

The plant will operate up to full capacity only in the unlikely event that the Laverton CLP became non-operational for an extended period to supply the national liquefied chlorine demand. Chlorine gas for derivative product requirements would be less available through this period. In this contingent operation mode, the Botany CLP will be used to degas and fill 920 kg chlorine drums and 70 kg, and 33 kg chlorine cylinders in addition to 13-tonne chlorine tankers.

In normal operation, the space required for drum and cylinder filling functions will be used to store drums and cylinders that are currently stored in an outdoor storage area. In the contingent operation mode, internal storage of drums and cylinders will be restricted and IXOM will use its supply chain capacity and existing licensed chlorine container storage locations across Australia to continue to handle and store containers.

3.4. Plant layout

A plant layout diagram for normal operation is provided in Figure 3.4. Layout diagrams for both modes are provided in APPENDIX C.

3.5. Chlorine liquefaction plant details

The CLP will be designed from proven equivalent IXOM processes consistent with industry good practices guidance for chlorine liquefaction. It will comprise:

- liquefaction unit comprising a shell and tube heat exchanger to liquefy chlorine
- ammonia refrigeration system with intermediate refrigerant (most of this system will be located outside of the containment building as it will not contain chlorine)
- chlorine separator to separate liquefied chlorine from any uncondensed chlorine gas and other incondensable gasses
- two 50-tonne chlorine stock tanks to store up to 50-tonne of liquefied chlorine at -34°C and atmospheric pressure. One tank will be kept in service and the other kept empty on standby
- two chlorine storage pumps to distribute chlorine for tanker and container filling
- vacuum chlorine catch pot to ensure any liquefied chlorine from filling functions will pass the absorption system as gas
- chlorine tanker loading station
- two chlorine drum filling stations
- two chlorine cylinder filling stations
- eight chlorine drum degassing stations
- twelve chlorine cylinder degassing stations
- degas reactor to absorb any uncondensed chlorine gas and other non-condensable gases from the separator and intermittent liquefied chlorine and chlorine gas from chlorine container filling and degassing functions. The degas reactor will be located outside of the containment building as it will contain minimal chlorine. The vent from the degas reactor will be directed to the containment building scrubbing system.
- containment building scrubbing system to absorb any fugitive emissions of chlorine in the building and to provide secondary absorption of any chlorine gas from storage and container degassing and filling functions.

3.6. Process description

A block diagram is shown in Figure 3.3. Process Flow Diagrams (PFDs) are provided in APPENDIX C.

The process is summarised below:

- The liquefaction unit is responsible for receiving chlorine gas from the CAP compressor and liquefying it. It also separates the liquid chlorine from non-condensable gas components, which mainly consist of carbon dioxide, nitrogen, hydrogen and oxygen.
- Two 50-tonne chlorine storage tanks (designed as pressure vessels) will operate in a duty/standby arrangement with one always kept empty. These tanks are insulated and self-cooled via chlorine evaporation. The tanks will be fitted with:
 - vents to allow transfer of gaseous chlorine to the degas reactor, and
 - two liquid chlorine transfer pumps (duty/standby) to provide recirculation flow and transfer liquid chlorine to tanker loading bays as well as drum and cylinder filling units. Pumps will be configured to allow remotely operable transfer to the standby tank in the case of failure of the online tank
- The tanker filling and production units will supply liquid chlorine to tankers, drums, and cylinders, as well as degassing of returned drums and cylinders.
- The degas reactor system absorbs chlorine gas from several sources by contact with sodium hypochlorite solution. Vent gas from the liquefier and chlorine storage tank are absorbed in the degas reactor scrubber. Sodium hypochlorite solution is used as the motive fluid for an ejector in the system to remove chlorine from piping systems used to fill and degas chlorine containers and to remove chlorine in cylinders that need to be degassed. The degas reactor system also efficiently removes liquid chlorine from drums before residual chlorine is degassed. The system discharges sodium hypochlorite product to storage in the CAP.

The scrubber is continuously running. The scrubbing system prepares dilute caustic for the degas reactor system. It scrubs vent gas from the degas reactor to ensure chlorine concentration is below 1 part per million (ppm) during normal operation. In case of a chlorine gas leak in the building, it's capacity will extend to scrub chlorine from the air in the building to below 25 ppm before discharging the air to atmosphere.

3.7. Chlorine liquefaction plant building

3.7.1. Overview

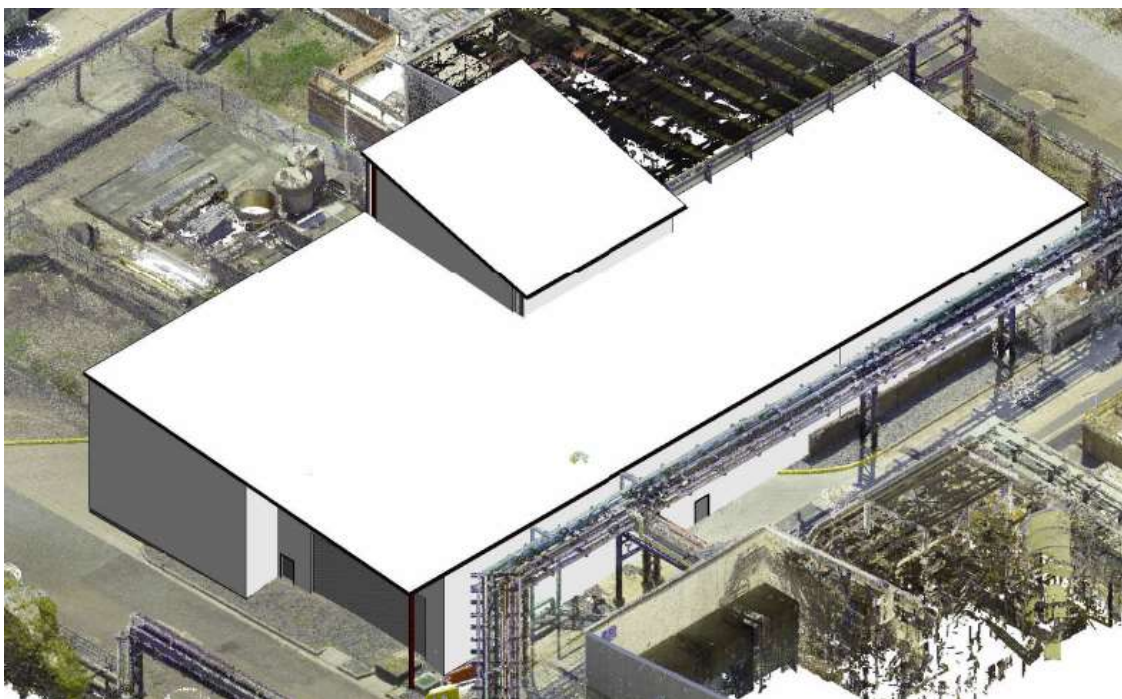
All handling, storage and packaging of liquid chlorine will be managed within a containment building. An isometric view of the CLP building is shown in Figure 3.1.

The CLP building has two roller doors on the west and east sides for vehicles entering/exiting the building, and four self-closing pedestrian doors located at each side of the building for operator access. Doors are designed to minimise air leakage. The roller doors only open to allow for vehicle entry and exit and remain closed at all other times.

The CLP building has a footprint of 1,258 m². The building wall is approximately 7 m high on the southeast side and ranges from 10 m to 15 m high on the other sides of the building. The total volume of the building is 11,402 m³.

Liquefaction plant equipment and chlorine storage tanks are located on the northwest side of the CLP Building. On the southeast side of the building, there is a double-line driveway to facilitate chlorine drum and cylinder (container) loading/unloading operations from the transport vehicle. The building space on the west side of the building is used for either container storage or chlorine container degas, filling and storage depending on the plant operation mode. For normal operation, either full or empty containers, are stored at the west side of the building. For contingent operation, the west side of the building shall have the container packing equipment installed. Refer to APPENDIX C.

Figure 3.1: Isometric view of the Chlorine Liquefaction Plant building



3.7.2. Building ventilation system

The building ventilation system has been designed to comply with Australian Standard (AS) 1668.1-2015, AS 1668.2-2012 and AS 2927-2019. It will provide 39,960 m³/hr to meet the most onerous standard requirement. The system consists of motorised inlet air louvres, dedicated exhaust ducting, a centrifugal exhaust fan, a motorised damper at the fan intake and an outlet stack. The fan draws air from outside the building, through the motorised inlet air louvres and discharges the air through the outlet stack.

The fan will normally be running to provide ventilation of the building except when it is manually stopped or when chlorine is detected in the building. A motorised air damper is provided at the fan intake. The damper will close when chlorine is detected in the

building. Orange flashing beacons will be mounted inside and outside the building at each access point to indicate when the ventilation system is not in service and to initiate an evacuation of the building.

Inlet air louvres are located in the upper section of the south-east building wall. The louvres will provide weatherproofing of the building and be fitted with vermin proof mesh. The inlet air louvres are normally in the open position but will close if chlorine is detected in the building and if the scrubbing system is not in operation.

The exhaust ducting will extend inside the building and extract air from the building close to ground level in the northern side of the building. The exhaust air extraction points will be regulated to provide even flow through each point. This arrangement will promote even air changeover across the building.

Control of the exhaust fan, the damper at the fan inlet and the motorised inlet louvres and all associated monitoring of the ventilation systems including chlorine gas detection is conducted at a Local Control Panel (LCP) outside of the building and is interfaced with the site Distributed Control System (DCS) system.

The benefits of such a design are:

- the damper on the fan suction will shut off immediately if chlorine gas is detected within the building retaining chlorine in the building
- lower risk of chlorine release through the inlet air louvres as the louvres are located away from potential chlorine leak points.

The makeup air louvres fail close. A chlorine gas leak would be contained in the unlikely event that the scrubbing system is not available.

3.7.3. Liquefaction Building Scrubber (LBS) System

The LBS system is provided to scrub chlorine gas from the building if required.

The LBS system has capacity for all chlorine release scenarios including the very unlikely events of a storage tank or road tanker catastrophic failure. The system uses the motorised air inlet louvres and also consists of dedicated exhaust ducting with dampers, a packed column served by redundant fans and pumps and an outlet stack. If the system must operate to attend to a chlorine gas leak in the building, a fan draws air from outside the building, through the motorised air inlet louvres, into the exhaust ducting through dampers, across the packed column, where any chlorine in the gas is absorbed, and then discharges the air through the outlet stack.

The LBS uses dilute sodium hydroxide solution in a packed column to absorb chlorine. The system has redundant analysers to continually monitor the capacity of the sodium hydroxide solution to absorb chlorine and to allow for the solution to be replaced as required.

The LBS is served with redundant pumps and fans in a duty/standby arrangement. The pumps provide recirculation of sodium hydroxide solution across the column. The fans induce a draft of gas through the column. Power to scrubber pumps and fans are supplied from separate supplies and those supplies are backed up by emergency generators.

The LBS has exhaust ducting that is independent of the building ventilation ducting. The ducting is made from PVC and is connected to the inlet of the LBS. The LBS ducting extends to potential chlorine leak points in the building and will be installed close to grade. At each extension, a damper is installed. The dampers are normally closed and will fail open. The dampers open automatically when chlorine is detected by sensors located near the dampers. The exhaust ducting also contains a damper in the common section of duct upstream of the LBS outside of the CLP Building. This damper will also open automatically when chlorine is detected by sensors located near the dampers. This damper is normally closed and will fail closed to contain a chlorine leak in the building if the LBS is not available. The state of the damper will be able to be manipulated from the field as required. Red flashing beacons will be mounted inside and outside the building at each access point and a siren will call attention to when chlorine is detected in the building to initiate immediate evacuation. The dampers can also be opened from the DCS or from hand switches on a control panel outside the building. When a damper opens, air is drawn into the through the building, through the associated extension point, and into the LBS.

The LBS is always in operation. The primary function of the LBS system is to always be available to scrub a potential chlorine gas leak in the CLP building. The LBS also receives scrubbed vent gas from the degas reactor when any processes upstream of the degas reactor are in operation.

The LBS system supplies sodium hydroxide solution to the degas reactor and both the inventory and quality of sodium hydroxide solution is maintained in the LBS system through the addition sodium hydroxide solution from storage through a redundant supply system.

Some benefits associated with the LBS system include:

- full redundancy for LBS fans and pumps under a power failure or a switch room failure event
- the LBS is always available to immediately attend to a chlorine gas leak as it will always be in operation
- air flow through the LBS system is restricted in normal operation to minimise the formation of carbonate in the scrubber solution and ensure scrubber performance.

The scrubber solution is continuously replenished in normal operation when the degas reactor is in service to manage the formation of carbonate in the scrubber solution.

3.8. CLP interface with CAP

The CAP is an existing MHF which manufactures gaseous chlorine and caustic soda and then uses the chlorine to make hydrochloric acid, ferric chloride, and sodium hypochlorite in downstream product plants. Liquid chlorine (from IXOM's Laverton plant) is also stored in drums, cylinders and a road tanker at the CAP.

3.8.1. Location and layout changes

The only change to the existing CAP layout is that the existing sodium hypochlorite tanker loading facility (located on Block L) will be moved north to the existing outdoor chlorine drum and cylinder area. Drums and cylinders and also the parked tanker will be relocated to inside the CLP containment building. An outdoor drum and cylinder storage area is not provided.

3.8.2. Production and process changes

There will be no changes to the overall production rate from the CAP, up to 50% of the production rate that is currently used by existing products plant will be able to be diverted to the CLP.

The CLP sources two DGs from the CAP and supplies one DG back to the CAP as per the following interfaces :

- Chlorine gas is sourced from the main supplying the hypo plant which runs in the pipe bridge alongside the new building.
- Sodium hydroxide (50% /w sodium hydroxide (NaOH) solution) is sourced from one of two 1,800 tonne storage tanks on site through redundant pumps and dedicated piping.
- Sodium hypochlorite (13.5% /w av. chlorine (Cl₂) solution) is transferred from the liquefaction plant back to the Sodium Hypochlorite Storage Tanks in the CAP.

The plant will also source various utilities from the site including electricity, nitrogen, compressed air, towns water and cooling water. Trade effluent and stormwater will be discharged into existing systems.

The proposed development will not affect the maximum production rate of the CAP, and no modification is required to the existing CAP process equipment i.e. the only changes are the pipework interfaces as mentioned above.

Figure 3.2: Site location

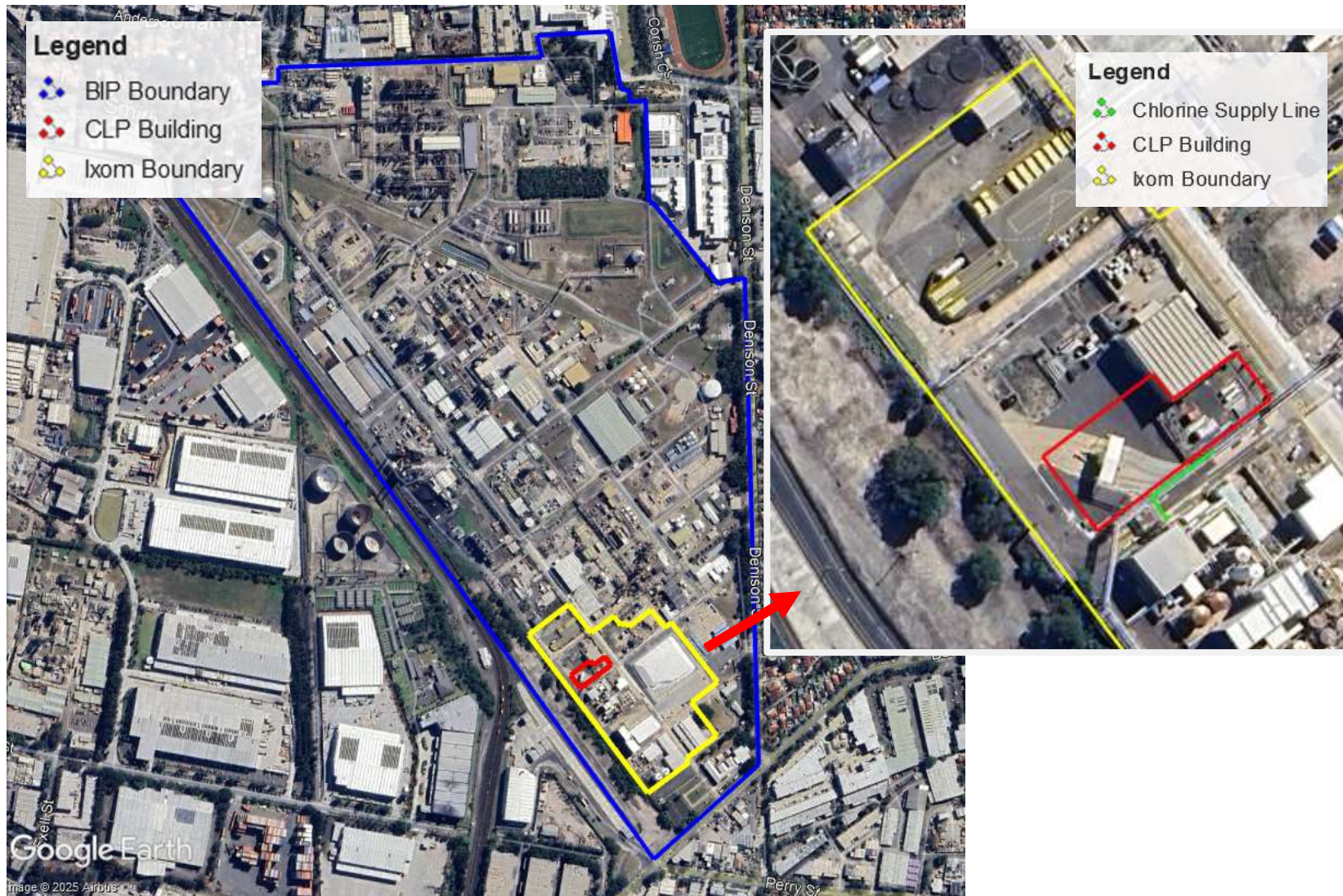


Figure 3.3: CLP block diagram

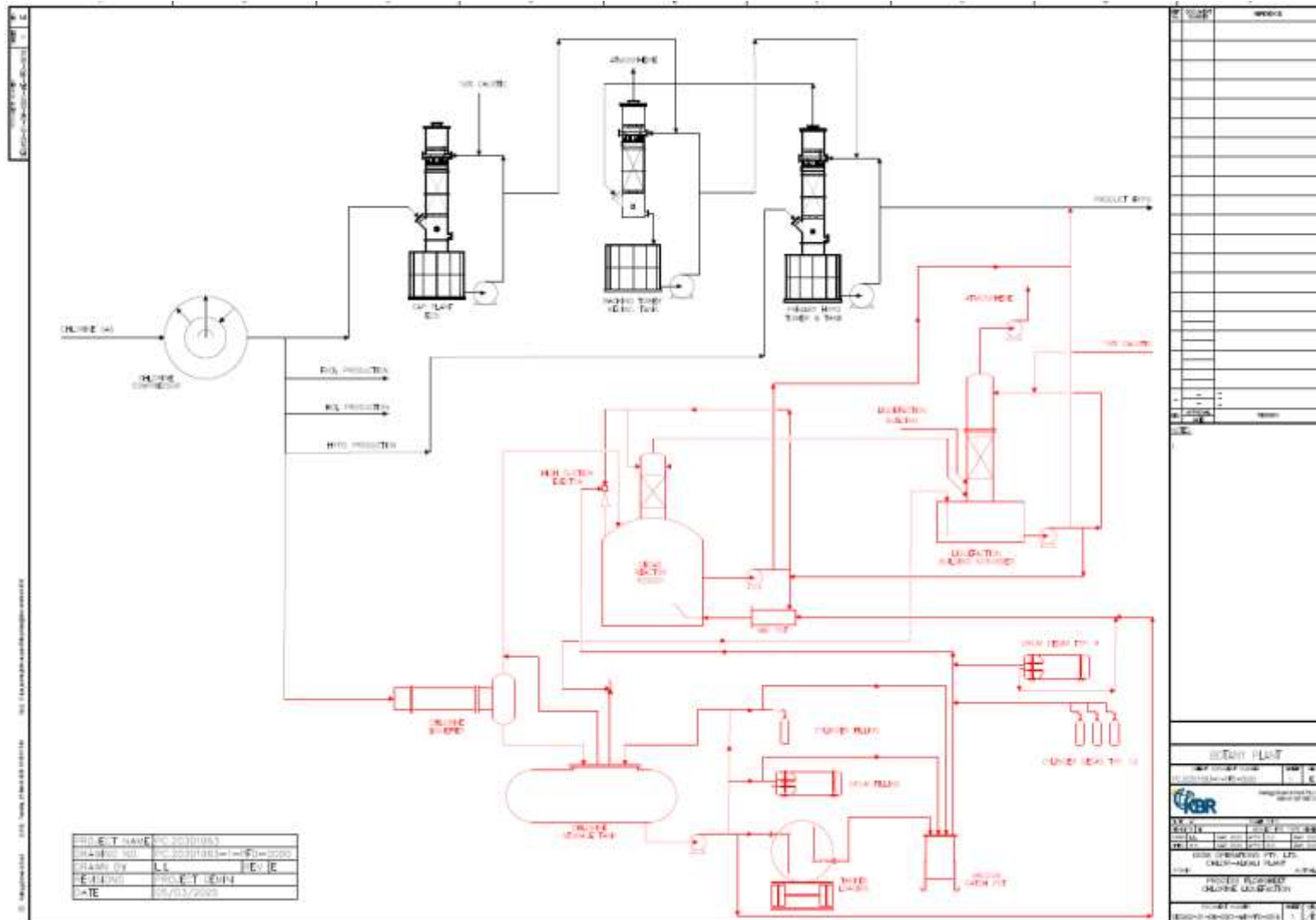
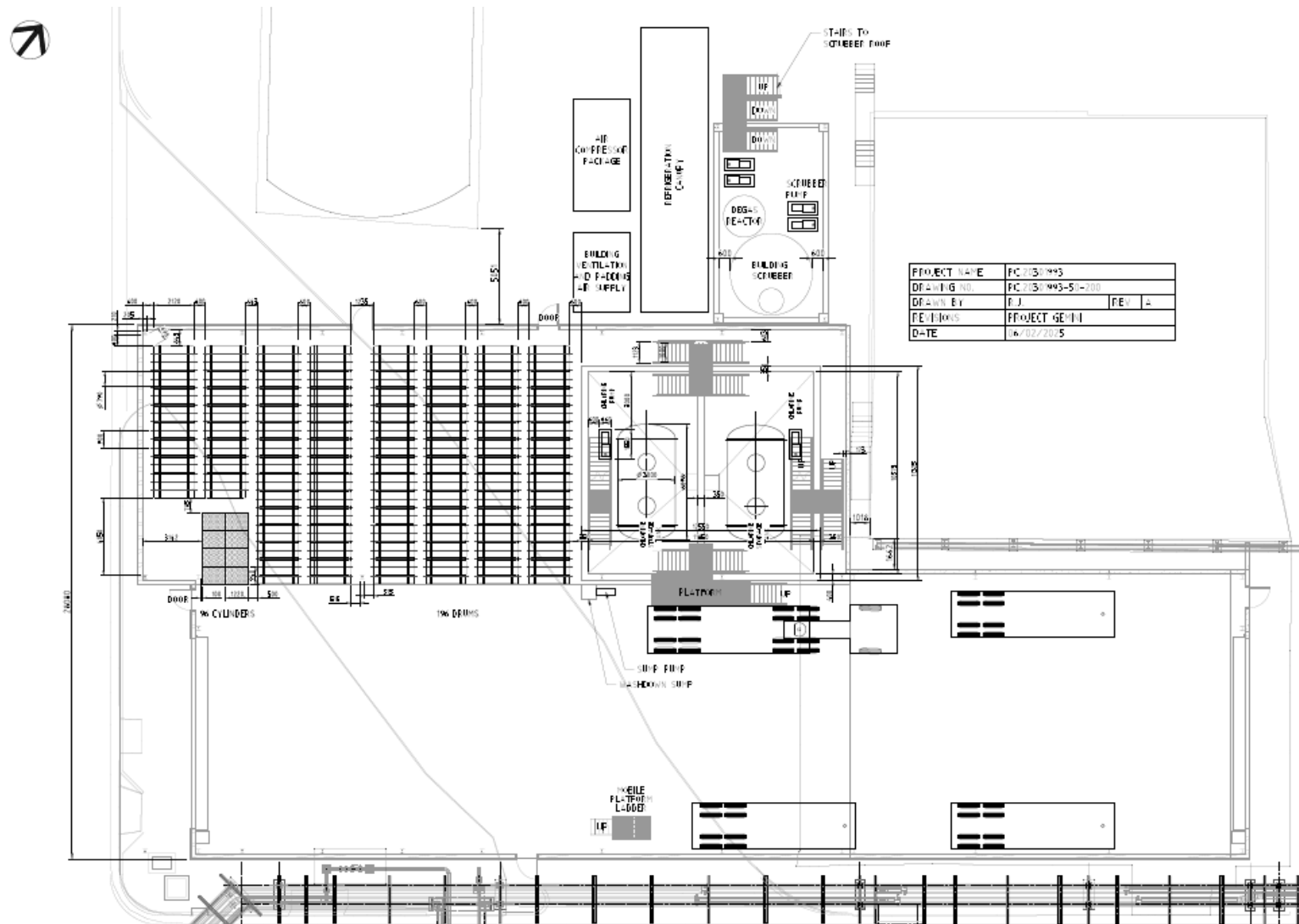


Figure 3.4: CLP building layout



3.9. Risk minimisation

Major Incidents (MI) scenarios associated with the CLP are typically chlorine releases. A summary of overall high level design choices that minimise risk of such events is provided in Table 3.2.

The overall intent of the design with respect to risk is to:

- ensure that the cumulative offsite individual risk (i.e. including the CLP) is not materially higher than from the current CAP operations, and
- ensure that the worst-case consequence is not larger than from the current CAP operations.

The following approach is also generally consistent with the HIPAP 4 qualitative risk criteria as follows with further detail provided in Table 9.2:

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

Note that there are also numerous engineering controls including Safety Integrity Level (SIL) rated instrumentation which will be further defined as part of the detailed design.

The approach is consistent with the intent to minimise risk SFARP as required under the MHF legislation and the design choices summarised in Table 3.2 will provide input to the demonstration required as part of the MHF Safety Case.

Table 3.2: Design choices to minimise risk

Design	Risk reduction hierarchy	Description
Development area – Block L within BIP selected	Substitute	Selection of site within BIP to ensure: <ul style="list-style-type: none"> • separation distance to the residential area along Denison St is maximised (other options were closer to Denison St) • separation distance to the IXOM Main Admin building and CAP control room is maximised. • extension of compressed chlorine piping from the existing CAP to CLP is minimised
Refrigerated storage condition for liquid chlorine	Eliminate/ Substitute	Replaces pressurised ambient temperature storage conditions with low temperature atmospheric pressure conditions. Note that storage tanks are still designed as pressure vessels eliminating loss of refrigeration as a cause of loss of containment. This minimises the flash fraction and hence scale and severity from a loss of containment of liquid chlorine.
Minimisation of bund surface area	Engineering control (passive)	Individual bunds are designed for each chlorine storage tank to contain leaked chlorine. The bund area is minimised to operationally practical size to reduce the evaporation rate from a loss of containment of liquid chlorine allowing building scrubber to be designed to practical scale. Refer to Section 6.3 for assessment of surface area on evaporation rate and associated effect distances. Bund coating will be selected at detailed design phase to minimise heat inleak/evaporation rate.
Minimisation of bulk Chlorine inventory and provision of spare empty bulk tank	Engineering control (passive)	Bulk inventory storage minimised to operationally practical level of 1 day production. Minimises the scale of the loss of containment that needs to be contained by building. Spare tank provides redundancy to transfer material and contain a leak in the event of vessel or tanker failure in the building. Pumps will be configured to allow remotely operated transfer between tanks
Containment building large enough to carry out all liquid storage and handling activities and sized to contain flash fraction of liquid chlorine scenarios including filled road tanker after warming up	Engineering control	The chlorine storage tanks, pumps and associated facilities will be located inside a large containment building. The design intent is that leaks can be fully contained (i.e. no significant openings in building that cannot be closed, designed to withstand both pressure and vacuum effects for worst release of chlorine) and then directed to a high reliability scrubber at a manageable rate to treat chlorine to a safe level before release via the scrubber stack. There is also an opportunity to re-locate the existing chlorine drums from outdoor storage area and the parked road tankers will remain inside the containment building with the intent of reducing the risk to below the current CAP risk level. The risk reduction effect of the containment building has been quantified in the risk model with an allowance for 5% ‘unavailability’ as per Section F2.

Design	Risk reduction hierarchy	Description
Building scrubber	Engineering control	<p>Highly reliable continuous scrubber provided:</p> <ul style="list-style-type: none"> • continuously running on low speed, ramp up fans on Chlorine detection (i.e. scrubber does not need to start on chlorine detection and if fans do not ramp it up this affects the rate of contaminated air treated it does not affect the outlet concentration) • 3 x 100% fan/circulation pump sets (independent power supplies including back up generator) • continuous supply of caustic (without top more than 1 hour of containment capacity) • continuous removal of chlorinated caustic (capacity provided at Hypo Storage Tanks). <p>Note that the option of a batch scrubber was not selected to eliminate the risk of the scrubber not being able to start on demand. The advantage to locating the CLP at the existing CAP is that there is a readily available caustic supply available, and the hypo generated the scrubber can be directed to the Hypo Plant storage tanks meaning that a continuously running scrubber is technical feasible.</p>
Chlorine detection and automatic isolation	Engineering control	<p>Multiple chlorine detectors will be installed onsite at various locations. In case of detection of chlorine, the automatic isolation will be activated to isolate the facility, and the operations will be immediately stopped. This will minimise the quantity of chlorine released. The scrubber fans will also ramp up automatically to scrub chlorine from the vent gas.</p>
Intermediate non-hazardous refrigerant for refrigeration package	Substitute	<p>To eliminate cross contamination and nitrogen trichloride formation. Prevents any interaction between ammonia (refrigerant) and chlorine in liquefaction building and avoid generation of nitrogen trichloride, an intermediate refrigerant (carbon dioxide) will be used in the refrigeration unit. The ammonia refrigeration unit, which contains limited inventory, is located outside the CAP building with no direct contact with chlorine. This approach also minimises the inventory of ammonia required</p>

3.10. Abnormal event control philosophy

While all equipment in the CLP is equipped with control and monitoring systems to prevent Loss of Containment (LOC) events, the CLP design also includes safeguards to mitigate the potential consequences. The controls are summarised in APPENDIX G (Hazard Identification table). The controls implemented in the design are based on good industry practices published by chlorine industry associations (e.g. The Chlorine Institute, Euro Chlor).

In event of a chlorine release within the CLP, the key control to mitigate offsite impacts is the implementation of containment building and scrubber system.

- The building is a physical barrier which confines any chlorine in air to within the building and obstructs and contains toxic gas dispersion. The building has no significant openings that cannot be closed both locally and remotely from the CAP control room.
- The scrubber system maintains a negative pressure within the building. A fan draws air from outside the building, through the motorised air inlet louvres, into the exhaust ducting through dampers, across the packed column, where any chlorine in the gas is absorbed, and then discharges the air, with a chlorine content less than 25 ppm, through an elevated outlet stack.

The containment building in combination with a reliable scrubber system ensures that the toxicity level of gas emissions due to a LOC from process equipment primary containment would be below injurious levels.

The design basis of the scrubber is provided in Table 3.3.

Table 3.3: Scrubber design summary

Parameter	Value
Column dimension (L x W x H)	1.3 m x 1.3 m x 5 m
Stack height	18.7 m
Venting gas flowrate (emergency condition)	10,000 m ³ /hr
Design case chlorine in inlet gas	4,200 kg/hr ^(a)
Target chlorine concentration in discharge ^(b)	Less than 1 ppm (normal operation) Less than 25 ppm (chlorine leak event)
<p>Note:</p> <p>(a) The scrubber design accommodates both the rupture of a chlorine tanker and the rupture of a stock tank. The scrubbing system has capacity to scrub the maximum liquid chlorine inventory (i.e. 50 t).</p> <p>(b) Consequence modelling for release of equivalent flowrate Cl₂ under design conditions when treating a leak (i.e. 25 ppm in 10000 m³/h air is 0.0002 kg/s Cl₂) shows concentrations > Acute Emergency Guideline Level (AEGL) 2 are limited to less than 10 m from the stack and remain elevated 17 m above ground level. These scenarios are not included in the QRA as they have no effect on fatality, injury or irritation risk at receptor heights of 1.5 m.</p>	

4. STUDY BASIS AND ASSUMPTIONS

4.1. Overview

The risk assessment requires multiple inputs and assumptions. The key inputs to the study are provided in the following sections. An overall assumptions register is provided in APPENDIX B which summarises the approach to key assumptions, together with commentary on the sensitivity and level of conservative in the assumptions.

Broadly the QRA assumptions are conservative in that inventories and throughputs are assumed to be at the upper limit all of the time. A best estimate approach which reflects known conditions, data or operations is typically adopted for assumptions where data is available, e.g. meteorological conditions, population data, frequency estimates.

4.2. Inventory and throughputs

The liquid chlorine inventory for the current operations as well as the proposed CLP is summarised in Table 4.1. Throughputs are summarised in Table 4.2.

Table 4.1: Chlorine inventory QRA basis

Product	Basis – current CAP ^(a,b,c)	Basis – CAP including CLP ^(d)
Stored Cylinders (70 kg) (ambient conditions)	100 cylinders Outdoor storage area Assumed present 100% of time.	100 cylinders Inside liquefaction building Assumed present 100% of time.
Stored Drums (920 kg per drum) (ambient conditions)	200 drums Outdoor storage area Assumed present 100% of time.	200 drums Inside liquefaction building Assumed present 100% of time.
Bulk chlorine tanker (13 t) (ambient conditions)	1 parked tanker Outdoor area 50% of time as per conditions of consent	1 tanker being filled (refrigerated) 1 tanker warming up (to above 0°C) prior to going on road Inside liquefaction building
Bulk storage (refrigerated conditions)	-	2 x 50 tonne storage tank (duty/standby arrangement) Inside liquefaction building 1 tank assumed full 100% of time. The other tank is standby.
<p>Notes:</p> <p>(a) CAP in-process inventory estimated at 150 kg unchanged by CLP.</p> <p>(b) Minor extension to compressor Chlorine header (from CAP plant compressor discharge) in QRA model.</p> <p>(c) No change to CAP max production rate – CLP is simply another user as per existing products plants.</p> <p>(d) Storage is assumed to be the same, i.e. upper limit for normal and contingent cases. For the contingent case it is likely that the number of stored drums/cylinders at any one time will be lower as they will be filled to order then go to customers. This has not been accounted for in the QRA</p>		

Table 4.2: CLP chlorine throughputs QRA basis

Botany CLP Facility	Unit	Normal	Contingent	Comment
CLP maximum production rate	kg/s	0.58	0.58	Note normal case will typically be a production rate of 0.06 kg/s (10% of max capacity). Conservatively, the normal case also assumes full production rate.
Number of cylinders stored		100	100	All inside containment building.
Number of drums stored		200	200	All inside containment building.
Number of drum trucks through site	per year	484	520	
No of drums filled per year	per year	0	13520	Based on max 26 drums loaded on every truck and consistent with Laverton annual throughput. Assumes contingent mode activity occurs over full year. Conservative.
No of drums handled	per year	12584	13520	Note 2024 CAP QRA has 5650 full drums per year as actual site throughput so conservative.
No of road tankers through site	per year	156	187	
No of road tankers filled	per year	156	187	All 13 tonne tankers.
No of road tankers parked	per year	1 (50% of time)	1 (50% of time)	Road tanker is assumed to be parked inside containment building up to 50% of time as this is consistent with existing CAP conditions of consent. This is in addition to the time road tankers are present while being filled. Conservative.

4.3. Meteorological data

The meteorological data up to 2024 from Sydney Airport has been used as per Table 4.3. The detailed analysis of the data and the wind rose are provided APPENDIX D.

The following environmental conditions were used for consequence modelling:

- Ambient air temperature: 19°C
- Relative humidity: 67%.

Table 4.3: Meteorological data summary

Pasquill stability class	Wind speed (m/s)	Description
B	2.8	Daytime, moderate wind speed
D	1.7	Low wind speed, split between day and night
D	4.3	Moderate wind speed, split between day and night
D	8.4	High wind speed, split between day and night
E	3.1	Nighttime and moderate wind
F	1.4	Nighttime/early morning, low wind speed

4.4. Population data

The day and night population data used for the societal risk calculations reflects the recent changes to the BIP operations and surrounding areas as discussed in APPENDIX E. Population data for surrounding land use is largely from the 2021 Census from the Australian Bureau of Statistics (ABS). As per previous QRAs for the BIP site, the following assumptions have been applied to populations:

- 10% of the population during the day outdoors (with daytime being between the hours of 6 am to 6 pm).
- 5% of the population outdoors at night (with nighttime being between the hours of 6 pm to 6 am).

Population on the BIP site (except for the IXOM facility) is included assuming future land use populations for the Qenos and Indorama areas of the BIP as per Section 8.4.

4.5. Toxicity effects

Fatality and injury effects due to toxic exposure depends on the nature of the material, the concentration, the duration and mode of exposure. Table 4.4 summarises the toxic injury and irritation Acute Emergency Planning Guideline Levels (AEGLs) and probit equations of the form $Pr = A + b \ln(c^n t)$ used to estimate the probability of fatality based on concentration and duration of exposure for chlorine and ammonia. This approach is consistent with previous QRAs for the BIP site, additional details for chlorine toxicity are provided in APPENDIX H, Section H6.

Table 4.4: Toxic fatality, injury and irritation criteria

Material	Probit equation (ppm ⁿ min)	Threshold Concentrations (ppm)		
		Fatality (outdoor dose) Probit prediction – example ^(a)	Injury threshold AEGL 3 (10 mins)	Irritation threshold AEGL 2 (10 mins)
Chlorine (Cl ₂)	-4.86 + 0.5ln(c ^{2.75} t)	103 ppm (1% fatality 10 mins)	50 ppm	2.8 ppm
		1% fatality equivalent dose: 3.47E6 ppm ^{2.75} min	equivalent toxic injury dose: 4.7E5 ppm ^{2.75} min	equivalent toxic irritation dose: 1.69E2 ppm ^{2.75} min

Material	Probit equation (ppm ⁿ min)	Threshold Concentrations (ppm)		
		Fatality (outdoor dose) Probit prediction – example ^(a)	Injury threshold AEGL 3 (10 mins)	Irritation threshold AEGL 2 (10 mins)
Ammonia (NH ₃)	-16.286 + ln(c ² t)	1794 ppm (1% fatality at 10 mins)	2,700 ppm	220 ppm
		1% fatality equivalent dose: 3.32E7 ppm ² .min	equivalent toxic injury dose: 7.29E7 ppm ² .min	equivalent toxic irritation dose: 4.84E5 ppm ² .min
Notes:				
(a) This is an example only. QRA fatality, injury and irritation risk estimates use calculated cumulative dose based on variable concentration and variable exposure duration calculated within Riskcurves.				

4.6. Offsite risk criteria

For offsite risk Individual Fatality Risk (IFR), toxic injury and irritation risk and societal risk have been assessed against risk criteria in NSW DPHI HIPAP 4 (2011), *Risk Criteria for Land Use Safety Planning*, Ref [2].

4.6.1. Individual risk

Individual risk represents the probability of some specified level of harm (usually fatality or injury) to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken, hence is considered to cover sensitive or vulnerable individuals such as the very young, sick or elderly. NSW DPHI quantitative individual risk criteria are summarised in Table 4.5. The criteria are expressed in terms of IFR or likelihood of exposure to threshold values of heat radiation, explosion overpressure or toxicity. For this study, the relevant hazard is toxicity.

Table 4.5: NSW HIPAP 4 risk criteria

Description	Risk criteria (per year)	Applicable
Individual Fatality Risk (IFR)		
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5 x 10 ⁻⁶	Yes
Fatality risk to residential and hotels	1 x 10 ⁻⁶	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10 ⁻⁶	Yes
Fatality risk to sporting complexes and active open spaces	10 x 10 ⁻⁶	Yes
Fatality risk to contained within the boundary of an industrial site	50 x 10 ⁻⁶	Yes
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 x 10 ⁻⁶	No. (No significant flammable inventories)

Description	Risk criteria (per year)	Applicable
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}	Yes
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}	Yes
Escalation		
Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed a risk of 50 in a million per year for the 23 kW/m ² heat flux level.	50×10^{-6}	No. (No significant flammable inventories)
Incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings should not exceed a risk of 50 in a million per year for the 14 kPa explosion overpressure level	50×10^{-6}	No. (No significant explosive/ flammable inventories)

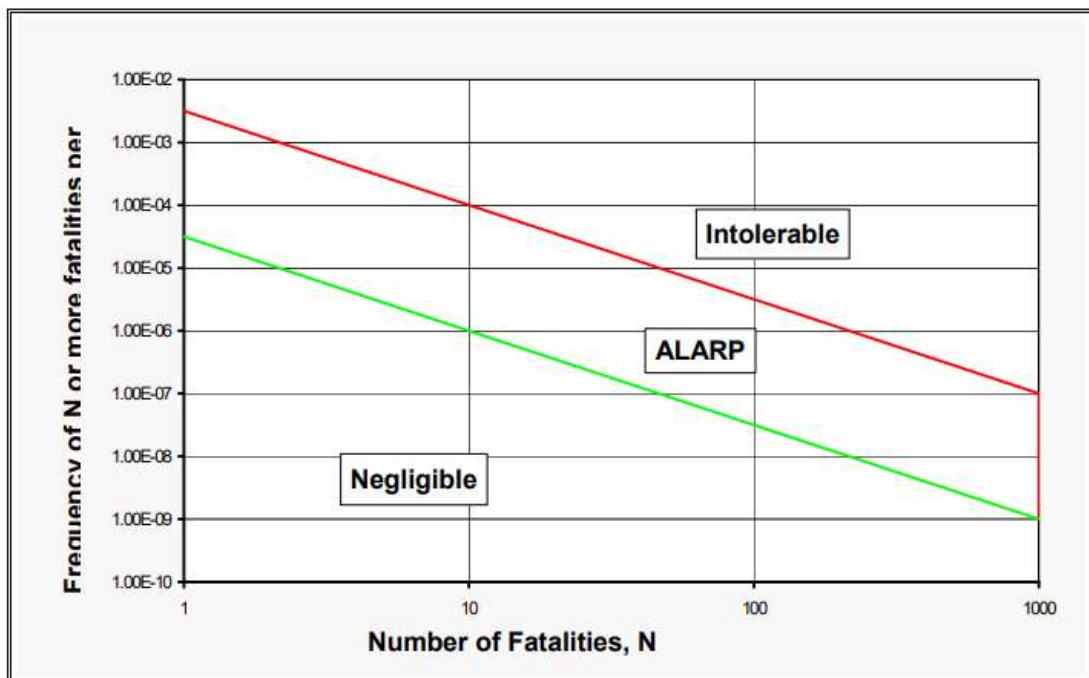
4.6.2. Societal risk

Societal risk is a measure of the probability of incidents affecting an actual population (rather than a theoretical individual as in individual risk). It is usually presented in the form of an 'FN' curve which is a graph of the cumulative frequency of fatality (F) of a number (N) or more people. Societal risk is considered in three regions, Ref [2]:

- 'Intolerable region' represented by an upper criterion line above which an activity is considered undesirable, even if individual risk criteria are met.
- 'Negligible' represented by a lower criterion line below which, provided other individual criteria are met, societal risk is not considered significant.
- 'As Low As Reasonably Practicable (ALARP)' region in between the 'negligible' and 'intolerable' where the emphasis is on reducing risks as far as possible towards the negligible line. Provided other quantitative and qualitative criteria of HIPAP 4 are met, the risks from the activity would be considered tolerable in the ALARP region.

HIPAP 4 provides indicative societal risk criteria as shown in Figure 4.1.

Figure 4.1: Indicative societal risk criteria from Figure 3, HIPAP 4 (2011)



4.7. Software

Consequence calculation was carried out for toxic releases using commercially available risk and consequence assessment software, GEXCON Riskcurves v12.5.1 and Effects v12.5.1. The consequence models used for assessing toxic dispersion within Effects and Riskcurves are documented in the TNO Yellow Book, Ref [6], and supplementary technical manuals for the software.

5. HAZARD IDENTIFICATION

5.1. Overview

Hazard identification is the process of identifying hazardous material properties as well as hazardous incidents that could result in an adverse impact, together with their causes, consequences and existing safeguards. The main hazards associated with the proposed facility are from the storage and transfer of liquid chlorine.

5.2. Hazardous material

The hazardous materials that have the potential to contribute to risk levels are:

- Chlorine (Cl₂)
- Ammonia (NH₃)
- Nitrogen trichloride (NCl₃).

5.2.1. Chlorine

Chlorine is a greenish-yellow highly reactive halogen gas with a pungent odour. It is heavier than air (specific gravity is 2.4 relative to air). It is a highly irritating and corrosive gas that reacts directly with moist surfaces in the eyes and respiratory tract producing hydrochloric and hypochlorous acids. It is easily detected by odour by most people at low levels (around 0.3 ppm).

Chlorine reacts violently with most classes of chemicals, including organics, acids, alkalis and combustibles. It is non-flammable and classified under the Australian Dangerous Goods (ADG) Code as a Class 2.3. Toxicity information is provided in APPENDIX H.

5.2.2. Ammonia

Ammonia is toxic, colourless gas at room temperature. Ammonia toxicity occurs when susceptible individuals suffer exposure to external sources of ammonia via ingestion, inhalation, direct contact with skin, or contact with the eye.

Ammonia is also flammable but is very difficult to ignite with a narrow flammable range. Based on the properties and the small quantities in use, toxic properties are the focus of the hazard study.

5.2.3. Nitrogen trichloride

Nitrogen trichloride (NCl₃) is a highly explosive compound that can form from the reaction of nitrogen-containing compounds (which may be present in the raw materials) with chlorine. It may be present in non-hazardous trace quantities in produced liquid chlorine. If the chlorine is vapourised accumulation of nitrogen trichloride in the liquid chlorine inventory can increase concentration to dangerous level and increases the risk of explosion events that rupture process equipment.

5.3. Hazard identification

Hazard Identification (HAZID) for the CLP was undertaken as a desktop activity based on experience with chlorine plants, review of similar operations and input from the site operators including the project hazard studies completed for the CLP. This included review of the MHF MIs at the IXOM Laverton liquefaction plant in Victoria and was also generally informed by Chlorine Institute and Euro Chlor guidance.

For the existing CAP the most recent 2024 Chloralkali Facility QRA Report, Ref [4], prepared under Development Application DA 35/98 together with updates agreed with DPHI in June 2025 Ref [5], was referenced.

The HAZID table for the CLP is provided in APPENDIX G. The hazardous incident scenarios can be broadly grouped as follows:

- Mechanical failures resulting in liquid or gaseous chlorine leaks from piping and process equipment.
- Liquid or gaseous chlorine leaks due to mechanical failure in storage tanks, drum, cylinder or parked tanker.
- Liquid or gaseous chlorine leaks due to damage during cylinder and drum handling.
- Liquid chlorine leaks from transfer pump or transfer hoses.
- Overfilling of cylinders, drums or road tankers (human error).
- Release of ammonia from ammonia circulation in refrigeration unit.
- Nitrogen chloride accumulation in liquid inventories (explosion hazards).

QRA loss of containment scenarios have been developed around these scenario groupings as noted in APPENDIX G. Detail of any scenarios screened from quantitative assessment are also provided in the HAZID table in APPENDIX G.

6. CONSEQUENCE ANALYSIS

6.1. Consequence results

Consequence analysis involves quantitative review of the identified hazardous incidents to estimate the potential to cause injury or fatalities.

The consequence results are summarised in APPENDIX H. The consequence modelling results for the CLP scenarios presented do not account for the impact of the containment building and scrubber system (i.e. releases were assumed to occur in an open area with no mitigation) in order to determine the maximum impact distances.

6.2. Worst-case consequences

The consequence results were reviewed to identify scenarios with the maximum consequence distances to 1% fatality. Among all modelled scenarios for the CLP, the liquid chlorine releases have the biggest consequence impact. The results indicates that the addition of the CLP to IXOM facility does not affect the maximum consequence impact as the existing parked road tanker release scenario has the greatest consequence effect for both current CAP operational case (parked road tanker at ambient condition) and liquefaction plant (road tanker within the CLP building). Therefore, the CLP does not result in an increase in the maximum consequence effect distance.

Note that the chlorine storage tank has a greater inventory than the tanker, however, as chlorine is stored at atmospheric pressure under refrigerated conditions, and the bund limits the surface area for evaporation this reduced the impact of the storage tank LOC scenarios compared to the parked road tanker impacts.

6.3. Storage tank bund impact

Two 50 tonne tanks in a duty/standby arrangement will store chlorine. Each tank is located in a separate bund. To evaluate the impact of the bund surface area on consequence distance, the storage tank rupture scenario was modelled for nominal bund sizes and the toxic consequence results were compared as per APPENDIX H Section H2. The results indicate that the bund can significantly reduce the impact distance of a major LOC such as tank rupture from 6 km to about 1 km.

A bund area of 57m² for each tank was adopted in the design as an operationally practical minimum and is used in the QRA to constrain the spreading area of pools where relevant.

7. FREQUENCY ANALYSIS

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. The overall approach and specific frequencies used in the QRA are given in APPENDIX I.

7.1. Release frequencies

To estimate the frequencies of hazardous events were estimated based on:

- statistical data for the frequency of failure from equipment items such as drums, vessels and piping,
- an estimated count of equipment items ('parts count') based on Piping and Instrument Diagrams (PIDs),
- operational failures (e.g. road tanker filling) based on the human error probability and number of operations,
- online time probability or proportion of time the equipment is in use.

7.2. Control measures

The risk reduction effect of safeguards in place to prevent LOCs or mitigate the consequences has been accounted for as per APPENDIX I.

At this stage of design the key control accounted for is the building containment /scrubber system for the CLP. An event tree has been developed to estimate the potential unavailability of the building containment/scrubber system. This covers failure modes as follows:

- Proportion of time doors are open (3% for contingent case, 1.3% for normal case) and also fail to close on chlorine detection or when manually activated.
- Failure of scrubber system to maintain extraction from containment building and treat chlorine.
- As per the event tree in APPENDIX F, for the purposes of the planning stage QRA the estimated overall containment 'unavailability' is 5% 'unavailable' for both short duration events where manual response is effective (4%) and completely unmitigated (1%) events. Conservatively the QRA assumes a 5% probability that all events are completely unmitigated, i.e. the LBS has no effect and does not model the short duration events separately.

Note that releases outside the building are not mitigated by the containment building and the event tree does not apply. The equipment outside is the extension of chlorine piping from the CAP, degas reactor, scrubber breakthrough and ammonia refrigeration. Specific scenarios where the building containment/scrubber system applies and does not apply are identified in APPENDIX I.

8. RISK ASSESSMENT

8.1. Modelled cases

A number of cases were defined to compare the cumulative and standalone risk profiles. The modelled cases, which are based on the scenarios defined by the SEARs, are described in Table 8.1.

Table 8.1: Sensitivity cases

SEARs proposed case	QRA case	Description
Cases 1 - 3	n/a	<p>These cases all cover operational cases associated with Qenos and Indorama.</p> <p>Case 1, Case 2 and Case 3 were <u>not modelled</u>, as by early 2025 Indorama and Qenos have shut down and hazardous materials removed (see https://botanyindustrialpark.com.au/updatesalerts/)</p> <p>They are no longer a source of risk and the overall risk contours last submitted to DPHI under DA 30/98 are not relevant.</p>
Sensitivity Case 1	SC1A (CLP - normal case)	<p>CLP only – normal case</p> <ul style="list-style-type: none"> No cylinder or drum filling operation Road tanker filling operation inside CLP building Storage of cylinders/drums as well as road tanker parking area inside building
	SC1B (existing CAP)	<p>CAP only – current operation</p> <ul style="list-style-type: none"> No cylinder, drum or road tanker filling operation Storage of cylinders/drums as well as road tanker parking area in open space <p>This case was defined to determine the impact of the CLP on the current risk profile. The 2024 CAP QRA risk results were used including updates agreed in 2025 with DPHI, Refs [4, 5].</p>
	SC1C (modified facility CAP & CLP - normal case)	<p>Cumulative risk – normal case</p> <ul style="list-style-type: none"> No cylinder or drum filling operation Road tanker filling operation inside CLP building Storage of cylinders/drums as well as road tanker parking area inside building
Sensitivity Case 2	SC2A (CLP - contingent case)	<p>CLP only – contingent case</p> <ul style="list-style-type: none"> Cylinder, drum and road tanker filling operation inside CLP building Storage of cylinders/drums as well as road tanker parking area inside CLP building
	SC2B (existing CAP)	<p>CAP only – current operation</p> <p>Not modelled explicitly, same as SC1B</p>
	SC2C (modified facility CAP & CLP - contingent case)	<p>Cumulative risk – contingent case</p> <ul style="list-style-type: none"> Cylinder, drum and road tanker filling operation inside CLP building Storage of cylinders/drums as well as road tanker parking area inside CLP building

8.2. Individual fatality risk results

8.2.1. CLP risk

SC1A (CLP – normal case) represents the normal operational case for the CLP, and SC2A (CLP – contingent case) shows the effect of cylinder and drum filling on the standalone liquefaction plant offsite risk assuming that this activity occurs over one year. The IFR contours for SC1A and SC2A are shown in Figure 8.1.

The cylinder and drum filling operation slightly increases the CLP risk as can be seen by the effect on contours. However, all IFR criteria in HIPAP 4 are met for CLP alone for both the normal and contingent cases.

8.2.2. Cumulative risk results (CAP and CLP)

The cumulative impact of the CLP on the existing CAP risk was assessed and the IFR contours for normal and contingent cases are shown in Figure 8.2 and Figure 8.3 respectively.

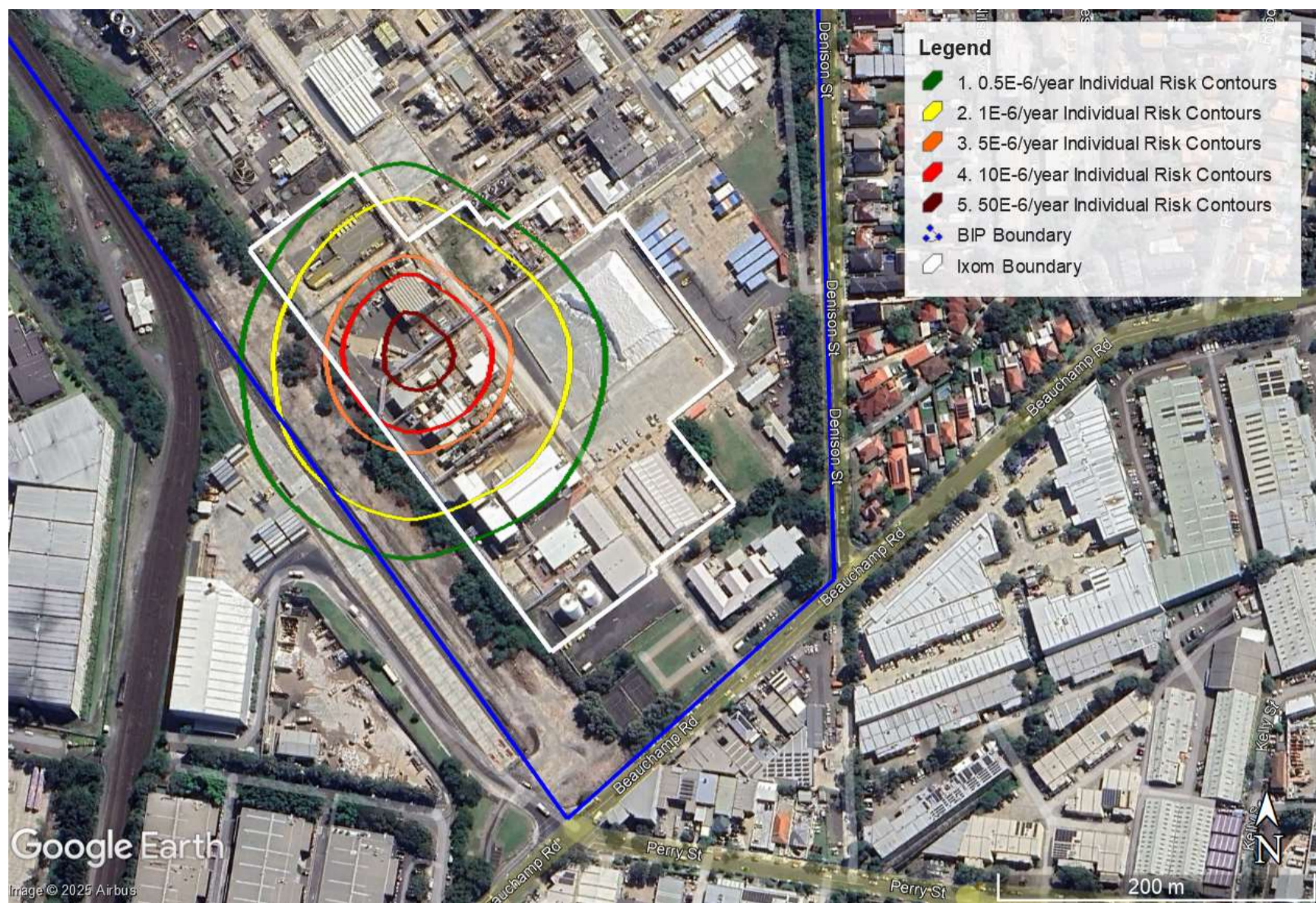
All fatality risk criteria are met for the cumulative (CAP plus CLP) risk case for both normal and contingent CLP operations as the 50×10^{-6} per year contour remains within the IXOM boundary and other contours do not extend to non-industrial land uses. (Note that it is assumed that the current Qenos and Indorama area remains industrial land use only as there is no current proposal for rezoning any part of the BIP).

A comparison between the most recent CAP risk contour (i.e. SC1B/SC2B) and the cumulative cases (i.e. SC1C and SC2C) indicates that the new risks posed by the CLP operations are managed by the proposed control measures and the CLP operation does not materially affect the existing risk level.

- Figure 8.4 compares the 1×10^{-6} per year contours for the cumulative cases (SC1A and SC2A) as well as the most recent CAP risk contour (SC1C/SC2C) for reference.
- Normal case: Comparing the cumulative risk against the current CAP risk indicates that the addition of the containment building would result in a reduction in the overall extent of the risk contour at the 1×10^{-6} per year level for the normal CLP cumulative case. This is because the drum storage and road tanker parking area (which are the current dominant risk contributor in the far field for the CAP) have been relocated inside the containment building.
- Contingent case: The 1×10^{-6} contours for the cumulative contingent case extend slightly further to the west, east and south than the current CAP case and have reduced to the north. However, there is no impact on non-industrial land and the 50×10^{-6} per year contour remains within the IXOM site boundary.

Figure 8.1: IFR contours – CLP only

Case SC1A – CLP only (normal case)



Case SC2A – CLP only (contingent case)

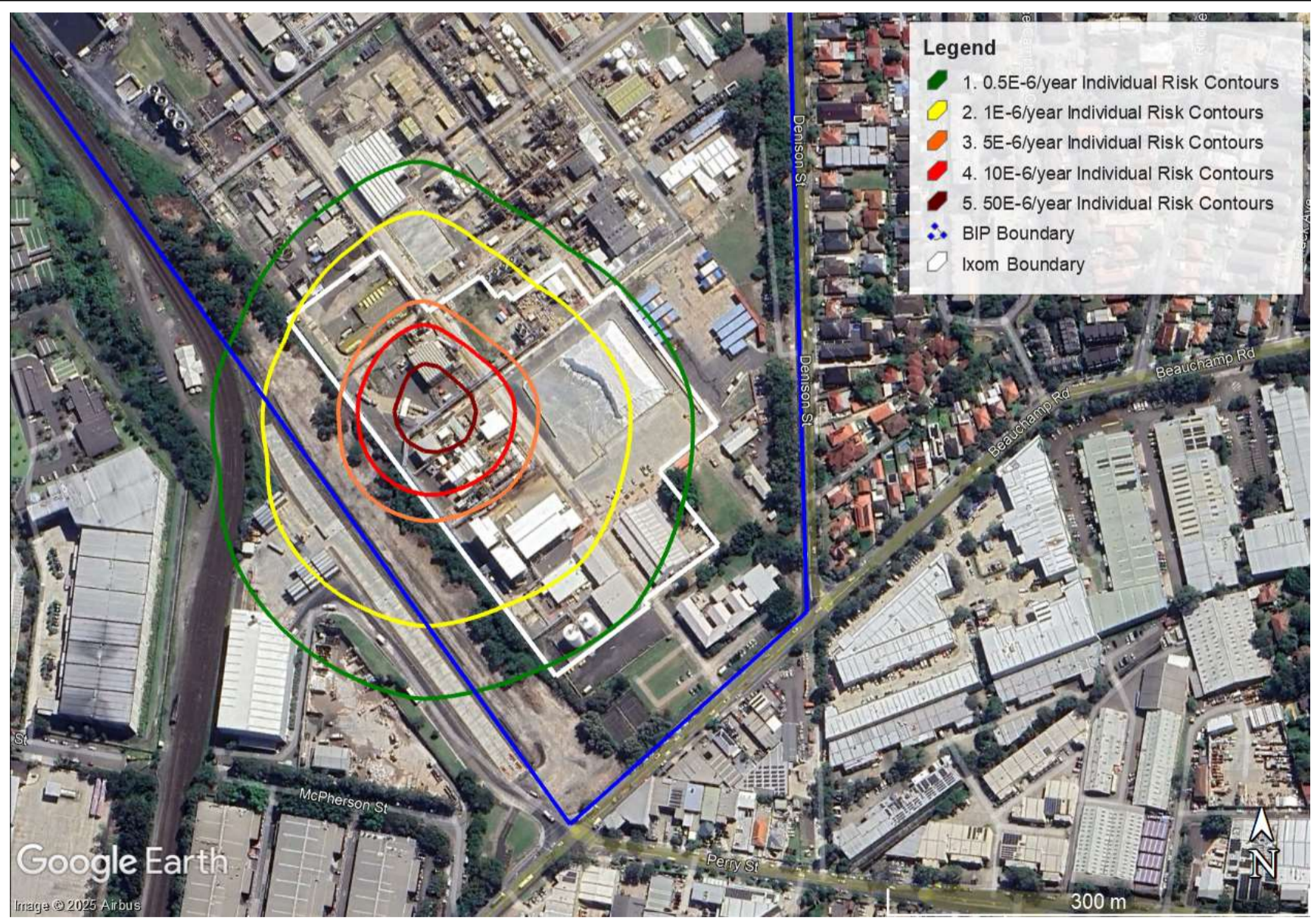
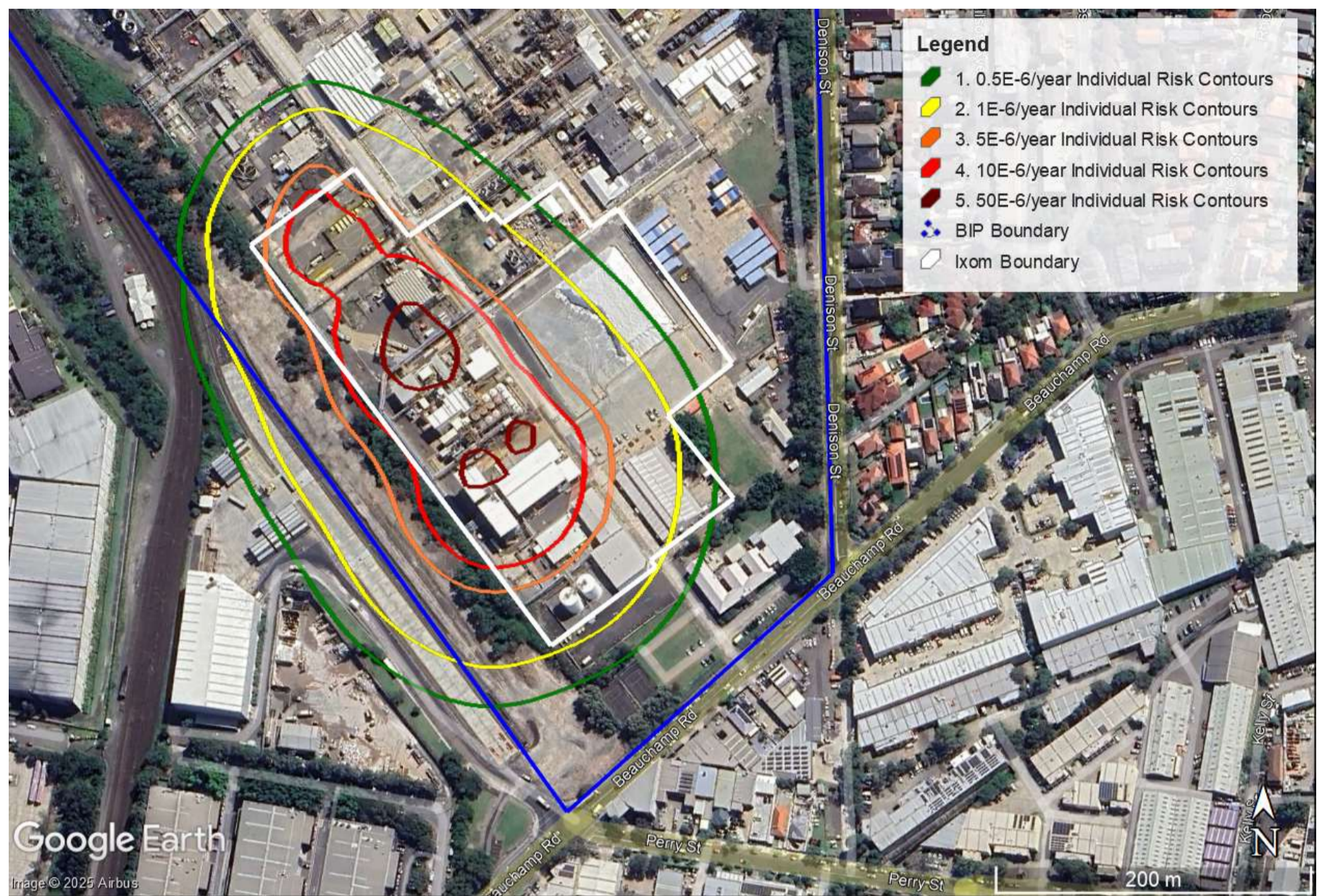


Figure 8.2: IFR contours – cumulative risk (normal case)

Case SC1C – modified facility (cumulative CAP & CLP normal case)



Case SC1B – existing CAP for reference

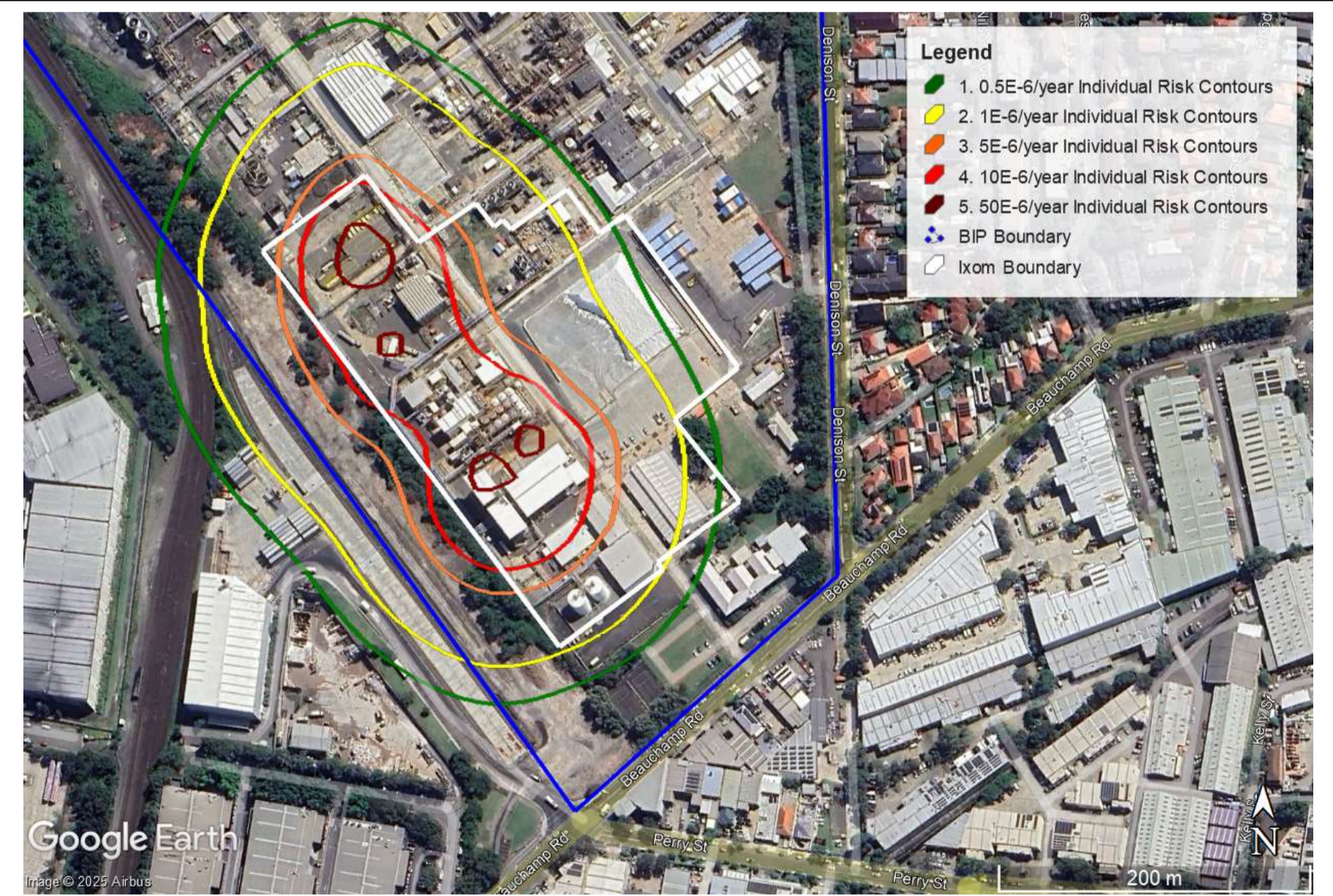
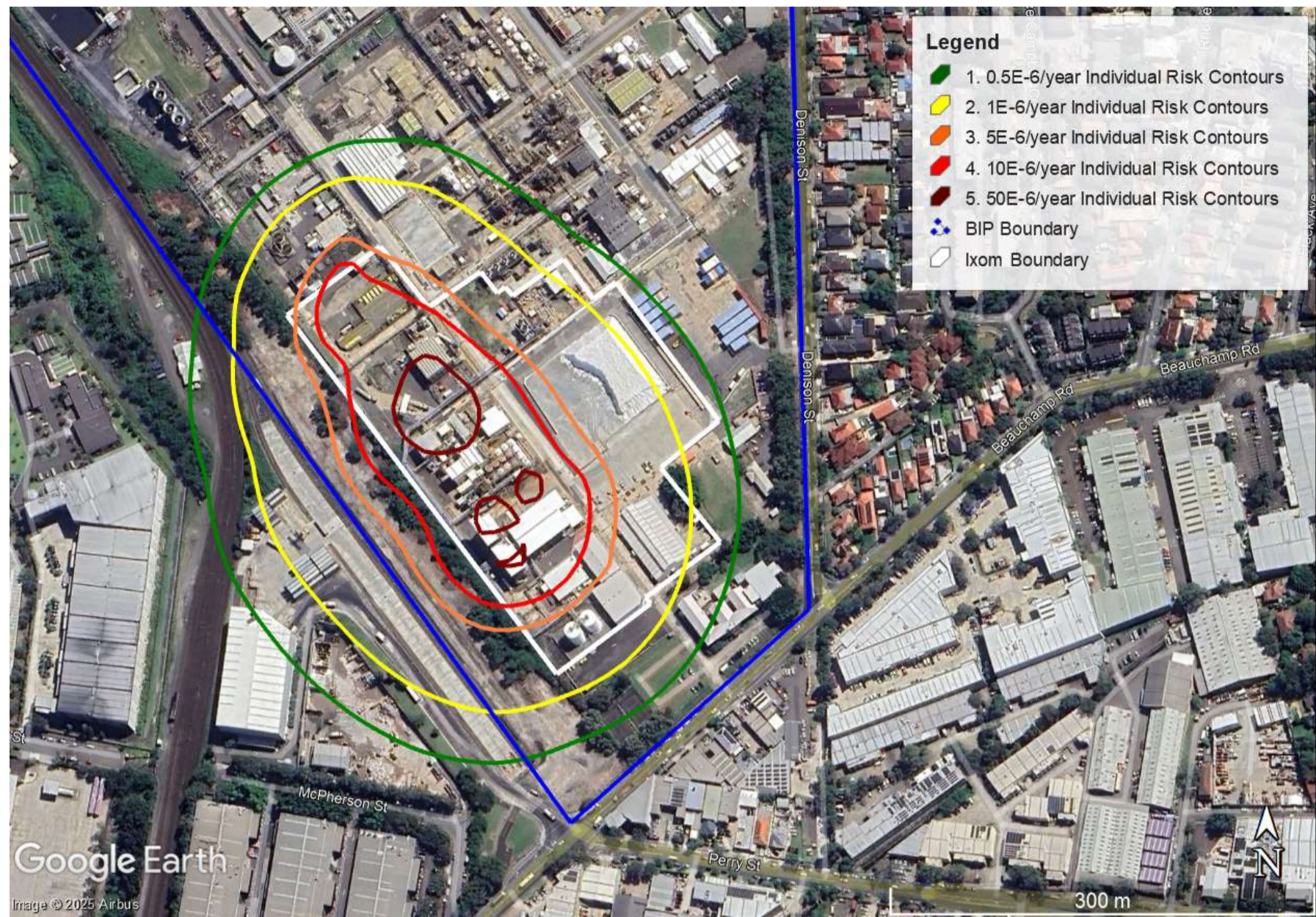


Figure 8.3: IFR contours – cumulative risk (contingent case)

Case SC2C – modified facility (cumulative CAP & CLP contingent case)



Case SC2B – existing CAP for reference

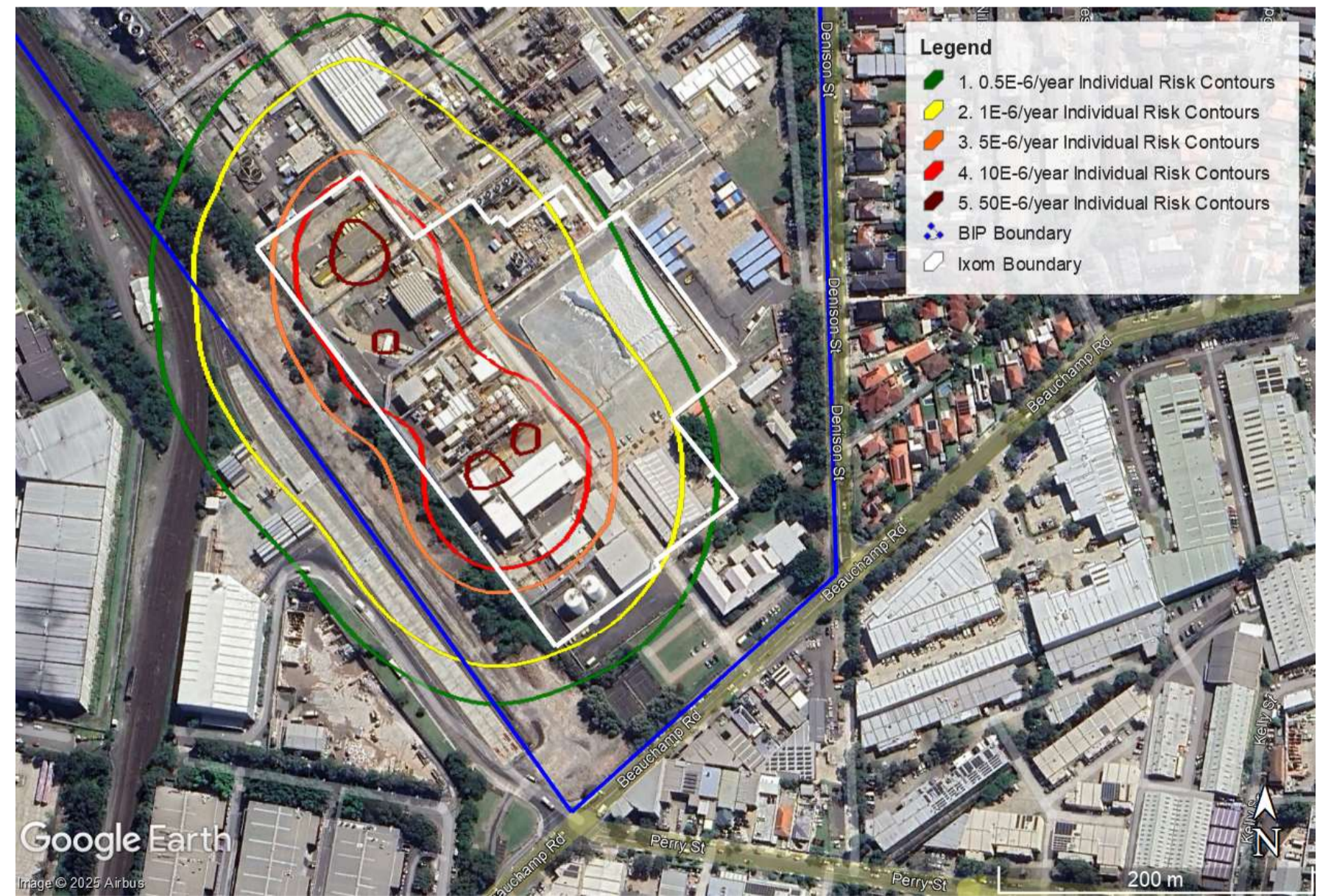


Figure 8.4: CLP impact on future risk



8.3. Injury and irritation risk

The injury and irritation contours indicate the likelihood of a threshold toxic dose being exceeded at a particular location.

Figure 8.5 shows the 10×10^{-6} per year toxic injury risk contours for the cumulative normal and contingent cases (SC1C/SC2C) and the CAP only, which represent frequency of exceedance of a toxic dose corresponding to the AEGL 3 (10 mins). For all cases, the contour extends beyond the IXOM and BIP boundaries. However, they do not reach the nearest residential areas to the east, so the HIPAP 4 toxic injury criterion is met.

Figure 8.6 indicates the 50×10^{-6} per year toxic irritation risk contours for the cumulative normal and contingent cases (SC1C/SC2C) and the CAP only, which represent frequency of exceedance of a toxic dose corresponding to the AEGL 2 (10 mins). For all cases, the contour extends beyond the IXOM and BIP boundaries. However, they do not reach the nearest residential areas to the east, so the HIPAP 4 toxic irritation criterion is met.

Figure 8.5: Toxic injury contour (AEGL 3 equivalent toxic dose, 10×10^{-6} per year contour)

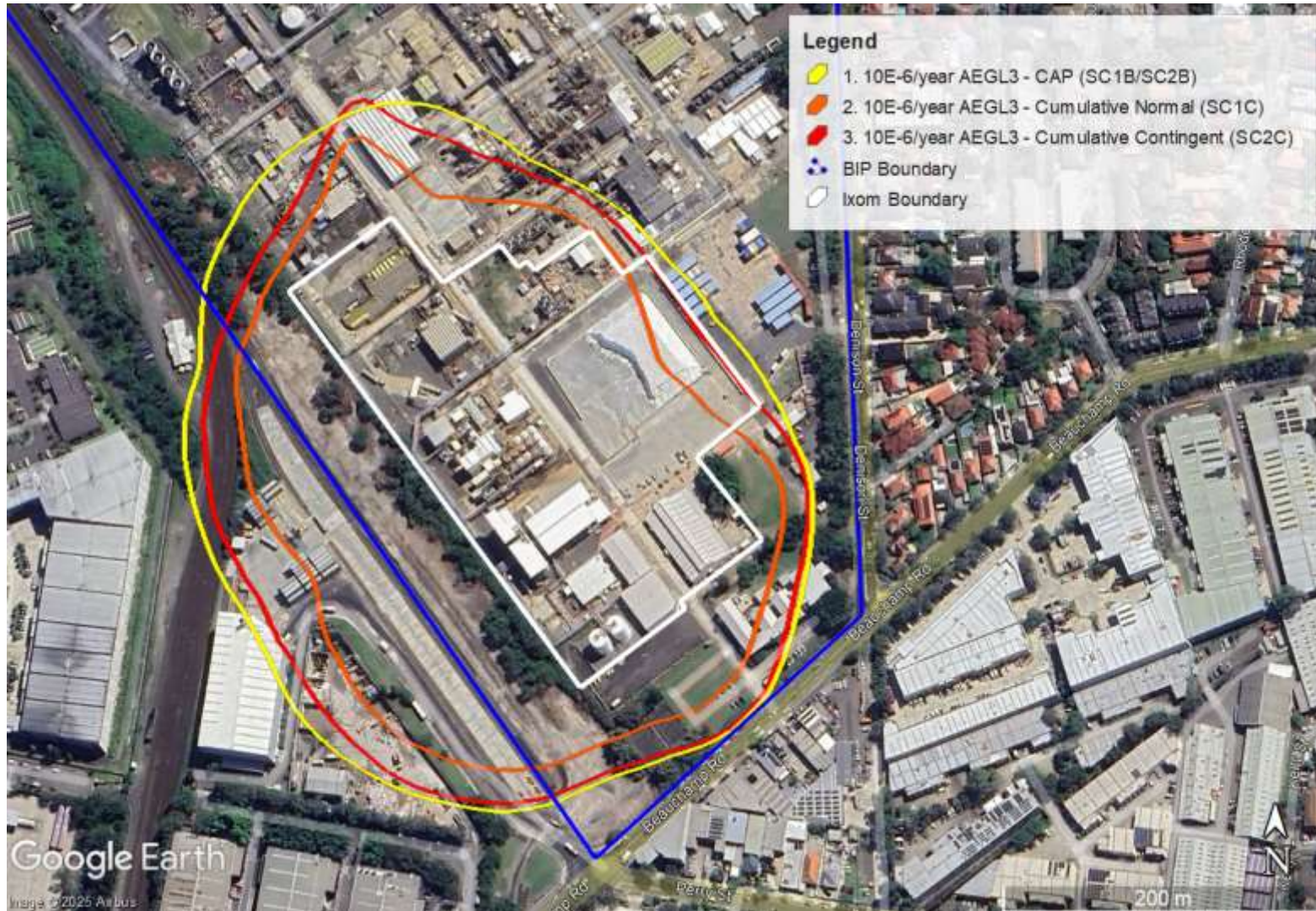
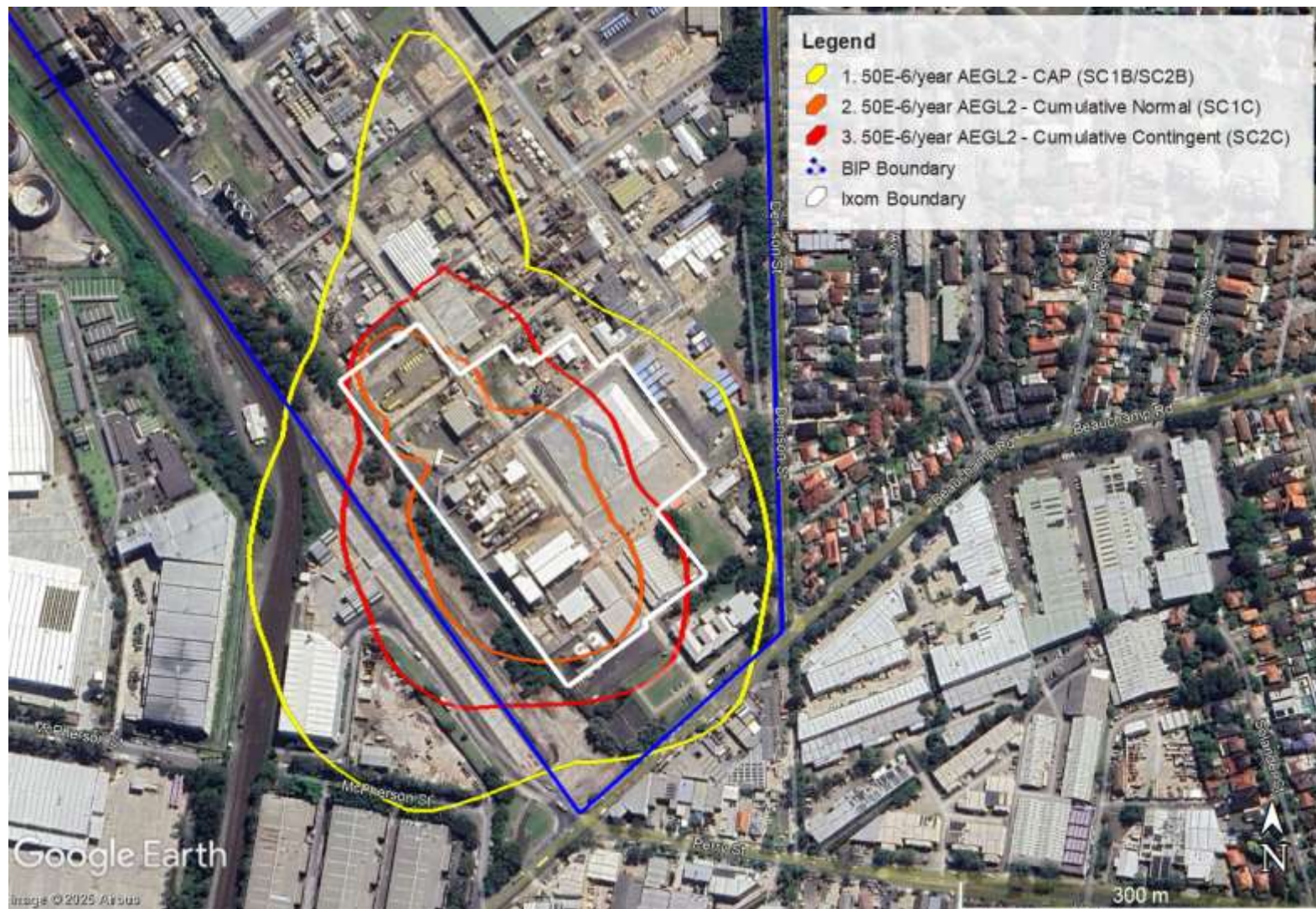


Figure 8.6: Toxic irritation contour (AEGL 2 equivalent toxic dose, 50×10^{-6} per year contour)



8.4. Risk contributors

APPENDIX J summarises the significant risk contributors (i.e. scenario contributing around 80-90% of the risk as a specific location) at the IXOM site boundaries and at various distances from the IXOM facility (albeit at low absolute risk levels below the HIPAP 4 criteria).

The major contributors to the offsite individual fatality risk are un-isolated liquid chlorine releases due to hose failures or piping failures in pumped liquid piping, i.e. for tanker loading for the normal case, and for drum and cylinder filling as well as tanker loading for the contingent case. It should be noted that these scenarios have been modelled conservatively i.e. the probability of failure of automatic isolation (0.1) and time to isolation (up to 3 minutes) has been selected conservatively for the planning stage QRA and may be refined in detailed design stage.

8.5. Societal risk

8.5.1. Current population

The societal risk calculations were conducted using the most recently available population data from the 2021 Census as summarised in APPENDIX E for populations around the BIP. Note this is consistent with the most recent CAP QRA and also the most recent overall BIP QRA (as submitted to DPHI in 2024).

Note that by convention for societal risk calculations, the population on the site under consideration is not included in the total population, so the population on the IXOM site is not included in societal risk calculations.

8.5.2. Future population

The future population on Qenos/Indorama sites is not clear yet. However, ESR the buyer of the site intends to develop industrial warehousing and advises 40 people per hectare is a conservative basis for these sites. The following case was therefore defined for societal risk assessment:

- 40 people per hectare for daytime and 4 people per hectare for nighttime.

8.5.3. Mitigation taken into account

The concentration of gas inside a building engulfed by a gas cloud will rise gradually until the release has stopped and the cloud diluted to non-hazardous levels. The indoor concentration then falls gradually towards zero. The peak concentration will be less than outside, (unless the duration of the release is very long, or the building has very high ventilation rates). Hence, a person inside will normally be exposed to significantly lower gas concentrations than someone outside and the risk of fatality from a toxic gas will be significantly less for a person located indoors than the risk in the open at the same location.

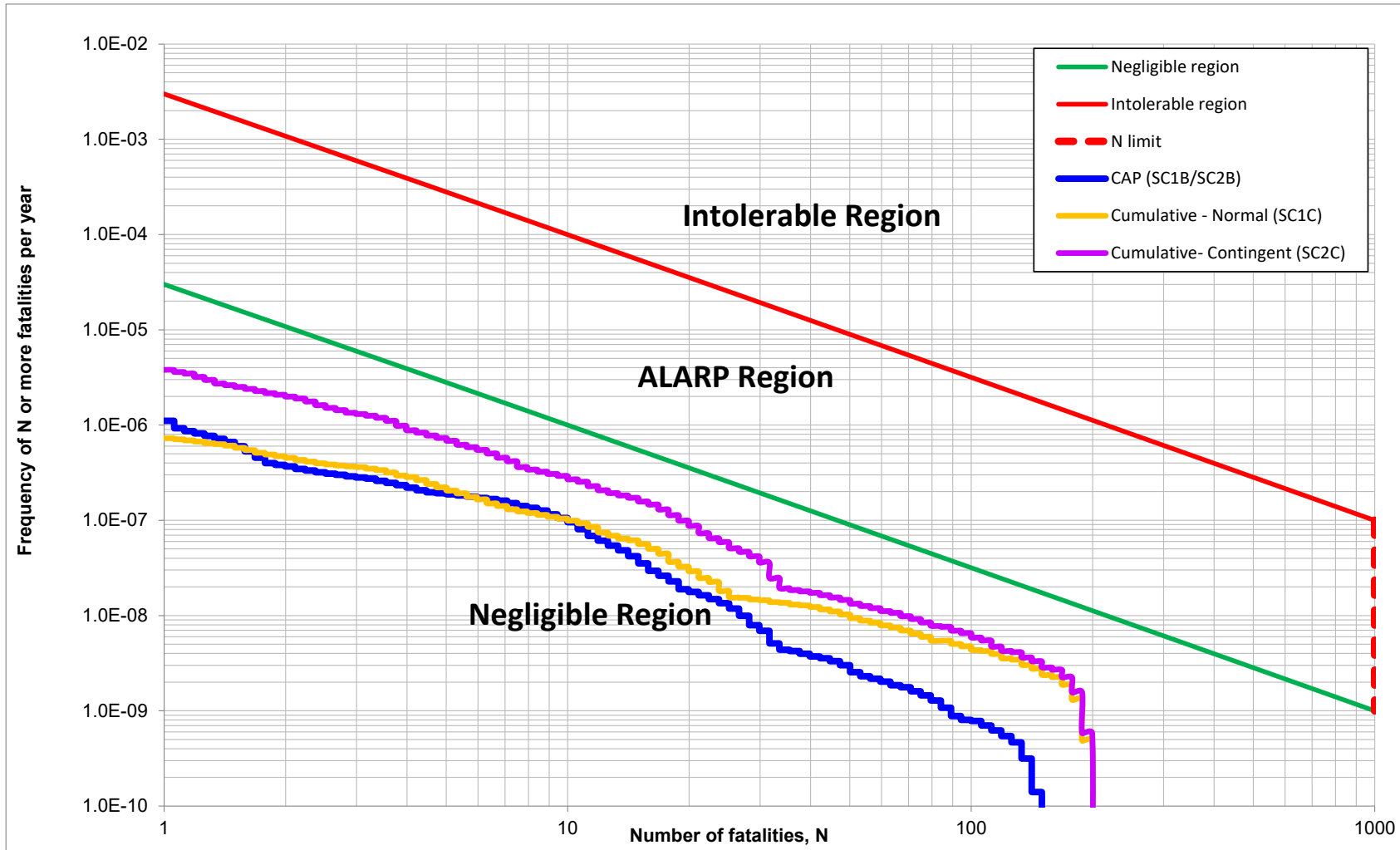
The toxic dose to indoor populations is calculated within the risk software based on building ventilation rates. For this QRA, natural ventilation (1 air change per hour) was assumed.

8.5.4. Societal risk results

The societal risk associated with the CAP current operation as well as the cumulative normal case and contingent case are presented in Figure 8.7, including the effect of the future population on the former Qenos and Indorama areas on the BIP site.

The results indicate that the societal risk level for the cumulative case does not reach the ALARP or intolerable regions and remains within the negligible region for all cases.

Figure 8.7: Societal risk – Population 1 (additional 40 people/hectare on former BIP operations)



8.6. Onsite risk

The purpose of the planning stage onsite risk calculation is to show that the worker risk will meet tolerability criteria. The results are not intended to demonstrate that worker risk is reduced SFARP as this demonstration will be undertaken as part of the MHF safety assessment. Risk estimates to onsite employees will be further refined to account for all relevant controls and ensure the risk is reduced SFARP as part of the MHF safety assessment process.

Onsite risk has been estimated for typical roles for both the normal and contingent cases including risk from the CAP plus the future CLP operations using the QRA model as per results in APPENDIX K. Additional factors that are not part of offsite risk calculations are included in the onsite risk estimate as follows

- Probability of presence (assumptions as per APPENDIX K)
- Exposure controls. In this case for the proportion of time a role is located inside the Control Room or the Main Admin building the toxic dose is reduced by accounting for ventilation rate and shutdown of air conditioning.
- For activities occurring inside the liquefaction building (tanker filling, etc.) the mitigation effect of the containment building is removed from the risk calculation.
- No mitigation factors or conditional modifiers relating to exposure (e.g. self-escape, PPE, local ventilation) for scenarios involving drum or tanker filling operations inside the containment building are accounted for hence the calculations are conservative.

There are no specific on site risk criteria in Australia. Therefore, the risk to a worker assuming a 40-hour work week was assessed against the UK HSE risk tolerability targets (from UK HSE R2P2, Ref [3]) for representative worker roles:

- Maximum tolerable criterion: 1×10^{-3} per year
- Broadly acceptable criterion: $< 1 \times 10^{-6}$ per year.

The resulting individual risk of fatality per annum (IRPA) for all roles is below the UK HSE 'intolerable' criterion of 1×10^{-3} per year and hence will be tolerable for all worker roles including the effect of the CLP as per the summary in Table 8.2.

Table 8.2: Onsite risk as day time individual fatality risk per annum (IRPA)

Role	Modified facility CAP & CLP – normal case	Modified facility CAP & CLP – contingent case
Day Plant Operator	3.65×10^{-5}	7.15×10^{-4}
Engineers/Planners	4.69×10^{-6}	1.17×10^{-5}
Technical/Quality	5.42×10^{-6}	1.43×10^{-5}
Operations	5.16×10^{-6}	1.24×10^{-5}
Admin staff	1.02×10^{-6}	2.65×10^{-6}

9. CONCLUSION

9.1. Main findings

The proposed development was assessed against the HIPAP 4 quantitative and qualitative risk criteria, as summarised in Table 9.1 and Table 9.2.

Key findings of this study are provided below:

1. Maximum consequence: No scenarios associated with the CLP were identified to have a greater consequence impact to the 1% fatality level than the existing CAP scenarios. The scenario with the largest impact remains a release from a 13-tonne chlorine road tanker at ambient conditions.
2. Control measures: High level design choices that minimise risk include:
 - Selection of the 'Block L' site within the BIP maximises the distance to residential areas along Denison St and also minimises the extension of the pressurised chlorine vapour piping from the CAP to the CLP that cannot be located within the containment building. This also maximises the distance to onsite occupied areas such as the existing CAP control room and administration building.
 - Refrigerated storage conditions (i.e. atmospheric pressure and a temperature of approximately -34°C) limit the release rate and associated evaporation rate of chlorine allowing containment within a building and treatment by a scrubber at manageable rates.
 - Minimising the bund surface area for the storage tanks and other liquid chlorine handling areas significantly reduces spill evaporation rate hence consequence impact of major release scenarios from refrigerated storage at atmospheric pressure such as storage tank failure.
 - Containment building large enough to carry out all liquid storage and handling activities and sized to contain flash fraction of liquid chlorine scenarios including filled road tanker after warming up in combination with the scrubber system is an effective risk reduction measure for the CLP. The QRA has estimated a 5% 'unavailability' of the containment building and scrubbing system. This will be verified as achievable as part of detailed design as per the recommendations.
3. Offsite risk:
 - All individual fatality risk criteria are met for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) as per Figure 8.2 and Figure 8.3 and as summarised in Table 9.1. This is consistent with the existing CAP.
 - Due to the effect of the containment building there is only a small difference in offsite risk between the normal and contingent cases as can be seen in the comparative risk contours in Figure 8.4.

- The toxic injury contour (see Figure 8.5) for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) does not reach the residential area hence meets the toxic injury criterion as per the current CAP case.
 - The toxic irritation contour (see Figure 8.6) for the modified facility (i.e. cumulative case of CAP and CLP for both normal and contingent cases) does not reach the residential area hence meets the toxic irritation criterion as per the current CAP case.
 - Societal risk is in the negligible region for both the normal and contingent cases as per Figure 8.7. The assessment assumes a population of 40 people/hectare on the Qenos and Indorama areas of the BIP.
 - Due to the containment building, the individual and societal risk profile does not materially increase compared to the existing CAP plant risk profile.
 - The overall extent of the individual fatality risk contours offsite is slightly reduced for the normal case compared to the current CAP due to the opportunity to relocate the existing liquid chlorine storages (drums, cylinder, parked road tanker) from the outdoor location to inside the containment building. The contingent case is slightly increased except to the north where it is decreased. (refer to Figure 8.4 for a comparative risk contour).
 - The toxic injury and irritation risk contours are slightly reduced for the normal and contingent cases compared to the current CAP due to the opportunity to relocate the existing liquid chlorine storages (drums, cylinder, parked road tanker) from the outdoor location to inside the containment building (refer to Figure 8.5 and Figure 8.6 for comparative risk contours).
4. Onsite risk: Onsite risk was estimated for typical roles for cumulative case including future CLP operations for the normal and contingent cases using the QRA model and also including adjustments for occupancy to calculate worker IRPA. The IRPA is below the UK HSE 'intolerable' risk of 1×10^{-3} per year and hence is tolerable for all worker roles including the effect of the CLP as per Table 8.2.

Risk contributors associated with operation of the modified facility are chlorine releases. There are small quantities of ammonia present in the CLP for the refrigeration system however ammonia risk contributions are very low due to the small inventory.

The dominant risk contributors to the offsite individual fatality risk are liquid chlorine releases due to hose failures or piping failures in pumped liquid piping, i.e. for tanker loading for the normal case, and for drum and cylinder filling as well as tanker loading for the contingent case. These scenarios have been modelled conservatively for the QRA, i.e. generic hose failure rates have been adopted, and the probability of failure of isolation and time to isolation has been selected conservatively for the planning stage QRA. These assumptions may be refined in detailed design stage further reducing the estimated risk.

9.2. Recommendations

The QRA is based on the design stage of the CLP. The key control that ensures the risk does not materially increase compared to current levels is the CLP containment building and scrubber. The dominant residual risk contributors are related to failures in equipment for transferring liquid chlorine between storages and tankers, drums or cylinders.

Recommendation 1: *It is recommended that as part of detailed design, the containment building and scrubber design should be verified to ensure that the estimated unavailability of no more than 5% is achieved. It is anticipated that this can be carried out as part of a Final Hazard Analysis (FHA) if project consent is received.*

Recommendation 2: *The QRA has conservatively assessed the probability of failure on demand (PFDavg) of automatic detection and isolation (PFDavg = 0.1) and time to isolation (up to 3 minutes) for isolatable chlorine leak scenarios. It is recommended that as part of detailed design, automatic detection and isolation time and probability of failure on demand for detection and isolation of chlorine leaks from hoses and pumped liquid systems be more accurately assessed to confirm whether greater risk reduction is achievable for the residual risk contributors.*

Table 9.1: Comparison against HIPAP 4 quantitative risk criteria

Description	Risk criterion (per year)	Risk criteria met?		Comments
		Existing CAP only	Modified facility CAP & CLP – normal and contingent cases (SC1C/SC2C)	
Individual Fatality Risk				
Sensitive uses, including hospitals, schools, aged care	0.5×10^{-6}	Yes	Yes	Contour extends past IXOM boundary but does not extend to any sensitive uses Matraville Botany Public School (Beauchamp Rd). Complies with criteria.
Residential areas and hotels	1×10^{-6}	Yes.	Yes.	Contour extends past IXOM boundary but does not extend to any residential land uses (Denison St). Complies with criteria.
Commercial areas, including offices, retail centres, warehouses	5×10^{-6}	Yes	Yes	Does not reach any commercial uses. Complies with criteria.
Sporting complexes and active open spaces	10×10^{-6}	Yes	Yes	Does not reach any open space uses. Complies with criteria.
Contained within the boundary of an industrial site	50×10^{-6}	Yes	Yes	Contour remains within IXOM boundary Complies with criteria.
Injury/Irritation Risk				
Injury (residential areas only)	10×10^{-6}	Yes	Yes	Contour extends past IXOM boundary to the south and west but does not extend to any residential or sensitive uses Matraville Botany Public School (Beauchamp Rd) to the east. Complies with criteria.
Irritation (residential areas only)	50×10^{-6}	No	No	Extends past the IXOM boundary and slightly into residential areas to the east. Not a material change as this the case for the existing CAP.

Description	Risk criterion (per year)	Risk criteria met?		Comments
		Existing CAP only	Modified facility CAP & CLP – normal and contingent cases (SC1C/SC2C)	
Societal Risk				
Populations external to BIP	HIPAP 4 (2011) criteria	Yes	Yes	Max N < 1000 Results curve within negligible area for all cases.

Table 9.2: Comparison against HIPAP 4 qualitative risk criteria

Criteria	Comments	Consistent?
<p>a) All 'avoidable' risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified.</p>	<p>As part of the project feasibility studies a variety of alternative locations were reviewed. Location of the plant at the existing CAP which provides appropriate infrastructure to contain and treat chlorine releases was selected as the most practicable option. Refer to additional information in planning application for alternatives considered.</p>	<p>Yes</p>
<p>b) The risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation. In all cases, if the consequences (effects) of an identified hazardous incident are significant to people and the environment, then all feasible measures (including alternative locations) should be adopted so that the likelihood of such an incident occurring is made very low. This necessitates the identification of all contributors to the resultant risk and the consequences of each potentially hazardous incident. The assessment process should address the adequacy and relevancy of safeguards (both technical and locational) as they relate to each risk contributor.</p>	<p>The plant is designed in accordance with inherent safety principles and best practices. The high-level risk reduction measures are discussed in Section 3.9 and include design choices from concept and site selection to engineering controls to reduce the risk SFARP. The CAP is an MHF with a documented SFARP demonstration.</p>	<p>Yes</p>
<p>c) The consequences (effects) of the more likely hazardous events (i.e. those of high probability of occurrence) should, wherever possible, be contained within the boundaries of the installation.</p>	<p>The chlorine releases will be contained within the building. The containment building in combination with the scrubber system would prevent significant impacts outside the CLP boundary. The design intent is to contain a chlorine release in a building and scrub the vent to below hazardous ppm. The containment building in combination with the scrubber system would prevent significant impacts outside the CLP boundary.</p>	<p>Yes</p>
<p>d) Where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.</p>	<p>The QRA results demonstrate that the addition of the CLP has minimal impact on individual and societal risk results and does not alter the assessment against risk HIPAP 4 criteria. The overall risk is reduced compared to the current risk due to the opportunity to relocate the liquid chlorine storages (drums, cylinder, parked road tanker) from the outdoor location to inside the containment building.</p>	<p>Yes</p>

APPENDIX A. SEARS CROSS REFERENCES

A1. SEARs (Hazard and risk only)

SEARs- Key issues - Hazard and Risks	
SEARs requirements	Study approach
<p>Include a Quantitative Risk Analysis (QRA) in accordance with the Department’s Hazardous Industry Planning Advisory Paper No. 6, ‘Hazard Analysis’ demonstrating that the existing chloralkali plant (CAP) with the proposed chlorine liquefaction plant (CLP) (‘the modified facility’ up to DA 35/98-Mod-6) complies with both the qualitative criteria, in particular the consideration of site location and technology, and the quantitative criteria in the Department’s Hazardous Industry Planning Advisory Paper No. 4, ‘Risk Criteria for Land Use Safety Planning’.</p> <p>The QRA must also include:</p>	<p>QRA was prepared as per HIPAP 6 guidance. Assessment against the HIPAP 4 quantitative and qualitative risk criteria is covered in Section 8.</p>
<ul style="list-style-type: none"> • a site layout diagram showing the location of all buildings enclosing the CLP and dangerous goods (DG) storage, and the location of all DG piping to and from these buildings. 	<p>Overall locations and CLP site layout are shown in Section 3.1.</p> <p>Additional site layout diagrams provided in APPENDIX C.</p> <p>The location of all DG piping to and from the new facility is described in Section 3.8.</p>
<ul style="list-style-type: none"> • a description of all buildings enclosing the CLP and DG storage including: <ul style="list-style-type: none"> – structural design specifications to enable full containment of major DG release incidents, – building capacities and ventilation rates, – scrubber design specifications including inlet and outlet conditions (flow rates, concentrations, etc.), – building layout diagrams showing the location of the CLP, DG piping to and from these buildings, DG storage, and staging and parking areas for vehicles associated with DG transport for all operating modes of the modified facility. 	<p>A description of the building and details such as volume, ventilation and scrubbing provisions and its functionality is provided in Section 3.7.</p> <p>The building structural design specification and layout is provided in APPENDIX C.</p> <p>Staging and parking areas provided in APPENDIX C.</p> <p>The location of all DG piping to and from the new facility is described in Section 3.8.</p>

SEARs- Key issues - Hazard and Risks	
SEARs requirements	Study approach
<ul style="list-style-type: none"> • a detailed process description of the CLP including: <ul style="list-style-type: none"> – process flow diagrams, – operating conditions (flow rates, temperature, pressure, state of matter, etc.), – maximum DG quantities for all operating modes of the modified facility, and – overview of mass balance between the CAP and the CLP for all operating modes. 	<p>A process description is provided in Section 3.6. A control philosophy (PC.20301993-06-100_B) is being reviewed and can be provided on request. Refer to PFDs in APPENDIX C.</p> <p>Some operating conditions are available in the process description. All operating conditions are provided in the master PFD's (PC.20301993-PFD-0010 to 0037) and can be provided on request. Maximum DG are provided in Section 4.2.</p> <p>An overview of mass balance between CAP and CLP available in Section 3.3.</p>
<ul style="list-style-type: none"> • a description of all necessary modifications at the CAP to accommodate the design and operation of the CLP. 	<p>CAP operation is virtually unchanged. With the CLP up to 50% of the output can be diverted to the CLP so total chlorine production does not increase. The project is a change in storage and handling of chlorine.</p> <p>Refer to Section 3.8.</p>
<ul style="list-style-type: none"> • major incident hazard identification and details of all safeguards to address these hazards with reference to all relevant engineering standards, codes of practice and best practice especially for chlorine and ammonia. 	<p>Section 3.9 discusses the safeguards implemented to minimise the risk of major incidents. APPENDIX G provides more details on controls in place for identified hazardous incidents.</p>
<ul style="list-style-type: none"> • a QRA assumptions register with justification on the appropriateness of all assumptions. 	<p>Refer to APPENDIX B. Key assumptions and approach are also described in relevant sections as pre cross reference details.</p>
<ul style="list-style-type: none"> • a list of all potential major incident hazards which may affect both on-site or off-site and the associated consequence distances with corresponding release conditions including and not limited to the total isolatable quantity, flow rate, temperature, pressure and state of matter. 	<p>Refer to APPENDIX H.</p>
<ul style="list-style-type: none"> • a description of the major incidents control philosophy of the CLP including identification of all preventative and mitigative safety critical engineering safeguards against all major incidents with required reliability for these safeguards where appropriate. 	<p>Key approaches are described in Section 3.10 and Section 3.9.</p> <p>APPENDIX I summaries the required reliability of the containment building/scrubber.</p>

SEARs- Key issues - Hazard and Risks	
SEARs requirements	Study approach
<ul style="list-style-type: none"> justification for all safeguards to minimise the risk from major incidents 'so far as is reasonably practicable' consistent with the intent under the Work Health Safety Regulation 2017 (WHS Regulation). 	Key approaches are described in Section 3.10 and Section 3.9.
<ul style="list-style-type: none"> all population assumptions with justification adopted in the QRA. 	Refer to APPENDIX E.
<ul style="list-style-type: none"> risk analysis for both on-site and off-site consequences from the modified facility for all major incident hazards. 	Onsite risk is covered in Section 8.4. For offsite risk, refer to Section 8.2 to Section 8.4.
<ul style="list-style-type: none"> the individual and societal risk results for the CLP and the modified facility for the following cases, and compare these results against the most recent Botany Industrial Park (BIP) QRA submitted under DA 30/98 and the most recent CAP QRA submitted under DA 35/98 up to MOD 5: <ul style="list-style-type: none"> Case 1: Currently approved operations in the vicinity of the modified facility including the Genos and Indorama facilities operating at its consent limits and the CLP operating at its expected utilisation intent across both normal operating mode or contingent operating mode, Case 2: Currently approved operations in the vicinity of the modified facility including the Genos and Indorama facilities operating at its consent limits and the CLP is only operating at the normal operating mode at all times, Case 3: Currently approved operations in the vicinity of the modified facility including the Genos and Indorama facilities operating at its consent limits and the CLP is only operating at the contingent operating mode at all times, 	Case 1, Case 2 and Case 3 were <u>not modelled</u> , as Indorama and Qenos have shut down and de-inventoried (see https://botanyindustrialpark.com.au/updates/alerts/) Therefore, they are no longer a source of risk and the overall risk contours last submitted to DPHI under DA 30/98 are no longer relevant. The future estimated population for future land use, however, were considered for societal risk assessment.
<ul style="list-style-type: none"> Sensitivity Case 1: Potential future operations replacing the Qenos and Indorama facilities following permanent shut-down of these facilities and the CLP is operating at its expected utilization intent across both normal operating mode or contingent operating mode, and Sensitivity Case 2: Potential future operations replacing the Qenos and Indorama facilities following permanent shut-down of these facilities and the worst-case scenario (higher risk profile) between the normal operating mode or the contingent operating mode. 	Sensitivity Case 1 and Sensitivity Case 2 were modelled in the risk analysis. The modelled scenarios are detailed in Section 8.1 and results presented in APPENDIX H.

SEARs- Key issues - Hazard and Risks	
SEARs requirements	Study approach
<ul style="list-style-type: none"> demonstration that risks from the modified facility will not have an effect on future developments in the vicinity of the modified facility; 	<p>Results indicate that risk profile is suitable for industrial land uses. Societal risk has accounted for potential future populations on the BIP. The proposed development will not significantly affect the existing risk level.</p> <p>Any future developments on the BIP will need to go through the DA process in any case.</p>
<ul style="list-style-type: none"> address all recommendations from the 2001 Botany/Randwick Industrial Area Land Use Safety Study Overview Report which are relevant to the modified facility; 	<p>Refer to APPENDIX L. The CLP and CAP cumulative risk is less than what previously was estimated in 2001. This is because of the inherent safer design and new controls are now introduced (e.g. containment building).</p>
<ul style="list-style-type: none"> include a Transport Risk Assessment (TRA) to evaluate the potential impacts from 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); 	<p>Transport risk results are presented in a separate document. Refer to Transport Risk Assessment Report (Sherpa report 218383-RP-003).</p>
<ul style="list-style-type: none"> Report on the consultation outcomes with: <ul style="list-style-type: none"> SafeWork NSW in regards to compliance with the requirements for major hazard facilities under the WHS Regulation, the Local Emergency Management Committees as per the State and Emergency Rescue Management Act 1989 (SERM Act) for the Bayside LGA and Randwick LGA in regards to emergency planning in the vicinity of BIP, the Regional Emergency Management Officer as per the SERM Act for the Central Metropolitan Region in regards to emergency planning for the credible worst-case scenarios and identify any issues in addressing such scenarios, BIP in relation to the potential future land uses within BIP, and the public in the vicinity of BIP in regards to the perception of risks from the modified facility. 	<p>The consultation outcomes are not included in this report and are provided in the overall DA submission.</p>

APPENDIX B. ASSUMPTION REGISTER

The assumptions register below summarises the high level approach for key inputs to each step of the QRA. Additional details specific to the project are provided in the link in the 'Report Reference' column

Assumptions are either 'conservative' in that risk may be overstated compared to actual operations, or 'best estimate' where assumptions reflect likely operations or conditions or available data specific to the item. As this is a planning stage QRA for sensitive assumptions a conservative approach is typically applied, which may be refined at the detailed design stage. .

Study area	Item	Approach for CLP	Report reference	Comments	Sensitivity of overall modelling	Level of conservatism
QRA basis	Inventories	Maximum isolatable inventory	Section 4.2	Maximum fill level for storage inventories Inventory in isolatable sections at process conditions for process equipment Data developed as available at design stage of project from PFDs/preliminary PIDs	Minor unless there are significant periods of time with low or no inventory	Conservative
	Throughputs	Maximum annual throughputs	Section 4.2	Maximum production rates assumed for both normal and contingent case, i.e. the QRA does not account for the normal case CLP operational production rate typically at 10% of maximum CLP production rate. Maximum annual throughputs for drum/tanker filling assumed	Minor unless there are significant periods of time with operations at low rates	Conservative
	Connecting pipelines	Not applicable	-	There are no pipelines containing hazardous materials connecting the IXOM facilities with any other facilities. Piping connecting the existing CAP and proposed CLP is process piping located within the IXOM site boundary	-	-
	DG Transport	Outside scope	-	Transport of hazardous materials outside the facility boundary is outside the scope of the QRA.	-	-
	Facility boundary	IXOM boundary	-	Boundary for the purposes of assessing risk against criteria is the overall IXOM site boundary (i.e. the IXOM boundary which is within the BIP boundary).	-	-
	Escalation (neighbours)	-	-	No potential events in the remaining plants on the BIP were identified as affecting the chlorine plant. Indorama and Qenos which posed explosion hazards, has now been shut down.	-	-
Hazard Identification	Hazardous materials	Cl ₂ , NH ₃	Section 5.2	The hazardous materials for the CLP are chlorine and ammonia. Other materials are present in the existing CAP refer to CAP QRA report for additional details (see 21972-RP-001).	-	-
	Mechanical integrity failures	Quantitatively accounted for using parts count and industry statistical leak frequency data	Section 5.3 APPENDIX I.	Statistical data for the frequency of failure from equipment items such as drums, vessels and piping, together with an estimated count of equipment items ('parts count') based on PIDs is used to estimate leak frequencies. The data used to estimate event frequencies in a QRA is based on historical information from a variety of plants and processes with different standards and designs with many contributing causes of failure. It is assumed that these generic failure frequencies apply to installations which have safety management systems corresponding to 'industry practice'. This assumption is believed to be conservative in that it will overstate the risk from modern, well-managed installations such as the IXOM facility which is regulated under the MHF licensing regime.	Sensitive. QRA is primarily depending on the number of equipment items and leak sources included in the model	Conservative
	Operational errors	Identified in HAZID Quantified if significant relative to mechanical integrity failure frequencies	Section 5.3 APPENDIX G APPENDIX I.	Statistical data includes all causes and will therefore include some proportion of human error/operational failures, hence if these are separately quantified there will be an element of double counting. Where relevant operational failures or human error frequency for events that could cause LOC may be estimated based on the human error probability guidance and number of operations where relevant e.g. misalignment of coupling during tanker/drum filling, driveaway. Specific scenarios included/excluded are noted in the HAZID and scenario frequency tables.	Sensitive r May materially affect the risk results if human error frequencies resulting in LOC are high compared to statistical leak frequencies	Conservative
	Process upsets	Identified in HAZID Quantified if significant relative to mechanical integrity failure frequencies	Section 5.3 APPENDIX G APPENDIX I.	Statistical data includes all causes and will therefore include some proportion of process upsets hence if these are separately quantified there will be an element of double counting. Examples of process upset events are high pressure resulting in a vessel failure, overfill resulting in LOC to atmosphere. Typically, these scenarios have multiple hardware control measures and provided standard techniques such as LOPA are used to demonstrate that controls reduce frequency of process upset events resulting in LOC to a frequency similar to statistical LOC frequencies these are not quantified in the QRA. Specific scenarios included/excluded are noted in the HAZID and scenario frequency tables.	Sensitive r May materially affect the risk results if human error frequencies resulting in LOC are high compared to statistical leak frequencies	Best estimate
	Mixing of incompatible materials (e.g. in road tankers)	Not credible	-	Not credible for CLP tanker filling. The road tankers are specific for chlorine and owned by IXOM. No connection to any other materials. NOTE: Existing CAP QRA includes scenarios for mixing incompatible materials, e.g. sodium hypochlorite and acid	-	-
	External factors/natural hazards	Not quantified	-	No natural hazards (e.g. earthquake, flood) identified as high risks Not under direct flight path Not quantified	-	-

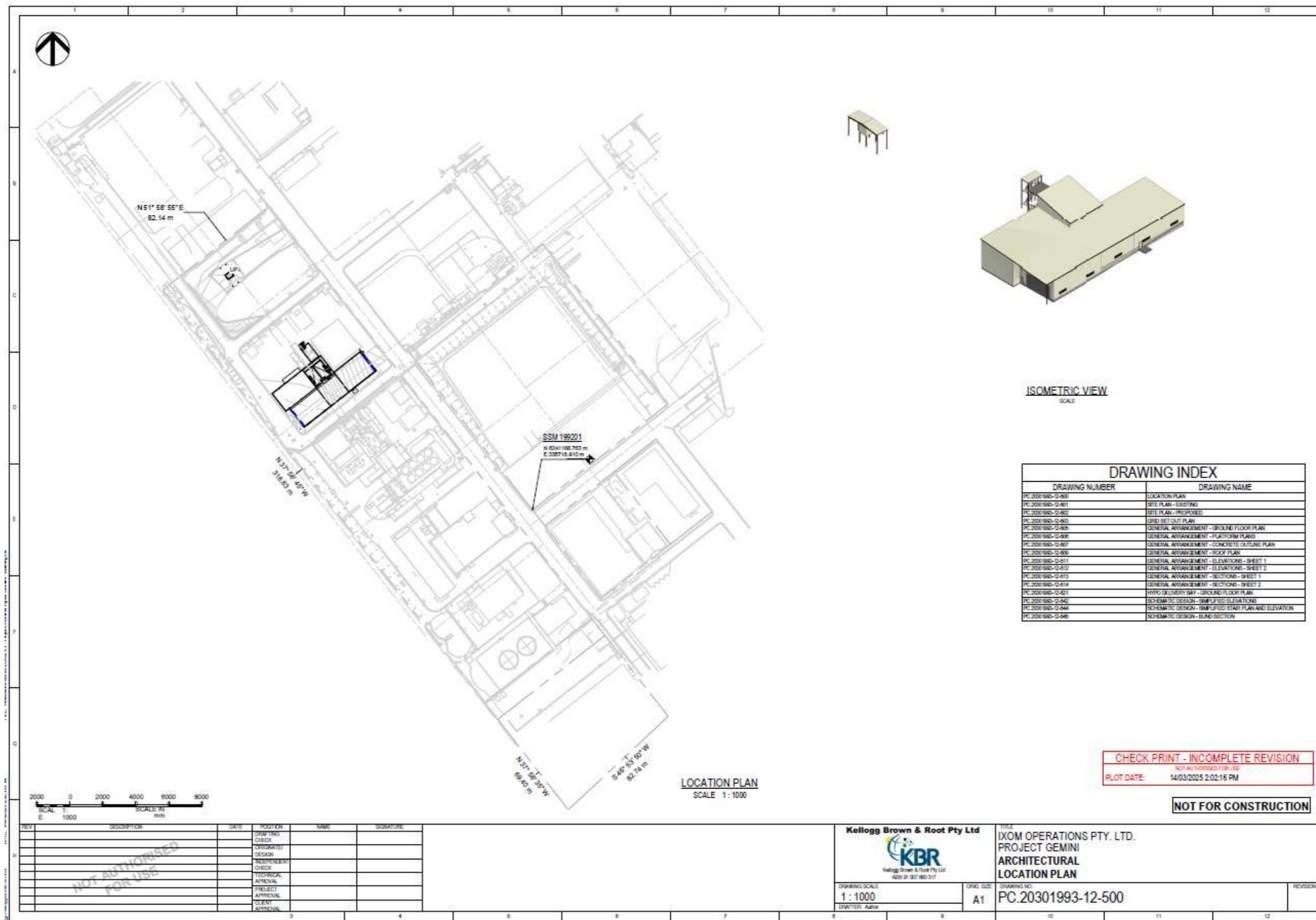
Study area	Item	Approach for CLP	Report reference	Comments	Sensitivity of overall modelling	Level of conservatism
Environmental factors	Meteorological data	Nearest BOM station Sydney Airport (AWS 66037)	APPENDIX D.	Nearest available meteorological station with hourly measurements of wind speed and direction. 10 years of data obtained and consolidated to format required for Riskcurves data entry.	Minor	Best estimate
	Environmental conditions	Nearest BOM station Sydney Airport (AWS 66037)	Section H5	The environmental data including ambient temperature, relative humidity used for the study is the average annual day and average annual night values from the nearest available meteorological station data	Minor	Best estimate
	Surface roughness factor	Estimated based on surrounding obstacle height	Section H5	Ground roughness affects turbulent flow properties of wind, hence the toxic dispersion behaviour. Surroundings fit the descriptor 'area with densely located low buildings or an industrial area with low structures' such as the BIP. This surface roughness factor is also appropriate for suburban areas adjacent to the BIP.	Sensitive Can have a significant impact on dispersion results. Higher surface roughness lengths result in smaller dispersion distances.	Best estimate
Consequence analysis	Process condition	Normal process conditions as per mass and energy balance	Section H6.	Data developed as available at design stage of project from PFDs	Minor	Best estimate
	Limiting flowrate	Physical limits downstream of pumps, control valves applied	Section H6.	Where relevant maximum release rate was limited to the maximum production or feed rates, or design flowrate for pumps or control valves. This avoids unrealistically high calculated leak rates that are not physically possible	Minor	Conservative
	Release inventory	Maximum isolatable inventory	Section H6.	Maximum inventory in the vessel or isolatable section.	Minor unless there are significant periods of time with low or no inventory	Conservative
	Bunds	Liquid spills constrained to surface area as per layout	Section H6.	Each storage tank has a separate bund (57.4 m ² each). The releases from the liquefier, pumps and associated piping are contained by the bund.	Minor (unless unconstrained)	Best estimate
	Modelled hole sizes	Typically 3mm to and rupture	Section H6.	The hole sizes are based on the corresponding leak sizes provided in the frequency data used. These cover a range of leak sizes from small (3 mm), medium (25 mm) to rupture i.e. full pipe diameter.	Minor	Best estimate
	Maximum release duration	1 hour	Section H6.	By convention in QRAs (which cover only abnormal accident events, not longer duration/chronic exposures in the workplace), the maximum event duration is set to a maximum of 1 hr as it is not reasonable to assume static conditions for the release, environmental conditions or exposure for longer periods. Also note that for dispersion modelling typically a release duration longer than 15-30 minutes is effectively a continuous source term, i.e. the maximum effect footprints are reached	Sensitive	Conservative
	Isolation time	3 mins to 1 hour	Section H6.	Durations of 3 to 60 minutes to manually isolate and control a leak from the plant or remotely from control room have been assumed. Isolation times only apply to transfer activities such as production rate and pumping to fill drums or a tanker. Isolation times are not applicable to inventories such as storage tanks. These durations judged to apply as noted in scenario tables are based on process alarms that would alert the operator to a problem, and also a large number of chlorine detectors distributed throughout the plant area. Accounting for automatic detection and isolation would be anticipated to reduce this and can be verified at detailed design stage.	Sensitive	Conservative
	Toxicity criteria	Probit for fatality AEGL for injury/irritation toxicity thresholds	Table 4.4. Section H6	Toxic dose based on probit was used to assess fatality effects Equivalent toxic dose based on AEGL 10 minutes was used to assess injury/irritation effects as use of concentration values only does not account for exposure duration.	Sensitive	Best estimate

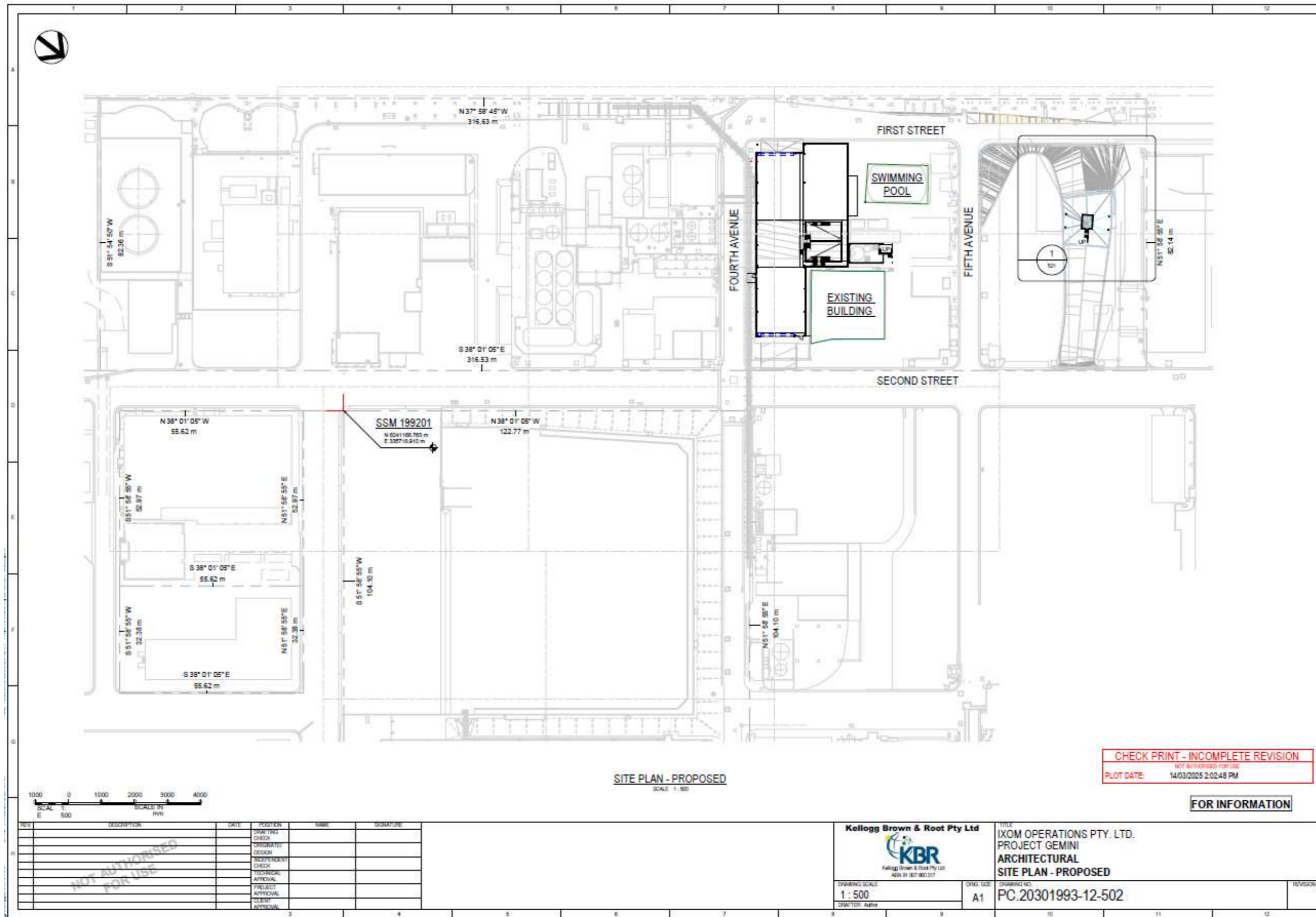
Study area	Item	Approach for CLP	Report reference	Comments	Sensitivity of overall modelling	Level of conservatism
	Receptor height	1.5 m	Section H5	Around upper body/face height.	Minor as majority of releases at ground level (Can have a significant impact on dispersion results if receptor is at different elevation to release point).	Best estimate
Frequency analysis	Base frequencies	Statistical leak frequency data	Section I2	Statistical data for the frequency of failure from equipment items such as drums, vessels and piping, together with an estimated count of equipment items ('parts count') based on PIDs is used to estimate leak frequencies. The data used to estimate event frequencies in a QRA is based on historical information from a variety of plants and processes with different standards and designs with many contributing causes of failure. It is assumed that these generic failure frequencies apply to installations which have safety management systems corresponding to 'industry practice'. This assumption is believed to be conservative in that it will overstate the risk from modern, well-managed installations such as the IXOM facility which is regulated under the MHF licensing regime	Sensitive. QRA is primarily depending on the number of equipment items and leak sources included in the model	Conservative
	Online probability	Applied only for periodic activities such as tanker loading	Section I3	Continuous plants assumed to be on line 100% of time with maximum inventory 100% of time This is conservative as there will be periods where plants have no or lower inventories (e.g. planned shutdowns).	Minor	Conservative
	Effect of control measures	Estimated using databases or event trees	APPENDIX F containment building/scrubber) Section I4 (other control measures)	The main safeguards accounted for in the CLP are the containment building/scrubber and chlorine detection and automatic shutdown. An event tree has been developed to estimate containment building/scrubber failure probability of the using conservative data. For the purposes of the planning stage QRA the estimated overall containment unavailability is 5% 'unavailable' for both short duration (4%) and completely unmitigated (1%) events. Conservatively the QRA assumes that 5% of all events are completely unmitigated, i.e. the LBS has no effect and does not model the short duration events separately. At the detailed design stage, the QRA may be refined to differentiate between short duration and unmitigated releases but at the planning stage the approach taken is regarded as appropriately conservative.	Sensitive	Conservative
Societal risk	Population data	2021 Census supplemented as relevant	APPENDIX E	Census 2021 supplemented by estimates from developer for Qenos and Indorama sites on BIP. Sensitivity study doubling likely expected population on BIP land.	Minor	Best estimate
Onsite risk	IXOM occupancy	Shift patterns for normal and contingent case	APPENDIX K	The number of operators for the normal and contingent case was estimated by IXOM and used for onsite risk modelling to adjust probability of exposure .	Minor	Best estimate
Risk assessment	Risk criteria	HIPAP 4	Section 4.6	The risk results assessed against the HIPAP 4 quantitative and qualitative risk criteria. By convention, and as a conservative measure, risk contours are usually plotted on the basis that the individual is exposed for the full duration of the hazardous incident and no account is taken of evasive action or protection by clothing, buildings etc. HIPAP 4 contour levels have been set by the authority such that risk is very low compared to risk routinely accepted Societal risk criteria are indicative as per HIPAP 4	Not applicable – risk criteria are set by DPHI	Conservative
	Societal risk	Population data from Census for probability of presence and numbers Mitigation factors allowed for indoor protection based on ventilation rate	APPENDIX E Section H6	Accounts for <ul style="list-style-type: none"> the number of people in the affected area, the nature and scale of incidents which contribute to particular risk levels at particular points proportion of indoor/outdoor population outcomes of these incidents including any mitigation effects e.g. from being indoors resulting in a reduced toxic dose. 	Sensitive	Best estimate

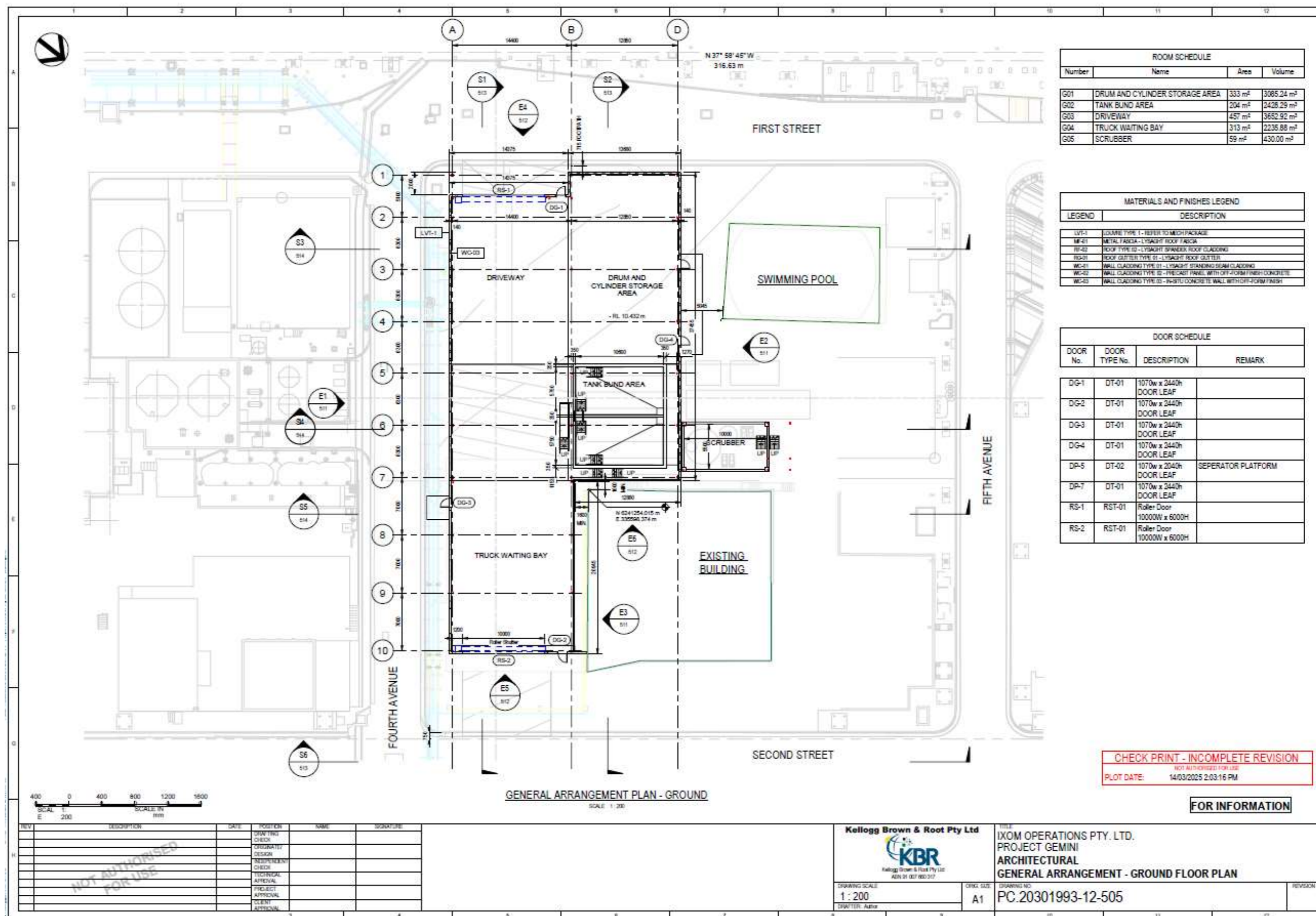
APPENDIX C. DRAWINGS

C1. Layouts

This includes various views of the CLP building layout for both normal and contingent cases

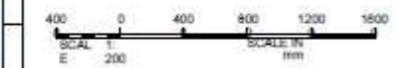






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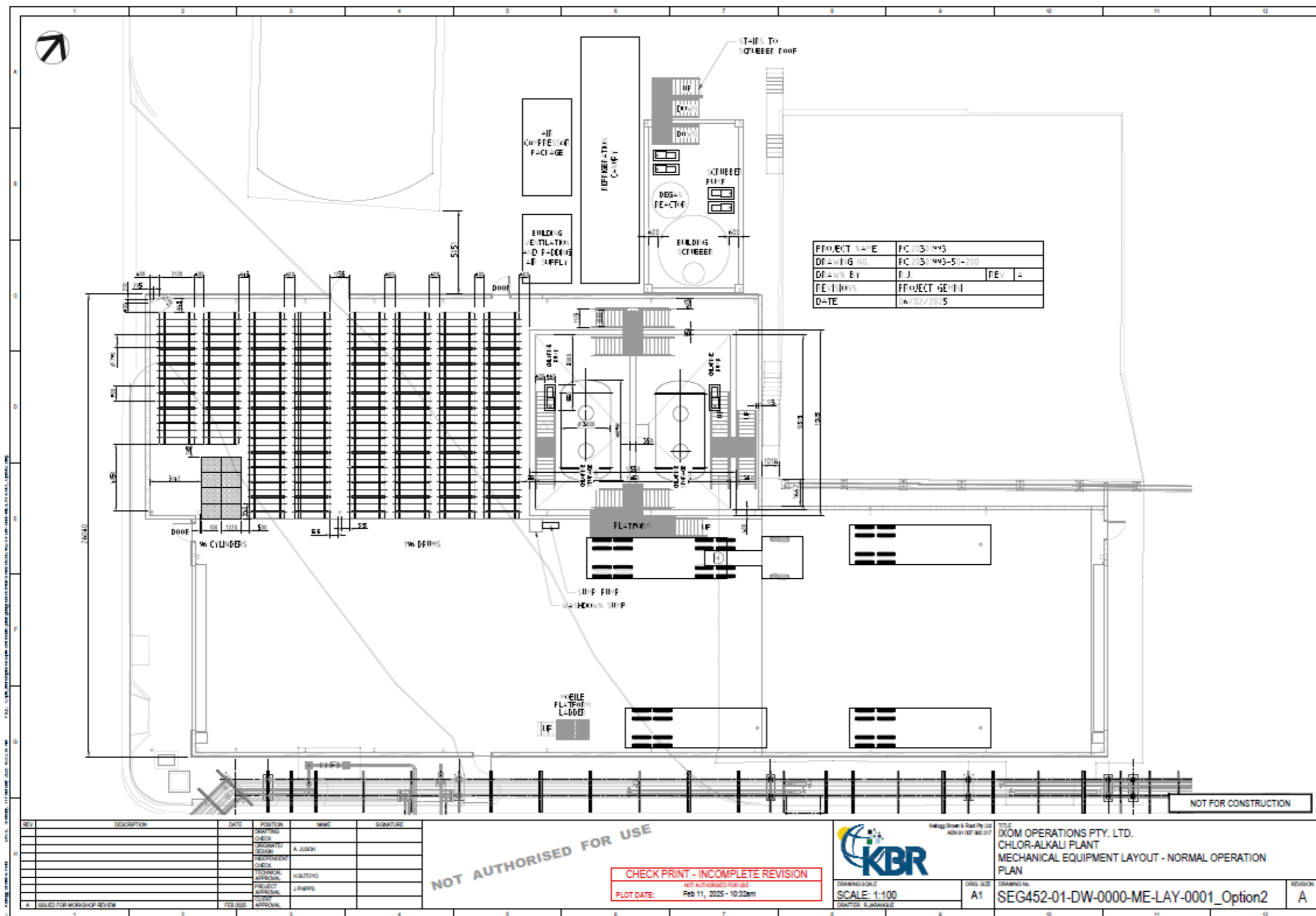


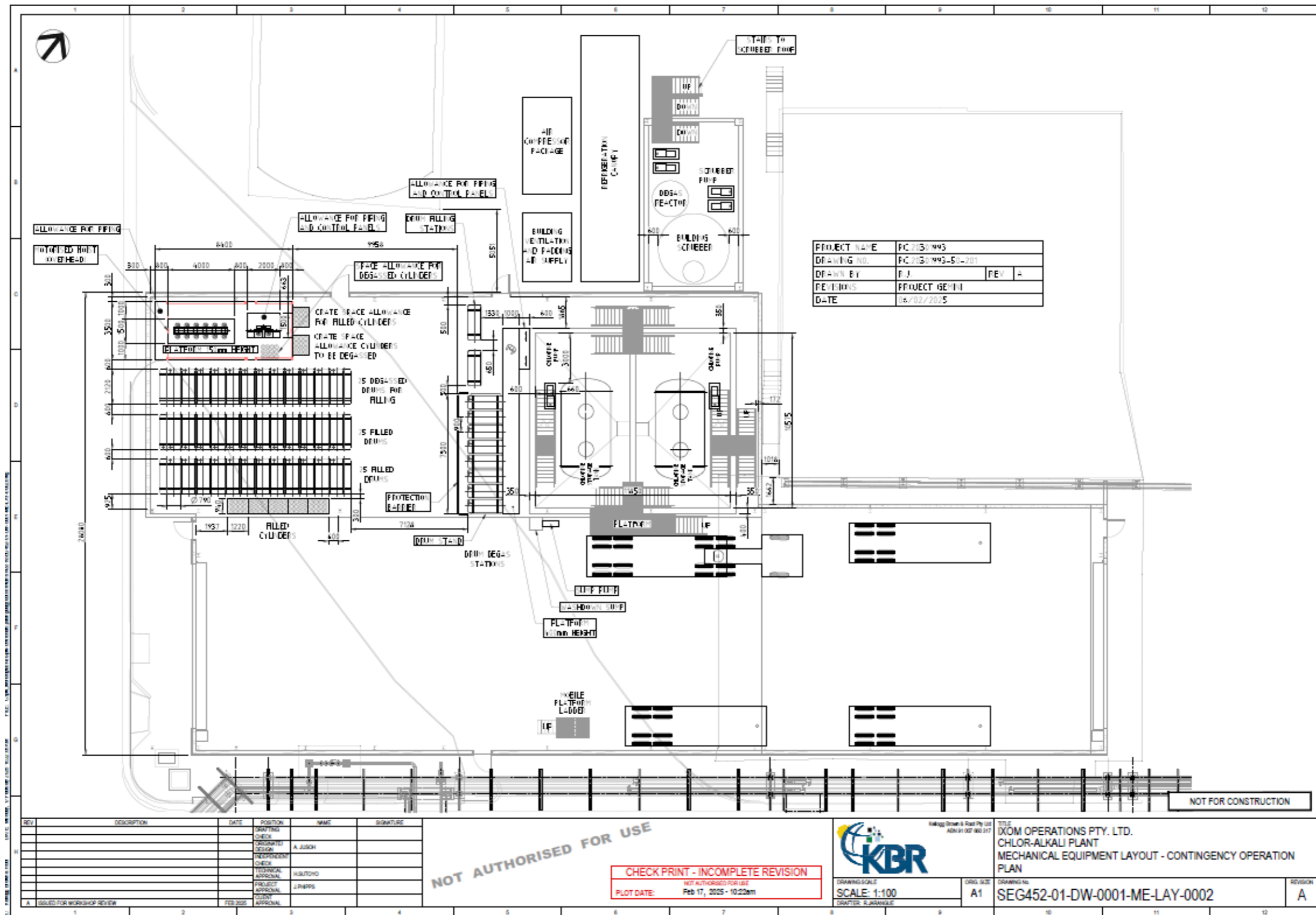
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Kellogg Brown & Root Pty Ltd

IXOM OPERATIONS PTY. LTD.
PROJECT GEMINI
ARCHITECTURAL
GENERAL ARRANGEMENT - GROUND FLOOR PLAN

DRAWING SCALE: 1:200
 DRAWING NO: PC.20301993-12-505
 DRAWING SIZE: A1
 DATE: 14/03/2025





REV	DESCRIPTION	DATE	POSITION	NAME	SIGNATURE
	DRAFTING CHECK				
	DRAWING DESIGN			A. JESSON	
	INDEPENDENT CHECK				
	TECHNICAL APPROVAL			H. KATONG	
	PROJECT APPROVAL			J. HARRIS	
	ISSUED FOR WORKSHOP REVIEW	FEB 2025			

NOT AUTHORISED FOR USE

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NOT AUTHORIZED FOR USE
PLOT DATE: Feb 17, 2025 - 10:22am



DRIVING SCALE: SCALE: 1:100
DRAWN: R. RANJAN

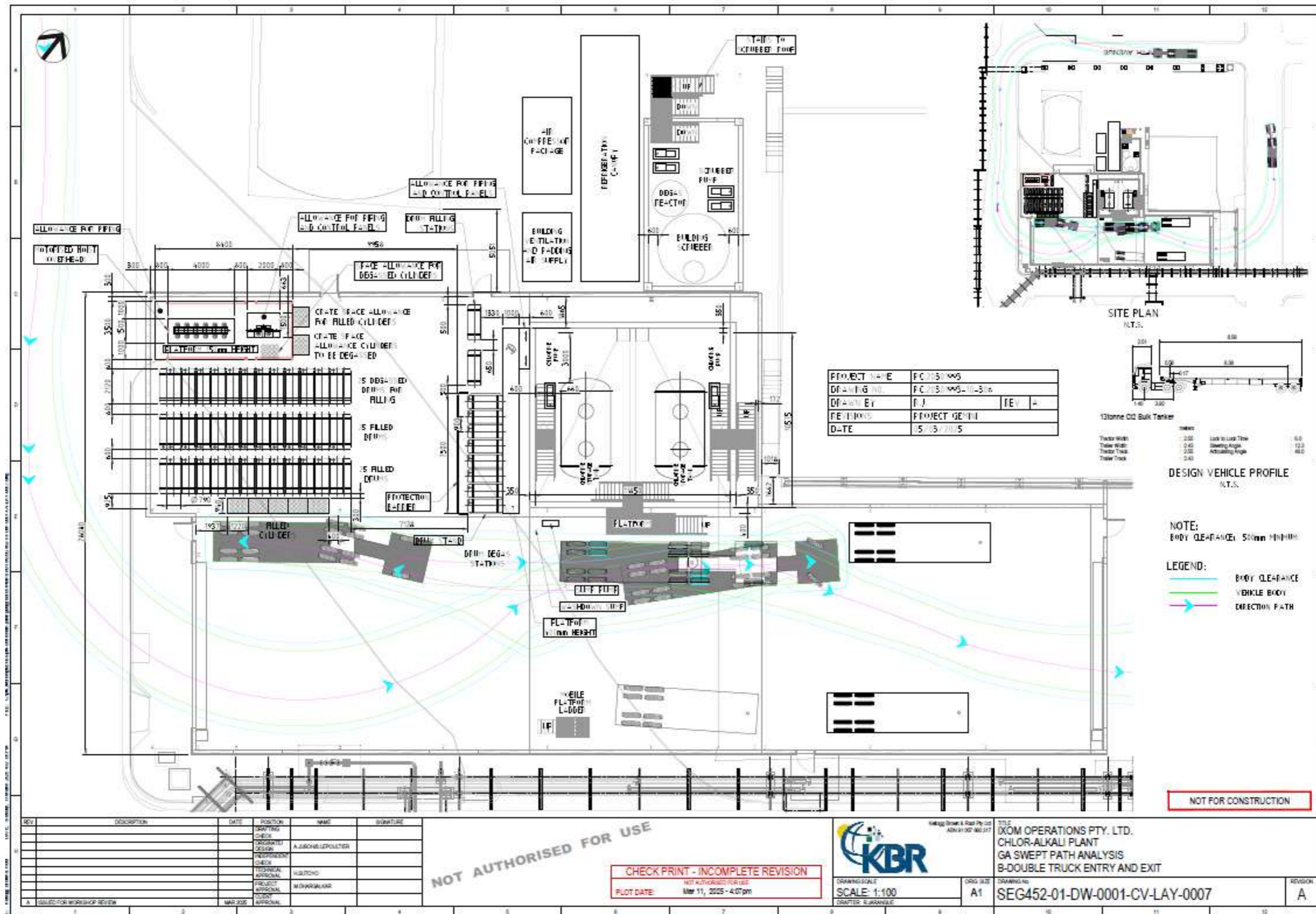
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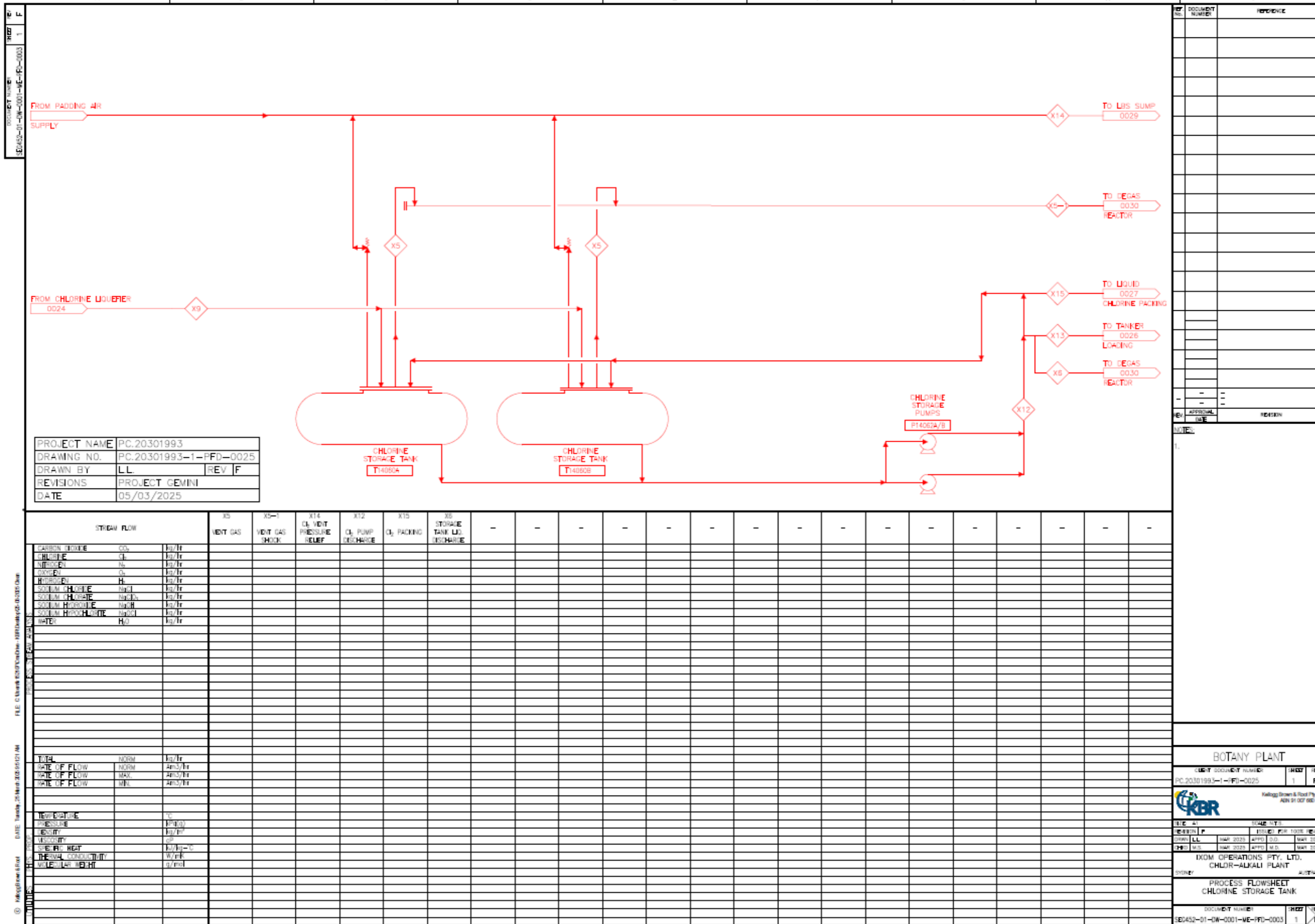
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CHLOR-ALKALI PLANT
MECHANICAL EQUIPMENT LAYOUT - CONTINGENCY OPERATION PLAN

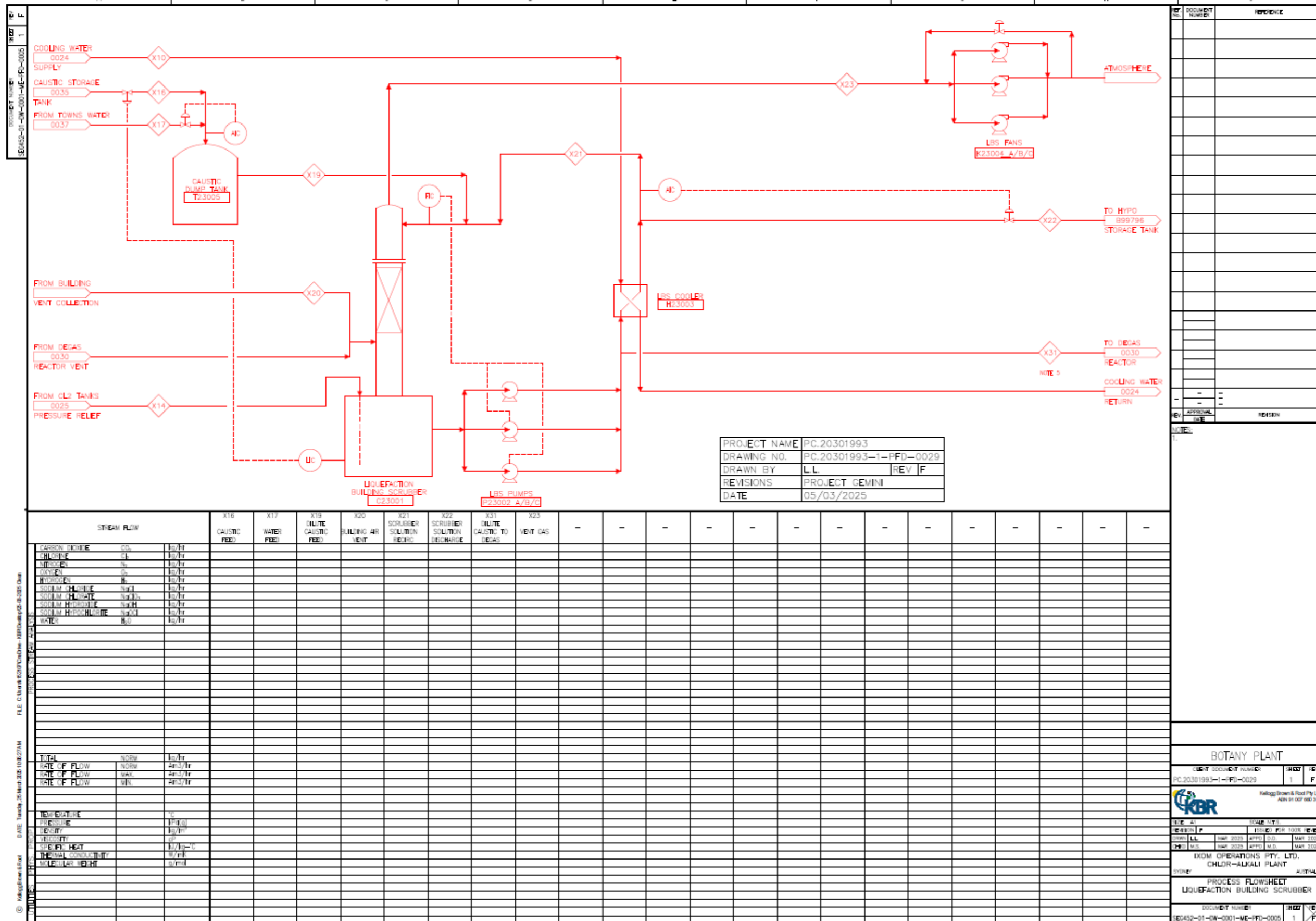
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REVISION: A

NOT FOR CONSTRUCTION







APPENDIX D. METEOROLOGICAL DATA

D1. Data source

Historical meteorological weather data for the 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 66037) over the period of June 2014 to June 2024. The station is located approximately 2 km away.

The following data were sourced from the BoM for AWS 66037:

- Wind speed
- Wind direction
- Temperature
- Humidity
- Ceilometer cloud data
- Solar elevation angle data.

D2. Pasquill stability class

The actual Pasquill stability classes were determined using the Gifford, Ref [7], definition of the conditions for different stability classes as summarised below. The ceilometer cloud and solar elevation data were used to accurately classify the data into stability classes defined by Gifford.

Table D.1: Stability class allocation

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

D3. Representative stability class and wind speed

The TNO Purple Book approach uses a correlation between the actual Pasquill stability class and wind speed to determine the representative Pasquill stability classes, as presented in Table D.2.

Suitable analysis of the obtained raw data from the BoM was performed using the approach detailed in the TNO Purple Book, and the data were consolidated into six different representative weather conditions, as per table above, which are:

- Pasquill stability class: B (medium); wind speed 2.8 m/s (B2.8)

- Pasquill stability class : D (low); wind speed 4.5 m/s (D1.7)
- Pasquill stability class : D (medium); wind speed 4.3 m/s (D4.3)
- Pasquill stability class : D (high); wind speed 8.4 m/s (D8.4)
- Pasquill stability class : E (medium); wind speed 3.1 m/s (E3.1)
- Pasquill stability class : F (low); wind speed 1.4 m/s (F1.4).

Table D.2: Allocation of observations into six representative weather classes

Surface wind speed, m/s	Actual Pasquill stability class							
	A	B	B/C	C	C/D	D	E	F
< 2.5	B Medium			D Low			F Low	
2.5-6				D Medium			E Medium	
> 6				D High				

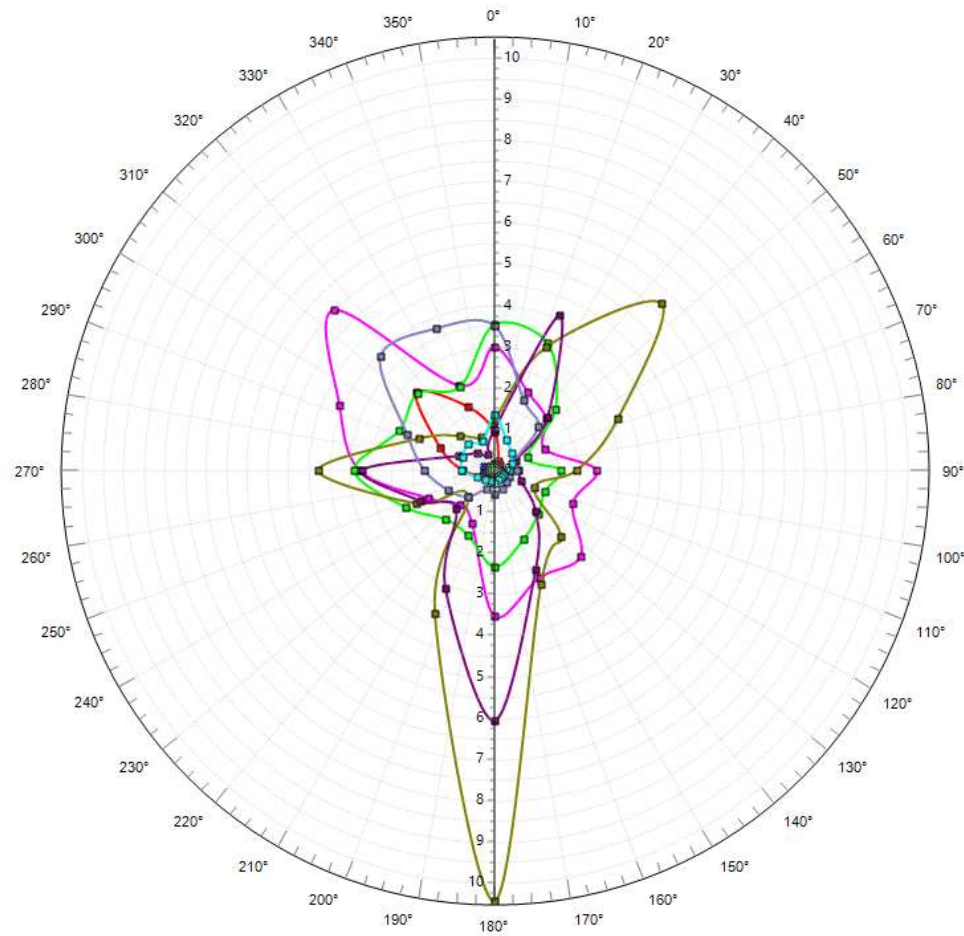
The meteorological data sets used for the QRA are presented in Table D.3. Additionally, the wind rose map is also provided in Figure D.1.

Table D.3: Meteorological data sets used for QRA

Direction wind from	Probability of occurrence of windspeed ranges (m/s), within stabilities classes in the day and at night												Total day	Total night
	B2.8	B2.8	D1.7	D1.7	D4.3	D4.3	D8.4	D8.4	E3.1	E3.1	F1.4	F1.4		
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night		
N	0.94	0.00	0.15	0.16	3.00	3.54	1.22	1.00	0.00	3.50	0.00	1.35	5.30	9.54
NNE	0.26	0.00	0.07	0.12	2.07	3.33	3.24	4.08	0.00	1.85	0.00	0.79	5.64	10.18
NE	0.16	0.00	0.06	0.11	1.78	2.07	5.72	1.80	0.00	1.48	0.00	0.60	7.72	6.06
ENE	0.11	0.00	0.08	0.08	1.32	0.87	3.24	0.56	0.00	0.49	0.00	0.44	4.75	2.43
E	0.14	0.00	0.12	0.09	2.48	1.61	1.98	0.58	0.00	0.54	0.00	0.35	4.72	3.16
ESE	0.08	0.00	0.09	0.07	2.06	1.32	1.06	0.70	0.00	0.40	0.00	0.25	3.29	2.74
SE	0.07	0.00	0.07	0.05	2.95	1.52	2.29	1.40	0.00	0.39	0.00	0.21	5.38	3.58
SSE	0.11	0.00	0.10	0.08	2.82	1.81	2.98	2.62	0.00	0.50	0.00	0.26	6.01	5.26
S	0.18	0.00	0.12	0.10	3.54	2.35	10.45	6.09	0.00	0.58	0.00	0.33	14.28	9.45
SSW	0.16	0.00	0.11	0.08	1.40	1.71	3.77	3.09	0.00	0.48	0.00	0.28	5.43	5.65
SW	0.19	0.00	0.12	0.08	1.19	1.68	0.90	1.34	0.00	0.89	0.00	0.33	2.40	4.31
WSW	0.33	0.00	0.18	0.09	1.75	2.33	2.07	1.94	0.00	1.23	0.00	0.45	4.34	6.04
W	0.78	0.00	0.25	0.16	3.28	3.42	4.29	3.23	0.00	1.71	0.00	0.79	8.60	9.32
WNW	1.41	0.00	0.29	0.15	4.08	2.49	1.98	0.95	0.00	2.31	0.00	0.83	7.76	6.73
NW	2.68	0.00	0.14	0.13	5.50	2.66	1.18	0.61	0.00	3.92	0.00	0.91	9.50	8.22
NNW	1.68	0.00	0.10	0.12	2.24	2.19	0.86	0.42	0.00	3.72	0.00	0.78	4.88	7.23
Total	9.27	0.00	2.06	1.68	41.45	34.89	47.22	30.41	0.00	23.99	0.00	8.96	100.00	100.00

Figure D.1: Wind Rose Distribution

B2.8 Day D1.7 Day D1.7 Night D4.3 Day D4.3 Night D8.4 Day D8.4 Night E3.1 Night F1.4 Night



APPENDIX E. POPULATION DATA

E1. Source data

Residential population data from the 2021 Census was obtained from the ABS. Employment population (i.e. industrial/commercial) was obtained from Transport for NSW (TfNSW). The Travel Zone (TZ) Projection 2025 developed from the 2016 Census was used.

The data was initially obtained for areas within approximately a 3km radius of the centre of the BIP site. This is greater than the largest estimated impact area to the 1% fatality consequence for any scenario in the QRA, so is sufficient to account for all potentially affected populations.

This data was then supplemented by specific data for particular locations such as Eastgardens and Bunnings.

Table E.1 summarises the various data sources used to compile the population data input to the QRA.

Table E.1: Data Sources

Data	Source	Comments
Data for general area		
Residential population	Aust Bureau of Stats www.abs.gov.au	Latest available ABS Census data is 2021. This data represents the maximum residential population (i.e. nighttime). Data was supplied by ABS as a centroid for each Census Statistical Area (SA) Level 1 (X, Y, no of people).
Employed population (i.e. commercial/ industrial)	TfNSW	Data was supplied by TfNSW for each Travel Zone around the BIP site as a centroid (X, Y, no of people). This data represents the number of people who travel into the area close to the BIP for work, i.e. the commercial/industrial population. The data is produced from information collected in the 2016 Census a sit has not been made available using the 2021 Census. The values projected for 2025 were used.
BIP site (current data)		
Population on BIP site (i.e. BIP, Nant St)	Refer to future BIP population	The population of the BIP (505 during day, 51 at night) has been removed from the employment data for the TZ that covers the BIP and the populations on the BIP site and Nant St set to 0. The remaining population from the employment data (TZ400) has been reallocated over the remaining area of the travel zone that the BIP is within. Qenos / Indorama area have population assigned as per Section E2

Data	Source	Comments
Additional point sources		
Schools	-	No specific data was entered for schools as the pupils are assumed to be largely local and covered by the Census data. The nearest school is Matraville Public around 400 m to the east of Denison St.
Eastgardens shopping centre	Joint Regional Planning Panel report (JRPP Number 2014SYDE076) for DA 2017/1107 by Bayside Planning Panel states car spaces as 3,089 (though 418 are for staff)	Eastgardens Shopping Centre population is assumed as <u>3,089</u> shoppers (in addition to the staff who are identified in travel zone data TZ423) for daytime only. Note: that this is regarded as a best estimate and could be an over or underestimate for shoppers as there would be multiple people in some cars and public transport usage, but people are not present all day.
Bunnings development, Denison St east side	Dangerous Goods Transport QRA, Denison St, Hillsdale (Systra Scott Lister Issued: 12th February 2015)	<u>200</u> people (daytime only).
BIP subdivision, Denison St west side	Statement of Environmental Effects (SEE) Botany Industrial Park Staged 20-Lot Subdivision 20 Dec 2010	DA 10/486 approved by Land and Environment Court on 13/09/2012 for 20 lot subdivision. Number of people over whole area (including former Masters site on Corish Circle) estimated at 40 based as this is a concrete batching works (reduced compared to 265 for previous QRA which was based on warehousing). <u>200</u> day time only on the southern part of the subdivided area along Denison St as advised by the DPE. Zero population on lots with covenant (i.e. R1 and R2 restrictions as per Deposited Plan 1204999) .
Meriton development Former BATA Site, Banks Avenue, Heffron Road & Bunnerong Road, Eastgardens	-	Not included. Sensitivity case in previous BIP QRAs – too far away to affect FN results.

E2. Future BIP population

For the areas within the BIP boundary, the density population of 40 people per hectare (daytime 100% and nighttime 10%) was assumed based on the future operations likely to be industrial warehousing and included in the societal risk calculation.

E3. Day and night population

Weighting factors (Table E.2) have been applied to the raw data to distribute population between day and night and inside and outside populations. The factors used are summarised in the following table. Note that these factors have been agreed with DPIE in previous studies and have not changed since the previous QRA.

The day and night factors have been applied to raw data from 2021 Census (residential) and TfNSW (employment), which are provided in Table E.3 and Table E.4. The population data were reviewed and adjusted in some cases as described in Table E.1

Table E.2: Population Factors

Factor	Value	Comments
Day and nighttime weighting factor	0.5	Assumed that day is 6am to 6pm
Night time population	Census	Residential only. Census data values used for residential population. The population of schools and industrial or commercial areas are assumed 0
Fraction of population outside at night	0.05	No particular basis. Has been used before in previous studies approved by DPIE.
Day time population	Census adjusted as per comments	No particular basis. Has been used before in previous studies approved by DPIE. Residential – use 1/3 of Census value. (Remaining 2/3 assumed at work out of area) Other industrial/commercial - use values in Travel Zone data and additional sources (e.g. Eastgardens shoppers) in Table A8.2.
Fraction of population outside during day	0.10	No particular basis. Has been used before in previous studies approved by DPIE.

Table E.3: Residential Populations (Reference: 2021 Census Data)

SA1 2022	Estimated Nighttime Population	Estimated Daytime Population
11701132001	4	2
11701132002	487	163
11701132003	0	0
11701132108	444	148
11701132113	521	174
11701132121	0	0
11701132124	356	119
11701132125	79	27
11701132126	314	105
11701132133	341	114
11701132135	383	128
11701132136	88	30

SA1 2022	Estimated Nighttime Population	Estimated Daytime Population
11701132137	397	133
11701132138	281	94
11701132139	755	252
11701132128	305	102
11701132129	367	123
11701132130	266	89
11701132302	295	99
11701132332	347	116
11701132334	386	129
11701132333	351	117
11701132335	555	185
11701132311	335	112
11701132312	299	100
11701132313	336	112
11701132314	412	138
11701132318	256	86
11701132319	389	130
11701132320	506	169
11701132331	364	122
11701132336	1212	404
11701132330	1492	498
11701132322	376	126
11701132323	478	160
11701132324	7	3
11701132325	377	126
11701132326	321	107
11701132327	431	144
11701132328	502	168
11701132329	252	84
11701132401	6	2
11802165318	393	131
11802165322	504	168
11802165303	495	165
11802165329	551	184
11802165310	678	226
11802165313	622	208
11802165308	503	168
11802165312	353	118
11802165323	336	112
11802165324	298	100

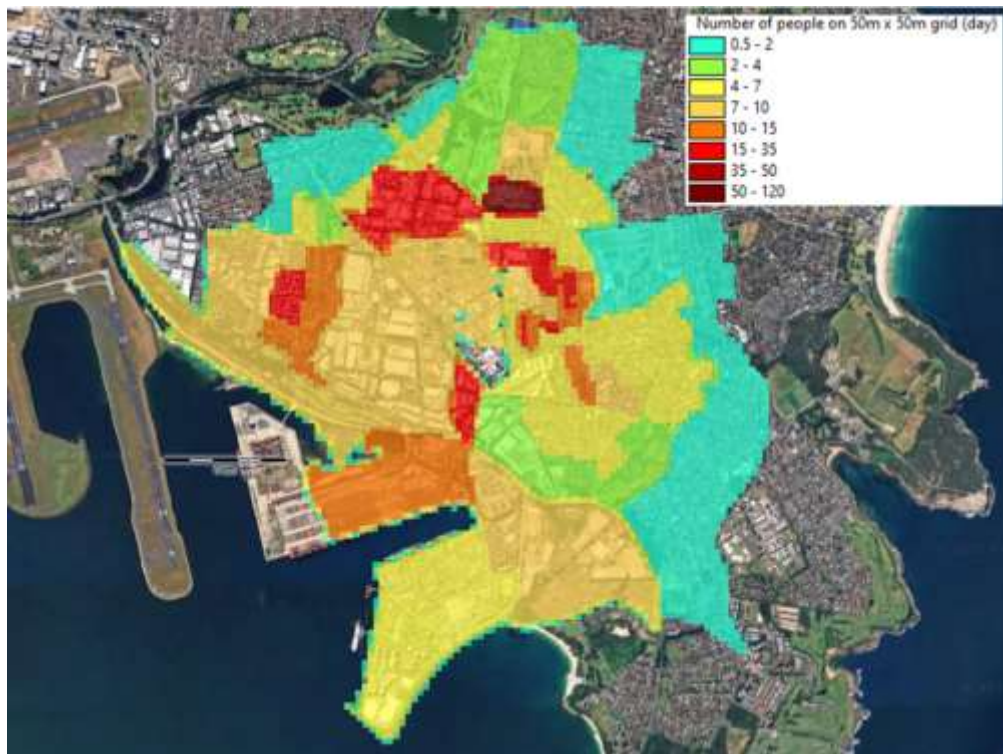
SA1 2022	Estimated Nighttime Population	Estimated Daytime Population
11802165328	510	170
11802165311	262	88
11802165309	538	180
11802165305	387	129
11802165319	321	107
11802165316	392	131
11802165321	375	125
11802156805	437	146
11802156815	591	197
11802156821	0	0

Table E.4: Transport Populations (Reference: TfNSW)

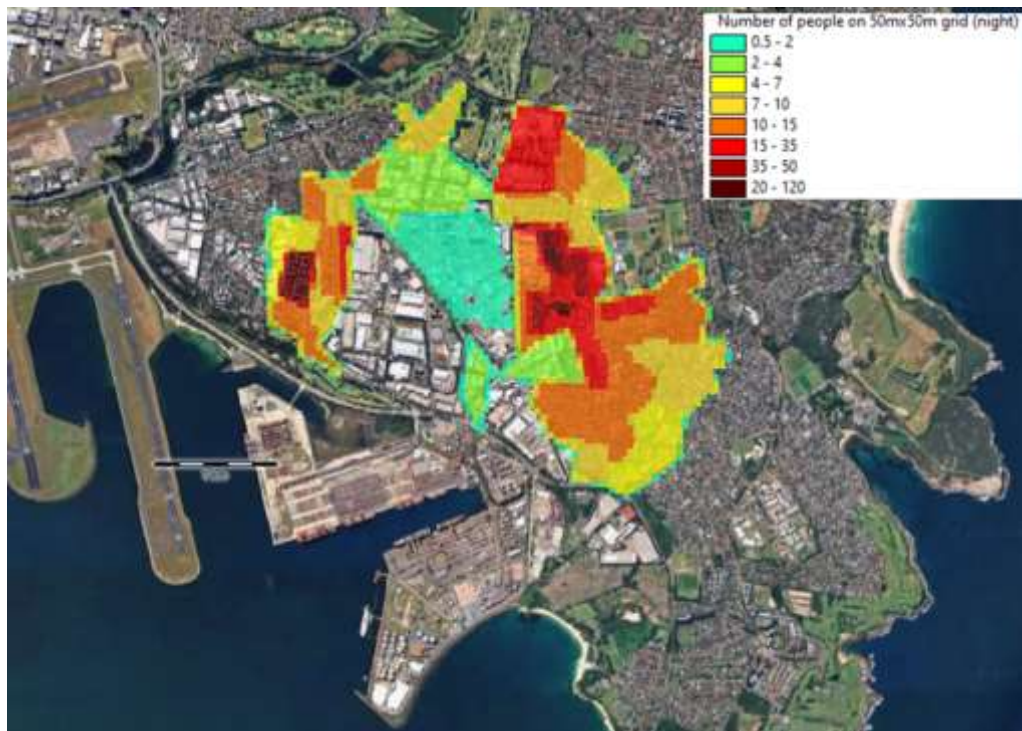
Transport Zone	Description	Estimated Daytime Population	Estimated Nighttime Population
400	Orica Australia	4897	0
401	Discovery Cove Industrial Park	3870	0
402	Caltex Sydney Terminal	3828	0
406	Botany William St	138	0
408	Botany Industrial Area	5242	0
421	Bonnie Doon Golf Club	1089	0
422	Pagewood Wentworth Av and Page St	341	0
423	Eastgardens Shopping Centre	341	0
424	South Point Shopping Centre	599	0
425	Matraville Public School	63	0
428	Port Botany Business Park West	371	0
429	Military Rd	3713	0
430	Port Botany Southern Container Terminal	2460	0
624	Matraville Eastern Rd and Beauchamp Rd	135	0
625	Matraville	667	0
627	Matraville Menin Av and Flinders St	528	0
628	Port Botany Business Park East	114	0
629	Matraville High School	744	0
640	South Sydney High School	524	0
645	Heffron Park	156	0

E4. Day and night population maps

Day time population (number of people per 50m x 50 m grid)



Night time population (number of people per 50m x 50 m grid)



APPENDIX F. LIQUEFACTION BUILDING AND SCRUBBER DESIGN

F1. Containment building

The majority of liquefaction facility except for the refrigeration unit and the building ventilation and scrubbing system will be located inside a large containment building. The refrigeration units are directly adjacent to the building wall around the chlorine liquefier to minimise pipe runs. The liquefaction building scrubber is located at the northeast side of the building adjacent to the degas reactor. The design intent is that any leaks can be fully contained and then directed to a scrubber at a manageable rate. The building site layout, showing the location of equipment and storage areas, are provided in Figure 3.4.

The building design incorporates the design of the liquid chlorine production and the packing/filling building at Laverton. The building wall is 15.7 meter high at the southeast side of the building to accommodate the chlorine liquefier. The building roof then slides down at 6° towards the northwest direction to 8-meter high.

The building ventilation system is used during normal and contingent operation to maintain a negative pressure in the building and provide adequate air recirculation. The ventilation fan is used to extract air from the building. The capacity of the building ventilation fan is 11.1 m³/s. When the ventilation fan is operating, the air velocity through the air inlet is estimated at around 0.7 m/s, and the building pressure will be maintained at a slight vacuum of around -15 Pa. Weatherproof louvres will be maintained manually open for any additional make up air.

When a chlorine release is detected in the building, ventilation fan and the motorised air damper will be closed. Various chlorine vent scrubbing isolation valves near the chlorine release point will open and the scrubber fan will ramp up to suck building air through the scrubber. The weatherproof louvre will be maintained manually open to provide make up air to the building scrubber.

F2. Containment building availability

The potential failure modes of the LBS have been identified, and an associated event tree has been developed to estimate the probability that a chlorine release will not be contained. There are two different event tree nodes considering different starting states. Note that:

- 'Building state closed' is the starting state of the building which is the case 97% of the time. In this case, as per the event tree, there is no action required in relation to closing the vehicle roller doors on chlorine detection as they are already in the closed state.
- For the starting state of 'Building open' (i.e. for the portion of time vehicles are entering or leaving) the roller doors would close as soon as the vehicle fully enters or exits the building. If this does not occur, an alarm will be generated, and the operator will have the ability to close the doors via a push button located on the

outside of the building or remotely from the control room using CCTV surveillance. Roller doors will be fitted with position switches and will be monitored remotely from the control room via CCTV therefore negating the need for manual inspection.

- In the event of a detected chlorine release in the building, an audible and visual alarm would be initiated at both the CLP Building and the control room, and the roller doors will automatically close if not already in the closed state. If an operator were in the building, they would be trained to immediately leave the building via the nearest exit to the site safe haven
- Percentages open has been determined by calculating the time a roller door needs to be open to allow for a truck to enter or exit the building for both the Normal Case and Contingent Case. Door opening and closing times are based on IXOM's Laverton North VIC Chlorine Liquefaction Plant. Only one roller door will be open at a time. That is, the entry roller door will open to allow a truck to enter the building then immediately close. The exit roller door will open when the vehicle is ready to leave then immediately close. An alarm will be raised if either door does not close after a truck has passed through it. There is no room in the building for truck queuing with open doors and there is no requirement for this based on throughputs.
- Pedestrian doors will be self-closing wind proof doors as per the Laverton Plant and will always be in the closed position except for when an Operator enters or exits the building. This is not quantified as the open time will be very short.
- Chlorine gas detectors wiring network will be designed with redundancy in the wiring such that the failure of a single chlorine detector will not lead to a loss of detection of a potential leak. Common cause failure of all chlorine gas detectors is not credible. Common cause failure of wiring may be possible however detailed design will ensure that there is sufficient redundancy of the wiring such that this failure is detected (i.e. fault detection/loss of communications detection is provided) and interlocked with the CLP operation which will lead to a failsafe state such that if chlorine detection is unavailable then liquefaction operations shall be shutdown and/or prevented from occurring. Failure of chlorine detection is not quantified in the event tree.

For the purposes of the planning stage QRA the estimated overall containment unavailability is 5% 'unavailable' for both short duration (4%) and completely unmitigated (1%) events. Conservatively the QRA assumes that 5% of all events are completely unmitigated, i.e. the LBS has no effect and does not model the short duration events separately. At the detailed design stage, the QRA may be refined to differentiate between short duration and unmitigated releases but at the planning stage the approach taken is regarded as appropriately conservative.

NOTE: Chlorine releases outside the building are not mitigated by the Containment Building and the event tree does not apply.

Event tree failure mode	Critical controls	Potential consequence	Justification	Included in event tree
Building ventilation - failed to stop on chlorine release - LBS starts	<ul style="list-style-type: none"> Motorized damper Operator detection – can shut down building ventilation remotely and locally 	Release chlorine through building exhaust	<p>If building fans fails to stop, the motorised damper stops air flow to the building ventilation fans. For a release to occur to atmosphere the building ventilation fan would need to remain running AND the damper would need to stay open</p> <p>Operators can also stop building ventilation fans and close damper remotely or locally.</p> <p>NOTE: If all other controls fail, the LBS once will still suck in most of chlorine as the ventilation building ventilation duct inlets are elevated and the LBS inlet ducts at lower at the level of the process equipment.</p>	<p>Yes</p> <p>Frequency included in the overall building unavailability event tree.</p> <p>Modelled as release in open area (i.e. building/scrubber assumed ineffective)</p>
Building ventilation stops AND LBS inlet dampers fails to open	<ul style="list-style-type: none"> Operator detection – can manually close air inlet dampers remotely and locally Multiple motorized LBS inlet dampers, fail open 	Discharge chlorine through building air inlet intakes	<p>If building fans stop and there is no flow path to LBS scrubber fan or LBS fans all simultaneously failed there is a potential leak path from the building air intake inlets. These can be closed remotely by operator</p> <p>NOTE: if there is a chlorine release, significant cooling inside will occur, and air would tend to be drawn into building even in the absence of fans running rather than let out.</p>	<p>Yes</p> <p>Frequency included in the overall building unavailability event tree.</p> <p>Modelled as release in open area (i.e. building/scrubber assumed ineffective)</p>
Failure of chlorine detection	<ul style="list-style-type: none"> Multiple Cl₂ sensors and alarm/shutdown 	Discharge chlorine through building exhaust	<p>This scenario only occurs if the chlorine release inside the building is not detected. Given that multiple detectors with redundant wiring and fault detection will be installed within the building, complete failure of Cl₂ detection is not credible.</p>	<p>No</p> <p>Extremely unlikely-not included.</p>
LBS - failed to open inlet dampers on chlorine release	<ul style="list-style-type: none"> Motorized LBS inlet dampers, fail open Operator detection – can manually open dampers remotely and locally 	Discharge chlorine through ventilation inlet air intakes		<p>Yes</p> <p>Frequency included in the overall building unavailability event tree.</p> <p>Modelled as release in open area (i.e. building/scrubber assumed ineffective)</p>
LBS – scrubber fan failed to ramp up	<ul style="list-style-type: none"> Fan configuration (3x 100%) Damper design (motorised, fail open) 	None	<p>3 x 100% fans are available. Simultaneous failure of all fans is extremely unlikely.</p> <p>Even if a fan fails to ramp up the rate of air drawn through the scrubber is lower, but the scrubber still works – rate of treatment is slower.</p>	<p>No</p> <p>Not included – no chlorine release</p>
LBS - failed to scrub (loss of caustic circulation)	<ul style="list-style-type: none"> -LBS pump configuration (3 x 100%) 	Release of chlorine from LBS stack	<p>The caustic circulation is always working at the design rate (i.e. no need to ramp up in case of chlorine release).</p> <ul style="list-style-type: none"> Two standby pumps are available in case of pump failure. LBS damper design is 'fail open'. Even if one fails to open, there are multiple air inlets to LBS. Operator can open dampers remotely. 	<p>Yes</p> <p>Modelled as scrubber breakthrough</p>
LBS - failed to scrub (caustic solution exhausted)	<ul style="list-style-type: none"> Continuous mode of scrubber – always a small makeup/removal flow 	Release of chlorine from LBS stack	<p>Continuous mode of scrubber operation minuses likelihood of problem with the caustic solution – always a small makeup/removal flow.</p> <p>Minimum volume available in Hypo Storage Tanks to dump scrubber volume if needed and significant quantity of bulk caustic available to top up.</p> <p>The caustic buffer volume in the scrubber sump has more than 1 hour capacity for scrubbing (i.e. can act as batch scrubber) without top up of caustic or removal of hypo solution. ie no immediate effect of deviation in caustic availability.</p> <p>Only other cause is catastrophic mechanical failure of scrubber. Very unlikely .</p>	<p>No</p> <p>Not included – no immediate effect</p>
Chlorine release while building vehicle doors open	<ul style="list-style-type: none"> Doors normally closed, wind rated with minimal leak paths Remote control of doors Doors automatically close on Cl₂ detection 	Release chlorine through vehicle doors	<p>Doors will be immediately closed after the road tanker goes in/out. If the roller door is left open, the scrubber fan will be unable to maintain the negative pressure within the building and chlorine can escape from the openings (e.g. door, louvers, etc.).</p>	<p>Yes</p> <p>Frequency included in the overall building unavailability.</p> <p>Modelled as release in open area (i.e. building/scrubber assumed ineffective)</p>

Event tree failure mode	Critical controls	Potential consequence	Justification	Included in event tree
Chlorine release while building pedestrian doors open	<ul style="list-style-type: none"> • Self-closing pedestrian doors, wind rated with minimal leak paths 	Release chlorine through pedestrian doors	Doors are self-closing. The scrubber fan will be able to maintain the negative pressure within the building and chlorine cannot escape from this opening even if open.	No Extremely unlikely-not included.
Common mode – power failure	<ul style="list-style-type: none"> • Redundancy of power supply to scrubber equipment • Fail safe position of dampers: • Air intakes open • Building ventilation damper – closed • LBS intakes – open 	Scrubber unavailable for treating chlorine	3 x100% scrubber fan/pump banks each with a different power supply, one of which is emergency generator. Manually box up building – all building openings can be remotely closed NOTE: no chlorine manufacturing or transfer can occur in a power failure case, static process equipment inventories only.	No Extremely unlikely-not included.

F3. Event tree

	Building state - vehicle doors closed	Building ventilation shut down	LBS Scrubber inlet dampers open	Operator action (remote within a few minutes)	Scrubber pump / fan running	Outcome
					Yes	Scrubber will still suck - design case (no release)
					0.99	9.8E-03
			Yes		No	Chlorine escaping from building
		No (failed to stop ventilation fan AND fail to close louvre)	0.99		0.01	9.9E-05
		0.01	No (failed to open LBS dampers)	Yes (opens LBS dampers)	Yes	Chlorine escaping from building - short duration
			0.01	0.9	0.99	8.91E-05
					No	Chlorine escaping from building - unmitigated
					0.01	9E-07
				No		Chlorine escaping from building - unmitigated
				0.1		1.0E-05
	Yes (doors in closed state)					
	0.97					
			Yes		Yes	Scrubber design case (no release)
			0.99		0.99	0.97
					No	Chlorine escaping from building - unmitigated
		Yes			0.01	9.8E-03
		0.99	No (failed to open LBS dampers)	Yes (opens LBS dampers)	Yes	Chlorine escaping from building - short duration
Chlorine release			0.01	0.9	0.99	8.8E-03
(QRA freq for scenario)					No	Chlorine escaping from building - unmitigated
					0.01	8.91E-05
				No		Chlorine escaping from building - unmitigated
				0.1		9.9E-04
		Building doors close automatically			Operator action (closes doors within a few minutes)	
	No (doors in open state)	Yes				Chlorine escaping from building - short duration
	0.03	0.99				0.030
	(contingent case)					
		No			Yes (closes doors)	Chlorine escaping from building - short duration
		0.01			0.9	2.7E-04
					No	Chlorine escaping from building - unmitigated
					0.1	3.0E-05
					Chlorine escaping from building - unmitigated	0.011
					Chlorine escaping from building - short duration	0.039
					Total unavailability	0.050

APPENDIX G. HAZARD IDENTIFICATION

Rev	Date	Description	Prepared	Checked									
A	21/02/2025	Draft for comment	M Amouzegar	J Polich									
1	30/05/2025	Minor updates for Rev 1 QRA report	M Amouzegar	J Polich									
Notes													
Added / changed for liquefaction project As per CAP HAZID													
HAZID No	Area	Activity / Operation	Material	Hazardous Event	Causes	Consequence	Comments re Frequency (site experience - takes into account control measures) see Note 1	Control Measures / Safeguards (try to formulate these in terms of barriers)			Carried forward for analysis (quantitative) in QRA?	Operating node Liquefaction Project (Normal/Contingent / both)	Comments
								Prevention	Detection	Protection / Mitigation			
1	CAP	Brine treatment and brine circuit	Chlorine	Release of chlorine	Failure of the dichlorination system	Evolution of chlorine from the spent brine	Unlikely	Brine at high pH. Acidic (i.e. low pH) conditions required for Cl2 release	Online analysers and alarm.	Very low rate of chlorine formation (<0.01kg/s)	No	Both	Localised effect
2	CAP	Brine treatment and brine circuit	Chlorine	Large spill of spent brine onto the ground.	Overfilling of tanks.	Evolution of chlorine vapours from spent brine.	Very unlikely	Brine at high pH. Acidic conditions required for Cl2 release	Level detection of tanks	Escape respirators for plant personnel & visitors	Yes	Both	Very large spill only included in QRA consequence calcs
					Operator error (e.g. failure to close valve, or erroneous opening of valves, maintenance activities etc).			Overfill protection of tanks.		Bund limits surface area for evaporation			
					Failure or rupture of piping.			Regular maintenance and periodic inspection of pipelines, instruments and tanks.					
3	CAP	Cells - electrolysis / catholyte system	Chlorine	Failure of piping or associated equipment	Impact or other mechanical damage.	Chlorine leak	Unlikely	System operates under slight vacuum (up to -10 kPag), i.e. air will leak in for small leaks	Cl2 detectors in the cell area.	Shut down and chlorine air purge of piping to the ECS .	Yes	Both	Large leaks included in QRA with generic failure frequency. Small leaks assumed to suck air in, ie fans are include as mitigation .
					Corrosion, wear and tear.			suitable materials of construction					
					Wrong gasket material or faulty flanges.			Periodic Non Destructive Testing (NDT).					
					Valve left open.			Minimum of 2 valves between Cl2 and atmosphere. NRV designed to let air into system rather than chlorine out					
4	CAP	Cells - electrolysis / catholyte system	Chlorine	Pressure seal relieves	High pressure blows the seal.	Cl2 ex seal to the ECS (i.e.. no loss of containment unless scrubber fails).	Unlikely	Operating procedures ensure level maintained in the seal.	High pressure trips cell power supply Double redundancy pressure trip is first line of defence	The pressure seal is relieved to the ECS which is sized for 10 minutes absorption of the full production.	Yes	Both	Included as a demand on ECS
					Operational error during maintenance of the seal.								
5	CAP	Cells - electrolysis / catholyte system	Hydrogen	Process explosion involving hydrogen	High pressure in cells causes membrane failure.	Hydrogen breaks through membrane Hydrogen/chlorine explosion in cells, electrolyser or in downstream equipment Explosion causes equipment damage, subsequent H2 leak and fire	Very unlikely	Membrane configured to minimise pressure fluctuation and exposure to gas phase, therefore maximising membrane life.	Continuous monitoring of differential pressure across the membranes, and the concentration of hydrogen in chlorine.	Plant trips (stopping H2 production) on cell membrane differential pressure upset, high H2 pressure, low brine flow or low caustic flow.	No	Both	Asset damage. Cl2 could be released but very similar to other scenarios considered. Frequency not assessed separately. MHF frequency estimate is< 1e-7 per year
					Maintenance issue (wear and tear) of membrane.			Maintenance of membranes.		Electrolysers trip on high voltage (stopping H2 production).			
					Loss of brine or caustic flow with power still on causes membrane to fail.					Bund limits surface area for evaporation			
6	CAP	Cells - electrolysis / catholyte system	Hydrogen	Hydrogen leak	Leak from pipework, flange, e.g due to corrosion, mechanical impact	Local torch fire, radiation impact on adjacent equipment / plant.	Very unlikely	Continuously welded pipeline to limit potential leak sites, minimum number of flanges around equipment items.	Low pressure trips of H2 supply system, initiated both upstream and downstream of hydrogen compressor discharge pressure control valve	Located in open-sided structure or in open, providing good natural ventilation and reducing likelihood of explosion.	No	Both	Localised effect Hydrogen is used at low flowrates (maximum production rate is 0.03 kg/s). Hydrogen is "leaky" due to its very low molecular weight, and also has a very low ignition energy, hence is very easy to ignite. Plant inventory is low, the maximum operating pressure is low (less than 100 kPag), and the effect area would be limited. Torch fire consequence model results show flame lengths of less than 1m and heat radiation levels above 4.7 kW/m2 confined to within 1m of the flame. In addition the number of joints in the hydrogen system has been minimised (i.e. piping is generally welded) to reduce the likelihood of leaks. Hydrogen is much lighter than air, hence is very buoyant and disperses very easily unless confined. All areas handling hydrogen are well ventilated (there is no hydrogen handled within buildings) so confinement of a leak and subsequent explosion is also very unlikely. As per conclusions in the previous issue of the QRA, hydrogen fires and explosions are not considered further as they would have no impact outside the immediate leak area. Escalation potential is also minimal as hydrogen inventories are very small and there are no external flammable or combustible inventories in the vicinity of the hydrogen piping and compressor.
						Build up of hydrogen, delayed ignition and explosion.		Low hydrogen pressure in plant (approx 2 kPag in cells and 50kPag downstream of compressor) minimises leak rate, likelihood of ignition and subsequent fire damage					

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								Prevention	Detection	Protection / Mitigation			
								Appropriate electrical hazardous area classification and equipment provided suitable for area classification.					
7	CAP	Cells - electrolysis / catholyte system	Chlorine	Chlorine Dioxide decomposition / explosion during chlorate destruction	Procedure not followed	Gaseous chlorine release	Very unlikely	Procedures			No	Both	Small , turbulent release - no offsite effects.
8	CAP	Chlorine cooling, drying and compression	Chlorine	Failure of piping or associated equipment	Corrosion (eg dryer failure) , wear and tear. Wrong gasket material or faulty flanges. Valve left open. Impact or other mechanical damage.	Chlorine leak	Very unlikely	Periodic Non Destructive Testing (NDT). Suitable materials of construction	Cl2 detectors in the cell area.	Shut down and chlorine air purge of piping to the ECS .	Yes	Both	Included at generic pipe / equipment leak frequencies
9	CAP	Chlorine cooling, drying and compression	Chlorine	Main plant trip trips the compressor but fails to trip the rectifier	Fault in electrical circuit, interference.	Chlorine production maintained at full rate without the compressor evacuating the chlorine from the piping. High pressure in header and relief of pressure seal	Cl2 ex seal to the ECS i.e., no loss of containment unless scrubber fails and operator fails to trip power.	Periodic testing of plant trips.	Chlorine alarms to control room.	Emergency scrubber (ECS) designed to absorb at least 10 minutes of full production chlorine stream.	Yes	Both	Included as a demand on ECS
										Manual shut down of plant.			
10	CAP	Chlorine cooling, drying and compression	Chlorine	Failure of chlorine compression.	Power failure causes failure of the compressor. Failure of compressor coolant	Chlorine gas not compressed.	Very unlikely	Preventative maintenance	Any compressor trip causes power supply to rectifiers to trip	Plant depressurises to ECS i.e., the chlorine contained in process equipment can safely be evacuated through the system to the scrubber. Scrubber sized for 10 min full production rate.	No	Both	No release - plant shutdown only.
										Automatic shut-down of plant in case of power failure.			
										Power to safety critical equipment supplied from the emergency diesel generator.			
11	CAP	Chlorine cooling, drying and compression	Chlorine	Large spill of chlorinated H2SO4 (from drying) onto the ground.	Overfilling of tanks. Operator error (e.g. failure to close valve, or erroneous opening of valves). Failure or rupture of piping.	Evolution of chlorine vapours from chlorinated H2SO4	Very unlikely	Overfill protection of tanks.	Level detection of tanks	Escape respirators for plant personnel & visitors	Yes	Both	Same type of scenario as HAZID 2
12	CAP	Chlorine cooling, drying and compression	Chlorine	Process fire (i.e not hydrogen related)	Dry chlorine reaches titanium cooler Chlorine / iron fire if temperature above 150oC, equipment damage Cl2 and hydrocarbon - leaking oil - accelerates corrosion	Chlorine / titanium fire in cooler - chlorine release via failed equipment Metal fire in chlorine compressor - chlorine release via failed equipment	Very unlikely	Titanium used in wet chlorine area of plant only (directly ex cells). Water spray into candle filter to ensure dry chlorine does not reverse flow. Water cooling of chlorine gas in compressor system.	Monitoring of chlorine exit gas temperature of sealing liquid. Alarm and trips on high temperature.		No	Both	Asset damage. Cl2 could be released but very similar to other scenarios considered. Frequency not assessed separately. MHF frequency estimate is < 1e-7 per year
13	CAP	Emergency Caustic Scrubber (ECS)	Chlorine	Loss of ECS suction through CAP	Failure to open/close the correct valves (e.g. after shut down) Loss of power	Chlorine release in event of simultaneous plant upset	Very unlikely	Procedures	Position detection (DCS) on valves.		Yes	Both	ECS failure probability estimated via fault tree
								Critical equipment, such as the standby fan will start up automatically if the duty-fan fails.	Chlorine detector in ECS stack	Back-up diesel generator for all critical equipment in case of power failure.			
14	CAP	Emergency Caustic Scrubber (ECS)	Chlorine	Failure of the caustic soda absorption circulation in ECS.	Pump failure. Blocked absorption tower due to salting out (due to high caustic strength)	Chlorine release in event of simultaneous plant upset.	Very unlikely	Caustic concentration to ECS dump tank limited to 18% to avoid scrubber salting up.	Alarm on failure of the circulation flow.	Chlorine detector in ECS stack	Yes	Both	ECS failure probability estimated via fault tree

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								Prevention	Detection	Protection / Mitigation			
					Power failure.			Critical equipment, such as the standby pump, will start up automatically if the duty pump fails Pumps designed to ride through voltage dip		Pumps on diesel generator emergency power back-up			
					Loss of caustic soda supply.			Caustic supplied from bulk caustic storage – large inventory		Emergency caustic dump tank contains some backup caustic supply.			
					Wrong strength caustic.				ORP measurement used to ensure caustic strength is in correct range				
15	Hypo Plant	Hypo destruction	Hypo	Reaction between hydrochloric acid (or other acids, e.g. sulphuric acid) and sodium hypochlorite.	Mixture in drains.	Formation of chlorine - toxic release.	Drain design prevented any mixing of acids (HCl, H2SO4) and Hypo.				Yes	Both	This has now been include for consistency with Safety Case. Release at EP6
					Contact in process piping.		Strict procedures for activities such as hypo destruction at hypo decomp tank						
16	Hypo Plant	Hypo production	Chlorine	Hypo caustic strength circulation or suction failure	Pump failure. Fan failure Wrong strength caustic causes plugging of make towers	Chlorine passes through make tower into back tower, Cl2 breakthrough if backing tower fails If suction fails emission from hypo circ tank (not backing tower)	Very unlikely	Critical equipment, such as the standby fan will start up automatically if the duty-fan fails.	Low flow alarm on circulation flow Caustic concentration controlled, deviations detected as per ECS High pressure trip if fans fail - isolate Cl2 feed	Backup tower exists at the Hypo plant	Yes	Both	Release frequency estimated by Fault Tree Split conseq into two locations with separate frequencies - 1. emission from backing tower and 2. emission from hypo circ tank (suction failure only)
17	Hypo Plant	Hypo production	Chlorine	Failure of feed chlorine piping	Corrosion, wear and tear.	Chlorine release.	Very unlikely	Periodic Non Destructive Testing (NDT).	Cl2 detectors in hypo	Shut down and chlorine air purge of piping to the ECS .	Yes	Both	Included at generic pipe / equipment leak frequencies
					Wrong gasket material, or faulty flanges.			Suitable materials of construction					
					Valve left open.			Minimum of 2 valves between Cl2 and atmosphere. NRV designed to let air into system rather than chlorine out					
					Impact or other mechanical damage.								
18	Ferric Plant	Chlorine feed	Chlorine	Failure of feed chlorine piping	Corrosion, wear and tear.	Chlorine release.	Very unlikely	Periodic Non Destructive Testing (NDT).		Shut down and chlorine air purge of piping to the ECS .	Yes	Both	Included at generic pipe / equipment leak frequencies
					Wrong gasket material, or faulty flanges.			Suitable materials of construction	Cl2 detectors				
					Valve left open.			Minimum of 2 valves between Cl2 and atmosphere. NRV designed to let air into system rather than chlorine out					
					Impact or other mechanical damage.								
19	Ferric Plant	Reaction	Chlorine	Chlorine unreacted and breaks through stack	Ineffective absorption in make towers Loss of suction in backing towers	Chlorine breakthrough, release to atmosphere	Very unlikely			Goes through Hypo backing tower	Yes	Both	Unlikely - same sort of scenario as hypo make tower failure but less likely. Included as demand on Hypo backing tower failure fault tree
20	HCl Plant	Chlorine feed	Chlorine	Failure of feed chlorine piping	Corrosion, wear and tear.	Chlorine release.	Very unlikely	Periodic Non Destructive Testing (NDT).	Cl2 detectors	Shut down and chlorine air purge of piping to the ECS .	Yes	Both	Included at generic pipe / equipment leak frequencies
					Wrong gasket material, or faulty flanges.			Suitable materials of construction					
					Valve left open.			Minimum of 2 valves between Cl2 and atmosphere. NRV designed to let air into system rather than chlorine out					
					Bellows failure			Bellows use minimised - only at burner to cater for temperature differential					
					Impact or other mechanical damage.								
21	HCl Plant	HCl synthesis	Chlorine	Release of toxic gases from the stack of the HCl plant.	Cl2 or H2 feed valve stuck open or opens prematurely during start up.	Chlorine release from top of stack.	Very unlikely	Trips on flame failure, instrument air failure, chlorine low pressure, hydrogen low pressure, flame failure.	Limit switches on valves (DCS controlled)	Automatic nitrogen purge on startup and shutdown.	Yes	Both	Release frequency estimated by Fault Tree

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								Prevention	Detection	Protection / Mitigation			
					Cl2 or H2 feed valve fails to close during shut down. Ratio control failure.				Chlorine detector in the vent stack from the scrubber. Monitoring of synthesis unit bursting disc with trip on failure detection				
					N2 ingress to H2 feed - Cl2 not within H2 / Cl2 flammability range								
22	HCl Plant	HCl synthesis	Hydrogen Chloride	Release of toxic gases the stack of the HCl plant.	Failure of absorption water or major, prolonged failure of cooling water.	HCl release from top of stack.	Very unlikely		Low absorption water flow trip HCl detector in stack	Burner shutdown	Yes	Both	Release frequency estimated by Fault Tree
23	HCl Plant	HCl synthesis	Chlorine Hydrogen	Explosion in burner unit	Attempt to ignite with flammable atmosphere in unit. Flame failure and no or inadequate nitrogen purging.	Confined explosion in burner chamber. Internal damage to synthesis unit. Burn back into hydrogen or chlorine supply lines.	Very unlikely	Automatic nitrogen purging after shutdown and prior to start-up. Automatic shutdown of plant after flame failure.	Flame detection to warn of flame failure.	Burst disc may rupture with small release of HCl or chlorine. Flame arresters in hydrogen and chlorine supply lines.	No	Both	Localised effect
24	HCl Plant	Hydrogen compression and supply	Hydrogen	Hydrogen fire	Leak of hydrogen gas from supply line Compressor failure	Local torch type fire with radiation impact on adjacent equipment / plant.	Very unlikely	Low hydrogen pressure in plant (approx 2 kPag in cells and 50kPag downstream of compressor) minimises leak rate, likelihood of ignition and subsequent fire damage	Low pressure trips of H2 supply system, initiated both upstream and downstream of hydrogen compressor discharge pressure control valve	Automatic isolation valves (number and location) to stem hydrogen flow and extinguish fire by stopping fuel supply	No	Both	Localised effect Hydrogen is used at low flowrates (maximum production rate is 0.03 kg/s). Hydrogen is "leaky" due to its very low molecular weight, and also has a very low ignition energy, hence is very easy to ignite. Plant inventory is low, the maximum operating pressure is low (less than 100 kPag), and the effect area would be limited. Torch fire consequence model results show flame lengths of less than 1m and heat radiation levels above 4.7 kW/m2 confined to within 1m of the flame. In addition the number of joints in the hydrogen system has been minimised (i.e. piping is generally welded) to reduce the likelihood of leaks. Hydrogen is much lighter than air, hence is very buoyant and disperses very easily unless confined. All areas handling hydrogen are well ventilated (there is no hydrogen handled within buildings) so confinement of a leak and subsequent explosion is also very unlikely. As per conclusions in the previous issue of the QRA, hydrogen fires and explosions are not considered further as they would have no impact outside the immediate leak area. Escalation potential is also minimal as hydrogen inventories are very small and there are no external flammable or combustible inventories in the vicinity of the hydrogen piping and compressor.
									Low pressure trip of supply to burner local to burner				
25	HCl Plant	Hydrogen compression and supply	Hydrogen	Explosion in hydrogen compression area	Leak of hydrogen along cable ducting. Leak of hydrogen into compressor crank case.	Explosion in switch gear Explosion in crank case, equipment damage	Very unlikely	Appropriate seal at end of cable ducting.		small hydrogen inventory and leak areas minimised as far as possible.	No	Both	Localised effect
26	HCl Plant	HCl synthesis	Hydrogen	Hydrogen fire at vent	Ignition of plant vent stack by lightning or static	Local torch type fire with radiation impact on adjacent equipment / plant.	Very unlikely	Lightning protection for stack and piping electrical continuity,	burn through tubing and alarm.	provision of nitrogen to snuff flame	No	Both	Localised effect
										Stack exit at least 20m from other equipment items.			
27	HCl Plant	Hydrochloric acid bulk storage and handling	Hydrochloric acid	Overfill of HCl stock tank or major spill of HCl into bund due to failure of tank.	Overfill protection fails. Mechanical failure of tank. Impact	Aqueous hydrochloric acid spill into bund. Release of toxic HCl fumes.	Very unlikely	Maintenance of equipment and instruments		Manual intervention for HCl spill - foam available to apply to spill surface to minimise evaporation.	Yes	Both	
28	HCl Plant	Hydrochloric acid bulk storage and handling	Hydrochloric acid	Spill during HCl tanker loading	Failure of loading arm at tanker loading bay or overfill of tanker. Tanker overfill protection fails.	Aqueous hydrochloric acid spill into banded unloading bay. Release of toxic HCl fumes.	Possible	Maintenance of equipment and instruments		Manual intervention for HCl spill - foam available to apply to spill surface to minimise evaporation.	Yes	Both	Release frequency estimated by Fault Tree
								Loading arm rather than hoses used		Banded area			
29	Chlorine drum and cylinder storage (inside liquefaction building - post liquefaction project)	Storage and handling	Chlorine	Dropping of drum / cylinder during handling	Wrong method used to move containers. Failure of the equipment (lifting jib on forklift) used to move containers. Operator error.	Damage to drum (eg, catastrophic rupture, leak from valve or plug) with subsequent release of chlorine to atmosphere.	Very unlikely	Procedures for moving drums. Drums handled using load rated, recommended lifting jib equipment. Drums designed to withstand dropping from height. Valves on drums capped.	Cl2 detectors. (Attended operation in any case)	Emergency procedures / capping equipment to disperse vapours escaping from damaged drum. Personnel with detailed knowledge and understanding of how to handle a chlorine emergency Containment building (offsite mitigation)	Yes	Both	Frequency estimated from IXOM drum failure data Drum handling occurs in similar manner using forklift jib pre and post liquefaction. Post liquefaction drums will be loaded / unloaded onto trucks inside containment building
30	Chlorine drum and cylinder storage (inside liquefaction building - post liquefaction project)	Storage and handling	Chlorine	Leak from static drum / cylinder	Mechanical impact Catastrophic failure Corrosion	Release of chlorine to atmosphere.	Very unlikely	Drums stored away from road way i.e. not exposed to impact. Drums designed and maintained to relevant codes and standards.	Cl2 detectors	Emergency procedures / capping equipment to disperse vapours escaping from damaged drum Personnel with detailed knowledge and understanding of how to handle a chlorine emergency Containment building (offsite mitigation)	Yes	Both	Frequency estimated from IXOM drum failure data

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								Prevention	Detection	Protection / Mitigation			
31	Chlorine drum and cylinder storage	Sampling from drums	Chlorine	Release from sampling apparatus	Technician error Overpressure of apparatus, eg blockage in tubing	Release of << 1 kg Cl ₂ .	Activity has been carried out over many years. (while drum filling was done at Botany) Release has occurred once (March 2005)	Activity discontinued	-	-	No	Contingent	This activity discontinued at Botany and transferred to Laverton. Will be reinstated for contingent mode post liquefaction. Small scale release not included in QRA, operator in PPE
32	Chlorine drum and cylinder storage	Sampling from drums	Chlorine	Release from drum while withdrawing sample	Technician error	Release of liquid chlorine from drum valve	Release from drum side has never occurred.	Activity discontinued	-	-	No	Contingent	This activity discontinued at Botany and transferred to Laverton. Will be reinstated for contingent mode post liquefaction. Small scale release not included in QRA, operator in PPE
33	Bulk tanker parking area (inside liquefaction building - post liquefaction project)	Static tanker	Chlorine	Leak from parked full tanker	Valve leak Flange leak Mechanical impact	Release of chlorine to atmosphere	Very unlikely	Tankers designed and maintained to relevant codes and standards Tanker parked in dedicated area away from impact by vehicles etc	Cl ₂ detectors Plant log each shift to check tanker	Personnel with detailed knowledge and understanding of how to handle a chlorine emergency Containment building (offsite mitigation)	Yes	Both	Frequency estimated from pressure vessel data Post liquefaction tankers will be loaded and warm up to above OdegC inside containment building Impact not quantified - assumed to be included in statistical data as no specific causes identified
34	Other Storages	Bulk Hypo storage	Sodium Hypochlorite	Leak from storage	Overfill	Spill of hypo, localised fumes	Possible	Fill enable and pumps interlocked with high level.	High and high high level alarms in tanks. high level interlock implemented in 2011	Bund	No	Both	
					Catastrophic failure of tank (construction defect, impact etc)	Large spill of hypo, fumes	Very unlikely	Appropriate materials of construction Located to minimise likelihood of impact Maintenance and inspection					Limited effect - local odours around hypo. No offsite effect
35	Other Storages	Bulk Hypo storage	Sodium Hypochlorite	Mixing of leaks with acidic medium in drains, chlorine formation	Leak in hypo system, drain system is acidic	Chlorine evolution from effluent system	Very unlikely	Drain systems designed so there are no interconnections between acid and hypo sources.	Bund high level alarms		Yes	Both	Included for consistency with Safety Case
			Sodium Hypochlorite	Dunk tank failure in hypo banded area	Acidic content reacts with hypo in bund	Chlorine evolution from spill reaction	Very unlikely	Bunds are kept empty, strict procedures	Cl ₂ detectors		No	Both	Not included in MHF Safety Case hence removed from QRA scenarios
36	Other Storages	Hypo tanker loading	Sodium Hypochlorite	Leak during unloading	Driveaway Hose failure	Spill of hypo, localised fumes	Unlikely	Maintenance of equipment (hoses) Driver training and loading procedures	Loading bay sump high level alarm	Bund	No	Both	Hypo spill - OHS issue only
37	Other Storages	Hypo tanker loading	Sodium Hypochlorite	Mixing of hypo with incompatible material in road tanker, chlorine formation	Residual chemicals in tanker (i.e wrong / undedicated tanker used) Tanker parked in wrong loading bay	Evolution of Cl ₂ .	Very unlikely that a large quantity of acid and hypo would mix without a stop being activated. More likely that a small residual reacts, however Cl ₂ quantity is limited by residual amount.	Dedicated loading bays for acid and hypo in separate locations. Dedicated tankers including contractual cleaning requirements. Tankers generally empty before refilling. Permissives (control room) before loading can occur	CCTV monitoring of loading bay Driver attendance	E stop (locally and in control room)	Yes	Both	Included for consistency with Safety Case
38	Other Storages	Other Storages - Bulk Ferric Chloride	Ferric chloride	Leak from storage	Overfill	Spill of ferric localised fumes (acidic)	Possible	Fill enable and pumps interlocked with high level.	High and high high level alarms in tanks	Bund	No	Both	Corrosive chemical - limited onsite effect area
					Catastrophic failure of tank (construction defect, impact etc)	Large spill of ferric, acidic fumes	Very unlikely	Appropriate materials of construction Located to minimise likelihood of impact Maintenance and inspection					
39	BIP transport	Vehicle incident on BIP roads involving Cl ₂ drums	Chlorine	Mixing of hypo with incompatible material in road tanker, chlorine formation	Vehicle collision	Release of Cl ₂ .	No incidents involving trucks carrying Cl ₂ drums within BIP	Speed limit 25km/hr Drums have very robust design		Emergency response	Yes	Both	Included for consistency with Safety Case. Assumed maximum of 2 drums inventory lost
40	Repack plant	Drum and IBC filling	Chlorine	Release of chlorine due to mixing of acid and hypo when filling packages	Returned package with material remaining	Evolution of chlorine gas from mixture	Unlikely	Wash out procedures and washout station for returned containers Segregation of clean / returned containers	Attended operation and shutdown by operator (Cl ₂ highly odorous)	Emergency response	No	Both	Top filling of IBCs does not occur onsite.
		Drainage system	Chlorine	Release of chlorine due to mixing of acid and hypo in drainage system, sumps or bunds	Spill not cleaned up	Evolution of chlorine gas from mixture	Very Unlikely	Spill clean up procedures Dedicated drainage systems for acid that are separated from hypo	pH and conductivity probes in truck sump High level switches and alarm in truck loading area sump and IBC storage area sumps Cl ₂ detector and alarm in drainage pits Cl ₂ detectors around plant area	Emergency response	No	Both	Similar but smaller scale than scenario above.
41	Liquefaction plant	Chlorine feed (CAP to liquefaction)	Chlorine	Failure of chlorine piping and fittings	Corrosion, wear and tear. Wrong gasket material, or faulty flanges. Bellows failure Impact or other mechanical damage.	Chlorine release	Very unlikely	Periodic Non Destructive Testing (NDT) Suitable materials of construction - Ixom piping specs consistent with Cl and Eurochlor guidance	Cl ₂ detectors Low flow alarm (flow transmitter upstream of liquefier)	Automatic shut down	Yes	Both	Included as generic pipe leak frequencies No history of leaks in pressurised Cl ₂ piping at Botany or Laverton

HAZID No	Area	Activity / Operation	Material	Hazardous Event	Causes	Consequence	Comments re Frequency (site experience - takes into account control measures) see Note 1	Control Measures / Safeguards (try to formulate these in terms of barriers)			Carried forward for analysis (quantitative) in QRA?	Operating node Liquefaction Project (Normal/ Contingent / both)	Comments
								Prevention	Detection	Protection / Mitigation			
42	Liquefaction plant	Liquefaction unit, storage and pumps	Chlorine	Failure of equipment or associated piping and fittings	Corrosion , wear and tear Wrong gasket material or faulty flanges Impact or other mechanical damage	Chlorine release	Very unlikely	Periodic Non Destructive Testing (NDT) Suitable materials of construction - specs consistent with CI and Eurochlor guidance	Cl2 detectors	Automatic shut down Bund limits surface area for evaporation Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	Yes	Both	Included as generic pipe / equipment leak frequencies
43	Liquefaction plant	Chlorine liquefaction	Chlorine	Loss of liquefaction Exceed liquefier capacity	Liquefier refrigeration unit failure High flow rate to liquefaction	Chlorine gas flows to the storage tanks or degas reactor and scrubber Potential exceedance of liquefaction capacity, high pressure in storage	Very unlikely Not credible - Designed out	Refrigeration unit control system Liquid level control in liquefier separator Physical restriction (RO or similar) preventing flow exceeding design feed rate (~50% of CPA capacity) to liquefaction	Low weight alarm on storage tank	Automatic shut down Chlorine vapour will continue to boil off under pressure control maintaining low temperature	No	Both	Loss of refrigeration does not lead to chlorine release. The maximum chlorine flow rate to the scrubber does not exceed the design capacity of scrubber. Chlorine vessels are designed as pressure vessels suited to ambient temperature / full pressure storage conditions .No loss of containment even if tanks fully warm up, PSVs discharge to scrubber
44	Liquefaction plant	Chlorine storage	Chlorine	Storage tank failure	Overfilling of storage tanks (overpressure, overflow)	Storage tank rupture and chlorine release	Very unlikely	Flow control valve on chlorine gas line, maximum flow limited by valve orifice Filled by weight (continuous weight measurement), Spare storage tank available that can be used to transfer content in case of emergency	Cl2 detectors High weight trip alarm	High high weight trip and automatic shut down PSV on storage tank relieves to scrubber Bund limits surface area for evaporation Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	No	Both	PSV is discharged to the scrubber. Multiple safeguards need to be failed to result in a tank rupture. Likelihood is covered by statistical vessel rupture frequency .
45	Liquefaction plant	Cylinder and drum filling	Chlorine	Release of chlorine from transfer hose and associated piping	Corrosion , wear and tear. Hose mechanical failure Coupling failure (operator error)	Chlorine release	Unlikely	Preventative maintenance and hose testing Operator checks the transfer hose before loading operation	Operator detection (attended operation) Cl2 detectors	Automatic shut down Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	Yes	Contingent	
				Cylinder/ drum failure	Overfilling of cylinder/ drum (human error)	Thermal expansion and high pressure in drum, chlorine release eg valve passing	Very unlikely	Filled by weight Drum design (dish end - reverse on overpressure) Cylinder high design pressure Training and procedures	High weight alarm Operator detection (attended operation) Cl2 detectors	Automatic shut down Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm. Operators wear PPE	No	Contingent	Not explicitly modelled due to the drum and cylinder design features - overfill will result in thermal expansion, potential overpressure and reversal of drum dished ends
				Release of chlorine when disconnecting filled cylinder/drum	Human error (e.g. cylinder valve left open, wrong isolation sequence)	Chlorine release	Very unlikely	Training and procedures	Operator detection (attended operation) Cl2 detectors	Containment building (offsite mitigation) Operators wear PPE Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	Yes	Contingent	Short duration release- operators in PPE can immediately isolate the leak
46	Liquefaction plant	Road tanker filling	Chlorine	Release of chlorine from transfer hose and associated piping	Corrosion , wear and tear. Hose mechanical failure Coupling failure (human error)	Chlorine release	Unlikely	Preventative maintenance and hose testing Operator checks the transfer hose before loading operation	Operator detection (attended operation) Cl2 detectors	Automatic shut down Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	Yes	Both	
				Release of chlorine from transfer hose	Road tanker driveway whilst still connected (human error)	Chlorine release	Very unlikely		Operator detection (attended operation) Cl2 detectors	Automatic shut down Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	No	Both	Physically impossible to have the loading arms connected when the prime mover connected to the road tanker (Ixm to confirm)
				Road tanker overpressure	Overfilling of road tanker	road tanker failure	Very unlikely	Filled by weight (continuous weight measurement) Flow totalizer Training and procedures Tanker relief valve	Operator detection (attended operation) Cl2 detectors	Automatic cut-off once max weight is reached Automatic shut down by chlorine detectors Containment building (offsite mitigation) Scrubber designed to absorb chlorine and reduce the chlorine concentration to below 25 ppm.	No	Both	Not credible to pump liquid through tanker PSV -the pumps do not have the sufficient head to lift the relief valve - reduces to thermal expansion scenario
47	Liquefaction plant	Chlorine refrigeration	Ammonia	Release of ammonia from ammonia circulation in refrigeration unit	Failure of equipment or associated piping and fittings	Release of ammonia, toxic exposure	Very unlikely	Refrigeration unit control system	Ammonia sensors at exhaust point	Shutdown	Yes	Both	Ammonia

HAZID No	Area	Activity / Operation	Material	Hazardous Event	Causes	Consequence	Comments re Frequency (site experience - takes into account control measures) see Note 1	Control Measures / Safeguards (try to formulate these in terms of barriers)			Carried forward for analysis (quantitative) in QRA?	Operating node Liquefaction Project (Normal/ Contingent / both)	Comments
								Prevention	Detection	Protection / Mitigation			
						Reaction with chlorine (NCl3 generation)	Eliminated by design				No		Ammonia inventory is located outside containment building, intermediate CO2 refrigerant inside building liquefaction equipment, no contact between NH3 and Cl2 in process equipment
48	Liquefaction plant	Liquid chlorine - vapourisation activities	Nitrogen trichloride	Accumulation of NCl3 to hazardous levels in liquid chlorine and decomposition if liquid chlorine vapourised,	<p>NCl3 forms from N impurities in feed: eg salt contaminated with ammonium compounds</p> <p>Sulphuric acid, sodium sulphite, coagulant and filter aid contaminated with ammonium compounds</p>	Decomposition and vessel rupture if NCl3 is accumulated to hazardous level.	Very unlikely	<p>Raw material quality management (e.g. periodic sampling)</p> <p>Restriction orifices in vent lines from liquid chlorine inventories restrict rate of vaporisation</p> <p>Degas reactor (very small inventory) is the only inventory where routine vapourisation is occurring Limited degassing of liquid chlorine from liquefier, storage tanks and road tankers.</p>	<p>Ammonia analyser for brine solution</p> <p>Regular testing of product NCl3 level as per Cl guidelines. Safe level is NCl3 below 20ppm</p>	Shutdown	No	Both	<p>The accumulation of NCl3 occurs over time and can be prevented through raw material quality assurance, regular measuring the nitrogen content in the product and limiting the degassing of the liquid chlorine. There is no history of NCl3 accumulation detection above safe levels at the CAP at Botany or Laverton.</p> <p>No environmental factors that would result in significant ammonia contamination (ie no source of nitrogen in surrounding sites)</p> <p>Continuous removal of liquid chlorine to tanker filling prevents accumulation of trace NCl3 in storage. .</p> <p>Decomposition frequency is not quantified. Covered by statistical failure frequencies for pressure vessels.</p>
					Chlorine contamination with ammonia in refrigeration unit	Generation of explosive gas (NCl3)	Designed out	Ammonia circuit located outside the building	Ammonia sensors at exhaust point	Shutdown	No	Both	The event is eliminated by having intermediate refrigerant (CO2), ammonia is physically separated and located outside the building.

APPENDIX H. CONSEQUENCE RESULTS

H1. Release sources

Releases from equipment mechanical leaks was generally modelled for the following hole sizes:

- 3 mm
- 13 mm
- 50 mm
- Rupture.

Release rates were calculated by Riskcurves from standard flow rate correlations based on the hole size, material state, the operating temperature and pressure defined. For scenarios where the calculated release rate exceeds a limiting process flow rate, the consequences were modelled using the limiting flow rate (e.g. maximum production rate, maximum pump flowrate, etc.).

A release from a drum or cylinder could be either gaseous or liquid depending on its orientation. If a leak develops as a result of a maloperation (e.g. by dropping the container and damaging a valve or a plug), the operator could orient the damaged end of the container resulting in a gaseous rather than liquid release. In this assessment, such emergency actions have been disregarded, and it has been assumed that 50% of all leaks involving drums result in a gaseous release, and 50% result in a liquid release.

H2. Flash and evaporation rate

In the case of a spill of liquid chlorine (e.g. from storage tanks or road tanker), part of the chlorine will initially flash off and evaporate, with any remaining liquid evaporating at a lower rate due to the cooling down of the liquid spill.

Flash and evaporation rate calculations were performed by Riskcurves with a normal concrete surface. Conservatively, no special concrete (e.g. insulating concrete) was accounted for at this stage of design. The maximum pool spreading area was defined based on the bund area or plant layout if the release occurs outside the bund.

Note that to evaluate the impact of the bund surface area on consequence distance, the storage tank rupture scenario was modelled for nominal bund sizes and the toxic consequence results were compared as per Table H.1. The modelling also includes the unconstrained scenario where the chlorine releases are not confined by the bund.

The distance to AEGL 3 concentration and 1% lethality for these cases are reported in the following table. The results indicate that the bund can significantly reduce the impact distance of a major LOC such as tank rupture from 6 km to about 1 km under F1.7 weather condition. A bund area of 57 m² for each tank was adopted in the design as an

operationally practical minimum and is used in the QRA to constrain the spreading area of pools where relevant.

Table H.1: Effect of surface area on evaporation rate

Scenario	Bund area (m ²)	Distance to (m) – D9.2		Distance to (m) – F1.7	
		1% lethality	AEGL-3 [600s]	1% lethality	AEGL-3 [600s]
1	30	189	228	551	811
2	45	224	269	680	1,029
3	57	254	305	765	1,189
4	80	290	347	900	1,444
5	120	336	405	1,096	1,814
6	Unconstrained	623	759	2,274	6,060

H3. Release inventory

The maximum release in the CAP was limited to the contents of the process equipment (approximately 150 kg) plus the amount lost before shutdown occurs (assumed to be up to approximately 3 minutes of production), i.e. set equal to 300 kg of chlorine if a catastrophic failure occurs.

For the CLP and chlorine storage (i.e. storage tank, drums, cylinders, road tanker) and associated piping, the inventory was limited to the maximum inventory in the vessel.

H4. Release duration

Durations of up to 60 minutes to manually isolate and control a gaseous leak from the plant have been assumed. The maximum duration of any scenario is set to one hour.

The release duration considered for each scenario is provided in the scenario tables in Section H6.

H5. Environmental data

The environmental conditions used for consequence modelling is summarised in Table H.2.

Table H.2: Environmental input data

Item	Value	Basis
Ambient temperature day	20.0	Weather data, average annual day temperature
Soil temperature day	20.0	Assumed equal to ambient day temperature.
Ambient temperature night	17.5	Weather data, average annual night temperature .
Soil temperature night	17.5	Assumed equal to ambient night temperature.
Relative humidity day	61.8	Weather data, average annual day relative humidity

Item	Value	Basis
Relative humidity night	72.9	Weather data, average annual night relative humidity
Roughness length	1 m	Ground roughness affects turbulent flow properties of wind, hence dispersion of a released material. Terrain effects are taken into account to some degree in dispersion modelling by use of a parameter known as surface roughness length. A surface roughness factor of 1 m was used, corresponding to an area with densely located low buildings or an industrial area with low structures such as the BIP. This surface roughness factor is also appropriate for suburban areas adjacent to the BIP.
Surface type	Concrete	Typical terminal surface parameters appropriate to concrete in plant area assumed for pool spreading calculation in EFFECTS. No special properties (e.g. insulating concrete) accounted for in QRA
Receptor height	1.5m	Typical face height

H6. Vulnerability due to chlorine toxicity

This section summarises the approach for assessing chlorine toxicity effects in the QRA. It is consistent with previous QRAs for the BIP site and the most recent CAP QRA.

H6.1. Toxicity to humans

Toxicity effects of chlorine on humans are summarised below.

Table H.3: Toxicity effects on humans

Exposure Level (ppm)	Duration (mins)	Effects
Chlorine		
0.2 - 3.5	Not stated in reference	Threshold of odour perception in those individuals without chronic exposure to low doses of chlorine
3 - 5	30 - 60	Tolerated without undue ill effect
5 - 8	Not stated in reference	Slight irritation of the mucous membranes of the upper respiratory tract and of the eyes
15	Immediate	Irritation of the nose, throat and eyes with cough and tearing
30	Immediate	Cough with choking sensation, chest pain and a sense of constriction in the chest. Wheezing may occur. Possibility of nausea and vomiting.
40 - 60	Not stated in reference	Development of chemical tracheo-bronchitis and pulmonary oedema.
100	1	Intolerable concentration

H6.2. Toxicity risk criteria summary

Table H.4 summarises the toxic fatality, injury and irritation effects and corresponding probability criteria used for chlorine in the QRA.

Table H.4: Toxic fatality, injury and irritation criteria

		Risk Criteria (set by HIPAP 4)		
		1 x 10 ⁻⁶ /yr	10 x 10 ⁻⁶ /yr	50 x 10 ⁻⁶ /yr
Material	Probit (Ref [8]) (ppm ⁿ min)	Threshold Concentrations (ppm)		
		Fatality (outdoor dose) Probit prediction – example ^(a)	Injury threshold AEGL 3 (10 mins)	Irritation threshold AEGL 2 (10 mins)
Chlorine (Cl ₂)	-4.86 + 0.5ln(c ^{2.75} t)	103 ppm (1% fatality at 10 mins)	50 ppm (as equivalent dose below)	2.8 ppm (as equivalent dose below)
		1% fatality equivalent dose: 3.47e6 ppm ^{2.75} min	equivalent toxic injury dose: 4.7e5 ppm ^{2.75} min	equivalent toxic irritation dose: 1.69e2 ppm ^{2.75} min
Notes:				
(a) This is an example only. QRA fatality risk estimate uses calculated cumulative dose based on variable concentration and variable exposure duration as calculated within Riskcurves.				

H6.3. Fatality prediction

To quantify the risk from toxic releases, probit equations of the form $Pr = A + b \ln(c^n t)$ are used to estimate the probability of fatality based on concentration and duration of exposure. These have generally been developed on limited human exposure data and extrapolation of animal experimental data. The relationship between probit and probability of fatality is determined from the standard probit curve or table as follows:

$$\text{Probability of fatality} = 0.5 \left(1 + \operatorname{erf} \left(\frac{Pr - 5}{\sqrt{2}} \right) \right)$$

For this analysis, the probit equations used to predict fatality risk from chlorine and hydrogen chloride are taken from the TNO Purple Book, Ref [8].

These have not changed since the previous QRA.

H6.4. Toxic injury/irritation risk

Injury due to toxic exposure depends on the nature of the material, the concentration, the duration and mode of exposure and on the sensitivity of the person exposed. It therefore follows that toxic criteria applicable to one chemical will not necessarily be appropriate for another chemical.

The approach required by HIPAP 4 is to assess each case on its merits based on known dose-effect relationships for a particular chemical, ("*Toxic criteria applicable to one chemical may not necessarily be appropriate to others. The department's experience*").

conclusively shows that the formulation of a uniform criteria to cover all toxic effects is not appropriate or valid. Instead, each case should be justified on its merits....", pg. 5).

The definitions are as follows:

- **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."

- **Irritation:**

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

Establishing the appropriate criteria for a particular chemical necessitates determination of the terms 'seriously injurious', 'sensitive', 'relatively short' and 'irritation'.

Given that a relationship between toxic effect and concentration/exposure time (i.e. dose) exists, it can be inferred that for shorter exposure durations higher concentrations would apply to obtain an equivalent effect and vice versa.

The US AEGLs are set for various exposure durations from 10 minutes to 8 hours. AEGL 'levels' are dictated by the severity of the toxic effects caused by the exposure, with Level 1 being the least and Level 3 being the most severe. All levels are expressed as parts per million or milligrams per cubic meter (ppm or mg/m³) of a substance above which it is predicted that the general population could experience, including susceptible individuals:

AEGL 1

Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL 2

Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL 3

Life-threatening health effects or death

The duration of the releases considered in the risk assessment of the facility ranges from a few minutes up to sixty minutes. The AEGL 10 minutes values (as shown in Table H.5) match most closely the 'relatively short' exposure duration in the HIPAP 4 criteria definition.

However, when comparing the threshold values against the exposure effects in Table H.3, it can be seen that the AEGLs are set conservatively, e.g. the Cl₂ AEGL1 for irritation is 0.5 ppm compared to irritation in Table H.3 at above 5 ppm, AEGL 2 for serious injury is 2.8 ppm with Table H.3 suggesting 30 ppm for serious injury.

Therefore, for the QRA, AEGL 2 (10 minutes) and AEGL 3(10 minutes) have been used as representative of irritation and serious injury respectively as per the HIPAP 4 definitions.

Table H.5: AEGL values

Interpretation	AEGL (10-minute)		
	AEGL 1	AEGL 2	AEGL 3
Intended usage by AEGL definition – onset threshold of effect for susceptible people	Irritation	Injury	Fatality
Usage in QRA study	-	Irritation threshold	Injury threshold
Chlorine	0.5 ppm	2.8 ppm	50 ppm

H6.5. Reduced dose experienced by indoor population

The concentration of gas inside a building engulfed by a gas cloud will rise gradually until the release has stopped and the cloud passed. The indoor concentration then falls gradually towards zero. The peak concentration inside will be much less than that outside, (unless the duration of the release is very long, or the building has very high ventilation rates).

Hence, a person inside will normally be exposed to significantly lower gas concentrations than someone outside and the risk of fatality from a toxic gas will be significantly less for a person located indoors than the risk in the open at the same location.

This effect is accounted for in the QRA within the risk model using the ventilation rate. Natural ventilation rate was assumed which is 1 air change per hour.

H7. Scenario inputs and consequence modelling results

The distances to AEGL 2 (irritation), AEGL 3 (injury) concentrations and 1% fatality dose were calculated by Riskcurves for the identified hazardous scenarios. The results for most common day condition (i.e. D8.4) and most conservative night weather condition (i.e. F1.4) are summarised in following table together with input assumptions for each modelled scenario for the CLP.

21838: Ixom Botany Chlorine Liquefaction Plant QRA															
QRA Basis - Isolatable Sections															
1	2	3	4	5	6	7	8	9	10	11	12				
ID	Description	Material released	Phase	Limiting Inventory (kg)	(m3)	Operating Time (hours/year)	Release conditions				Comments	Hazardous Properties		Typical causes	
							Limiting flowrate (kg/s)	Temp (°C)	Pressure (kPag)	Density (kg/m3)	Conc. (wt%)		Flammable?	Toxic?	
CLP-00	Release of HP chlorine from import line from compressor (outside)	Chlorine	Vapour	4200	523	8760	0.58	40	185	8.0	100	- Compressed chlorine header outside the building- assumed always online - Limiting inventory assumed 4.2 tonnes as it is the maximum total CAP chlorine production per hour - Max production rate to CLP 0.58 kg/s based on PFD	N	Y	Generic mechanical failures
CLP-01	Release of HP chlorine from import line from compressor (inside)	Chlorine	Vapour	4200	523	8760	0.58	40	185	8.0	100	- Compressed chlorine header outside the building- assumed always online - Limiting inventory assumed 4.2 tonnes as it is the maximum total CAP chlorine production per hour - Max production rate to CLP 0.58 kg/s based on PFD	N	Y	Generic mechanical failures
CLP-02	Release of chlorine from liquefier and separator	Chlorine	Liquid	2493	1.60	8760	-	-34	185	1558	100	Total volume 1.6 m3 ~ 1 hour production. - Liquefier (3.5m x 0.254m x 0.254m): 0.18 - Separator (0.91m diam x 2.25m height): 1.46	N	Y	Generic mechanical failures
CLP-03	Release of chlorine from LIQUID CHLORINE RUNDOWN	Chlorine	Liquid	2493	1.6	8760	-	-34	10	1558	100	- Limiting inventory assumed 2493 kg, same as liquifier	N	Y	Generic mechanical failures
CLP-04	Release of chlorine from TAIL GAS TO DEGAS REACTOR	Chlorine	Vapour	2493	712	8760	0.014	-20	1	3.5	100	- Limiting inventory assumed 2493 kg, same as liquifier - Design tail gas flowrate 0.014 kg/s	N	Y	Generic mechanical failures
CLP-05	Release of chlorine from liquid storage tanks	Chlorine	Liquid	50000	32	8760	-	-34	10	1558	100	- 2 tanks provided, 1 kept empty - Tanks (40 m3, 3.05m diam x 6.14m length), filling degree assumed 80% - Design pressure 1550 kPag	N	Y	Generic mechanical failures
CLP-06	Release of chlorine from relief line	Chlorine	Vapour	50000	15152	8760	0.8	-5	1	3.3	100	-Max flow through relief valve 0.8 kg/s (RV vented to scrubber so pipe failure during relief vent only scenario)	N	Y	Generic mechanical failures
CLP-07	Release of chlorine from pump suction	Chlorine	Liquid	50000	32	8760	-	-34	60.6	1558	100		N	Y	Generic mechanical failures
CLP-08	Release of chlorine from liquid storage pumps	Chlorine	Liquid	50000	32	8760	12.5	-34	750.0	1558.0	100	-Assumed always online. - Inventory limited to storage tanks volume - Max pump flowrate from pump curve when pumping against zero head is 12.5 kg/s	N	Y	Generic mechanical failures
CLP-09	Release of chlorine from tanker loading	Chlorine	Liquid	50000	32	8760	12.50	-34	700.0	1558.0	100		N	Y	Generic mechanical failures, connection errors.
CLP-10	Release of drum/cylinder filling supply line (CONTINGENT ONLY)	Chlorine	Liquid	50000	32	4380	12.50	-34	700.0	1558.0	100	Assumes annual filling of 13520 drums, 20 mins per drum . Some portion will actually be cylinders. Total time in use 0.5, split between cylinder and drum filing equipment for frequencies	N	Y	Generic mechanical failures
CLP-11	Release of chlorine from drum filling (CONTINGENT ONLY)	Chlorine	Liquid	50000	32	2253	12.50	-34	700.0	1558.0	100	Assumes annual filling of 13520 drums, 20 mins per drum . Some portion will actually be cylinders. Total time in use 0.5, split between cylinder and drum filing equipment for frequencies	N	Y	Generic mechanical failures, connection errors.
CLP-12	Release of chlorine from cylinder filling (CONTINGENT ONLY)	Chlorine	Liquid	50000	32	2253	12.50	-34	700.0	1558.0	100	Assumes annual filling of 13520 drums, 20 mins per drum . Some portion will actually be cylinders. Total time in use 0.5, split between cylinder and drum filing equipment for frequencies	N	Y	Generic mechanical failures, connection errors.
CLP-13	Release of chlorine from parked road tanker	Chlorine	Liquid	13000	9.21	8760	-	19	564.7	1412.0	100	Inventory limited to storage tanks volume	N	Y	Generic mechanical failures
CLP-14	Release of chlorine from stored cylinders and drums	Chlorine	Liquid	920	0.65	8760	-	19	564.7	1412.0	100	Inventory limited to drum volume	N	Y	Generic mechanical failures Handling errors
CLP-15	Release of chlorine from scrubber	Chlorine	Vapour	120	40.00	8760	0.58	20	0.0	3.0	100	-Venting flowrate assumed 0.58 kg/hr equal to max Cl2 flowrate to scrubber -Stack height 19m - Volume assumed 40 m3	N	Y	Generic mechanical failures Process upset scrubber breakthrough
NH3-01	Release of ammonia from ammonia fridge	Ammonia	Liquid	200	0.33	8760	-	20	VP	609	100	Client advised to assume 200 kg of ammonia stored	Y	Y	Generic mechanical failures NH3 Flammability effects excluded - toxic effects larger

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LIQ FRAC	OP PRESS kPa (g)	TEMP (deg C)	RELEASE HEIGHT (m)	Release Rate (kg/s)	AEGL2	D8.4 AEGL3	1% Fatality	AEGL2	F1.4 AEGL3	1% Fatality	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	COMMENTS	BUND SIZE (m2)	ASSUMPTIONS
																(mm)	(kg)	(kg/s)	(sec)			
CLP-00: Chlorine Supply (Extension from CAP-Outside Liquefaction Building)																						
00.01	SUPPLY PIPELINE (OUTSIDE)	80 mm RUPTURE	Cl2	V	0	185	40	1	0.58	646	145	122	2828	528	422	80	4200.0	0.58	300	Approx. 30m of piping outside the building.	-	N/A Gas release
00.02	SUPPLY PIPELINE (OUTSIDE)	50 mm HOLE	Cl2	V	0	185	40	1	0.58	641	143	121	2804	515	411	80	4200.0	0.58	300	Approx. 30m of piping outside the building.	-	N/A Gas release
00.03	SUPPLY PIPELINE (OUTSIDE)	13 mm HOLE	Cl2	V	0	185	40	1	0.08	222	50	42	1512	219	171	80	4200.0	0.58	900	Approx. 30m of piping outside the building.	-	N/A Gas release
00.04	SUPPLY PIPELINE (OUTSIDE)	3 mm HOLE	Cl2	V	0	185	40	1	0.01	48	9	7	287	41	32	80	4200.0	0.58	900	Approx. 30m of piping outside the building.	-	N/A Gas release
00.05	SUPPLY PIPELINE (OUTSIDE)	GASKET	Cl2	V	0	185	40	1	0.08	222	50	42	1512	219	171	80	4200.0	0.58	900	Welded piping, assumed 1 flange at connection point	-	N/A Gas release
CLP-01: Chlorine Supply (Inside Liquefaction Building)																						
01.01	SUPPLY PIPELINE (INSIDE)	80 mm RUPTURE	Cl2	V	0	185	40	1	0.58	646	145	122	2828	528	422	80	4200.0	0.58	300	Assume 25m of piping inside.	-	N/A Gas release
01.02	SUPPLY PIPELINE (INSIDE)	50 mm HOLE	Cl2	V	0	185	40	1	0.58	641	143	121	2804	515	411	80	4200.0	0.58	300	Assume 25m of piping inside.	-	N/A Gas release
01.03	SUPPLY PIPELINE (INSIDE)	13 mm HOLE	Cl2	V	0	185	40	1	0.08	222	50	42	1512	219	171	80	4200.0	0.58	900	Assume 25m of piping inside.	-	N/A Gas release
01.04	SUPPLY PIPELINE (INSIDE)	3 mm HOLE	Cl2	V	0	185	40	1	0.01	48	9	7	287	41	32	80	4200.0	0.58	900	Assume 25m of piping inside.	-	N/A Gas release
01.05	SUPPLY PIPELINE (INSIDE)	GASKET	Cl2	V	0	185	40	1	0.08	222	50	42	1512	219	171	80	4200.0	0.58	900	1 flange as per P&ID	-	N/A Gas release
CLP-02: Chlorine Liquefier																						
02.01	SEPARATOR	RUPTURE	Cl2	L	1	185	-34	1	-	766	158	130	4564	710	539	-	2492.8	N/A	n/a instantaneous	-	57.4	Assumed chlorine overfills from liquefier bund to storage tank bund
02.02	SEPARATOR	50 mm HOLE	Cl2	L	1	185	-34	1	10.60	827	171	142	4567	737	565	-	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
02.03	SEPARATOR	25 mm HOLE	Cl2	L	1	185	-34	1	2.65	757	156	129	4234	567	433	-	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
02.04	SEPARATOR	13 mm HOLE	Cl2	L	1	185	-34	1	0.77	627	129	106	3465	438	334	-	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
02.05	SEPARATOR	6 mm HOLE	Cl2	L	1	185	-34	1	0.18	296	61	50	1763	217	166	-	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
CLP-03: LIQUID CHLORINE RUNDOWN																						
03.01	PIPING DOWNSTREAM OF LIQUEFIER	RUPTURE	Cl2	L	1	10	-34	1	31.90	827	171	142	4677	776	613	80	2492.8	N/A	n/a instantaneous	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
03.02	PIPING DOWNSTREAM OF LIQUEFIER	50 mm	Cl2	L	1	10	-34	1	12.50	822	170	141	4587	745	575	80	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
03.03	PIPING DOWNSTREAM OF LIQUEFIER	13 mm HOLE	Cl2	L	1	10	-34	1	0.77	627	129	106	3465	438	334	80	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
03.04	PIPING DOWNSTREAM OF LIQUEFIER	3 mm HOLE	Cl2	L	1	10	-34	1	0.04	148	30	25	767	95	72	80	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
03.05	PIPING DOWNSTREAM OF LIQUEFIER	GASKET	Cl2	L	1	10	-34	1	0.77	627	129	106	3465	438	334	80	2492.8	N/A	3600	-	57.4	Assumed chlorine overflow from liquefier bund to storage tank bund
CLP-04: TAIL GAS TO DEGAS REACTOR																						
04.01	TAIL GAS TO DEGAS REACTOR	50 mm HOLE	Cl2	V	0	1	-20	1	0.01	89	18	15	564	72	55	50	2492.8	0.014	n/a instantaneous	Flowrate limited to design tail gas flowrate	-	N/A Gas release
04.02	TAIL GAS TO DEGAS REACTOR	13 mm HOLE	Cl2	V	0	1	-20	1	0.01	47	8	6	283	37	29	50	2492.8	0.014	900	Flowrate limited to design tail gas flowrate	-	N/A Gas release
04.03	TAIL GAS TO DEGAS REACTOR	3 mm HOLE	Cl2	V	0	1	-20	1	0.01	8	-	-	55	6	4	50	2492.8	0.014	900	Flowrate limited to design tail gas flowrate	-	N/A Gas release
04.04	TAIL GAS TO DEGAS REACTOR	GASKET	Cl2	V	0	1	-20	1	0.01	47	8	6	283	37	29	50	2492.8	0.014	900	Flowrate limited to design tail gas flowrate	-	N/A Gas release
CLP-05: Storage Tanks																						
05.01	STORAGE TANK	RUPTURE	Cl2	L	1	10	-34	1	-	1425	339	290	8443	965	735	-	50000	N/A	n/a instantaneous	Bund size as per site layout (~5.7 x 10.6 m)	57.4	Bund size as per site layout (~5.7 x 10.6 m)
05.02	STORAGE TANK	50 mm HOLE	Cl2	L	1	10	-34	1	11.45	952	199	165	7139	796	608	-	50000	N/A	3600	-	57.4	Bund size as per site layout (~5.7 x 10.6 m)
05.03	STORAGE TANK	25 mm HOLE	Cl2	L	1	10	-34	1	3.00	745	155	128	5300	581	442	-	50000	N/A	3600	-	57.4	Bund size as per site layout (~5.7 x 10.6 m)
05.04	STORAGE TANK	13 mm HOLE	Cl2	L	1	10	-34	1	0.89	674	138	114	4137	457	349	-	50000	N/A	3600	-	57.4	Bund size as per site layout (~5.7 x 10.6 m)
05.05	STORAGE TANK	6 mm HOLE	Cl2	L	1	10	-34	1	0.20	316	65	54	1989	233	180	-	50000	N/A	3600	-	57.4	Bund size as per site layout (~5.7 x 10.6 m)
CLP-06: STORAGE RELIEF																						
06.01	STORAGE TANK RELIEF	50 mm HOLE	Cl2	V	0	1	-5	1	0.07	195	43	36	1330	186	145	50	50000.0	0.8	n/a instantaneous	Max flow ex relief valve	-	N/A Gas release

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LIQ FRAC	OP PRESS	TEMP	RELEASE HEIGHT	Release Rate	AEGL2	D8.4 AEGL3	1% Fatality	AEGL2	F1.4 AEGL3	1% Fatality	LINE	LIMITING	LIMIT TO	MAX LEAK	COMMENTS	BUND SIZE	ASSUMPTIONS
																DIAM	INVENTORY	LEAK RATE	DURATION			
06.02	STORAGE TANK RELIEF	13 mm HOLE	CI2	V	0	1	-5	1	0.01	48	8	6	289	38	29	50	50000.0	0.8	900	Max flow ex relief valve	-	N/A Gas release
06.03	STORAGE TANK RELIEF	3 mm HOLE	CI2	V	0	1	-5	1	0.01	8	-	-	55	6	4	50	50000.0	0.8	900	Max flow ex relief valve	-	N/A Gas release
06.04	STORAGE TANK RELIEF	GASKET	CI2	V	0	1	-5	1	0.01	48	8	6	289	38	29	50	50000.0	0.8	900	Max flow ex relief valve	-	N/A Gas release
CLP-07 Pump Suction																						
07.01	PUMP SUCTION	100 mm RUPTURE	CI2	L	1	61	-34	1	42.00	1242	258	214	8769	1017	776	100	50000	N/A	n/a instantaneous		57.4	Pump located within tank bund
07.02	PUMP SUCTION	50 mm HOLE	CI2	L	1	61	-34	1	11.66	956	200	165	7168	800	611	100	50000	N/A	3600		57.4	Pump located within tank bund
07.03	PUMP SUCTION	13 mm HOLE	CI2	L	1	61	-34	1	1.31	658	141	117	4470	497	383	100	50000	N/A	3600		57.4	Pump located within tank bund
07.04	PUMP SUCTION	3 mm HOLE	CI2	L	1	61	-34	1	0.07	187	38	32	1058	129	99	100	50000	N/A	3600		57.4	Pump located within tank bund
07.05	PUMP SUCTION	GASKET	CI2	L	1	61	-34	1	1.31	658	141	117	4470	497	383	100	50000	N/A	3600		57.4	Pump located within tank bund
CLP-08: Storage Pumps																						
08.01	PUMP FAILURE	RUPTURE	CI2	L	1	750	-34	1	12.50	992	206	171	5932	789	604	80	50000	12.5	n/a instantaneous	Limited to pump maximum rate	57.4	Pump located within tank bund
08.02	PUMP FAILURE	3 mm HOLE	CI2	L	1	750	-34	1	0.21	360	81	68	3221	385	298	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
08.03	PUMP DISCHARGE	80 mm RUPTURE	CI2	L	1	750	-34	1	12.50	992	206	171	5932	789	604	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
08.04	PUMP DISCHARGE	50 mm HOLE	CI3	L	1	750	-34	1	12.50	1002	208	172	6095	815	622	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
08.05	PUMP DISCHARGE	13 mm HOLE	CI2	L	1	750	-34	1	3.67	1600	336	281	15403	2458	1899	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
08.06	PUMP DISCHARGE	3 mm HOLE	CI2	L	1	750	-34	1	0.21	360	81	68	3221	385	298	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
08.07	PUMP DISCHARGE	GASKET	CI2	L	1	750	-34	1	3.70	1600	336	281	15403	2458	1899	80	50000	12.5	3600	Limited to pump maximum rate	57.4	Pump located within tank bund
CLP-09: Road Tanker Filling (NORMAL)																						
09.01	TANKER FAILURE	RUPTURE	CI2	L	1	VP	-34	1	-	2199	425	349	15494	2464	1905	-	13000	N/A	n/a instantaneous		490	Assume limited to 25m diameter (building width)
09.02a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	1	700	-34	1	12.50	3188	632	526	17888	4808	3820	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.02b	HOSE FAILURE_isolation	RUPTURE	CI2	L	1	700	-34	1	-	1668	463	386	2885	537	438	50	108	12.5	9	Inventory estimated based on a shutdown time of 60s and flowrate of 1.8 kg/s (normal filling rate)	490	Assume limited to 25m diameter (building width)
09.03a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	1	700	-34	1	0.21	354	80	67	3161	379	293	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.03b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	1	700	-34	1	-	357	81	68	2029	326	264	50	108	12.5	540	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.04	HOSE FAILURE (TANKER OVERFILL TO CATCH POT)	RUPTURE	CI2	V	0	50	-34	1	0.01	80	17	13	499	65	51	50	13000		3600	Restricted by 12.5mm XFV in tanker	N/A	
09.05	HOSE FAILURE (TANKER OVERFILL LINE TO CATCH POT)	3 mm HOLE	CI2	V	0	50	-34	1	0.01	36	6	5	211	30	23	50	13000		3600		490	Assume limited to 25m diameter (building width)
09.06	TANKER FILLING LINE	50 mm HOLE	CI2	L	1	700	-34	1	12.50	2143	415	341	12211	1941	1487	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.07	TANKER FILLING LINE	13 mm HOLE	CI2	L	1	700	-34	1	3.56	1574	330	276	15232	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.08	TANKER FILLING LINE	3 mm HOLE	CI2	L	1	700	-34	1	0.21	354	80	67	3161	379	293	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.09	TANKER FILLING LINE	GASKET	CI2	L	1	700	-34	1	3.56	1574	330	276	15232	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
	ROADTANKER OVERFILL (RELIEF VALVE)	25 mm HOLE	CI2	V	0	50	-34	1	3.50	1368	271	223	8544	1383	1064	50	13000	1.3		Relief valve characteristic - average flowrate over 0.5 hours taking into account pressure decrease as cooling occurs	490	Assume limited to 25m diameter (building width)
9.10a	HOSE COUPLING ERROR_no isolation	50 mm HOLE	CI2	L	1	700	-34	1	12.50	3188	632	526	17888	4808	3820	50	0	12.5	0		490	Assume limited to 25m diameter (building width)
9.10b	HOSE COUPLING ERROR_isolation	50 mm HOLE	CI2	L	1	700	-34	1	-	1668	463	386	2885	537	438	50	0	12.5	9		490	Assume limited to 25m diameter (building width)
9.11	VACUUM CATCH POT FAILURE	RUPTURE	CI2	L	1	101	20	1	-	779	224	193	1226	229	185	50	15		n/a instantaneous		N/A	
CLP-09: Road Tanker Filling (CONTINGENT)																						
09.01	TANKER FAILURE	RUPTURE	CI2	V	1	564.7	-34	1	-	2199	425	349	15494	2464	1905	-	13000	N/A	n/a instantaneous		490	Assume limited to 25m diameter (building width)
09.02a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	1	700	-34	1	12.50	3188	632	526	17888	4808	3820	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.02b	HOSE FAILURE_isolation	RUPTURE	CI2	L	1	700	-34	1	-	1668	463	386	2885	537	438	50	65	12.5	5	Inventory estimated based on a shutdown time of 60s and flowrate of 1.08 kg/s (normal filling rate)	490	Assume limited to 25m diameter (building width)
09.03a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	1	700	-34	1	0.21	354	80	67	3161	379	293	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.03b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	1	700	-34	1	-	357	81	68	2029	326	264	50	65	12.5	324	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.04	HOSE FAILURE (TANKER OVERFILL TO CATCH POT)	RUPTURE	CI2	V	0	50	-34	1	0.01	80	17	13	499	65	51	50	13000		3600	Restricted by 12.5mm XFV in tanker	N/A	
09.05	HOSE FAILURE (TANKER OVERFILL LINE TO CATCH POT)	3 mm HOLE	CI2	V	0	50	-34	1	0.01	36	6	5	211	30	23	50	13000		3600		490	Assume limited to 25m diameter (building width)
09.06	TANKER FILLING LINE	50 mm HOLE	CI2	L	1	700	-34	1	12.50	2143	415	341	12211	1941	1487	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.07	TANKER FILLING LINE	13 mm HOLE	CI2	L	0	700	-34	1	3.56	1574	330	276	15232	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.08	TANKER FILLING LINE	3 mm HOLE	CI2	L	0	700	-34	1	0.21	354	80	67	3161	379	293	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
09.09	TANKER FILLING LINE	GASKET	CI2	L	1	700	-34	1	3.56	1574	330	276	15232	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
9.10a	HOSE COUPLING ERROR_no isolation	50 mm HOLE	CI2	L	1	700	-34	1	12.50	3188	632	526	17888	4808	3820	50	50000	12.5	3600		490	Assume limited to 25m diameter (building width)
9.10b	HOSE COUPLING ERROR_isolation	50 mm HOLE	CI2	L	1	700	-34	1	-	1668	463	386	2885	537	438	50	108	12.5	5		490	Assume limited to 25m diameter (building width)
9.11	VACUUM CATCH POT FAILURE	RUPTURE	CI2	L	1	101	20	1	-	779	224	193	1226	229	185	50	15		n/a instantaneous		N/A	

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LIQ FRAC	OP PRESS	TEMP	RELEASE HEIGHT	Release Rate	AEGL2	D8.4 AEGL3	1% Fatality	AEGL2	F1.4 AEGL3	1% Fatality	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	COMMENTS	BUND SIZE	ASSUMPTIONS
CLP-10: Drum/Cylinder Filling Supply Line																						
10.01	SUPLY LINE	50 mm HOLE	CI2	L	1	700	-34	1	12.50	2143	415	341	12211	1941	1487	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
10.02	SUPLY LINE	13 mm HOLE	CI2	L	1	700	-34	1	3.56	1574	330	276	15323	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
10.03	SUPLY LINE	3 mm HOLE	CI2	L	1	700	-34	1	0.21	354	80	67	3161	379	293	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
10.04	SUPLY LINE	GASKET	CI2	L	1	700	-34	1	3.56	1574	330	276	15323	2386	1836	50	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
CLP-11: Drum Filling																						
11.01a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	1	700	-34	0	4.60	1818	376	313	16200	2748	2145	25	50000	12.5	3600	Limited to pump maximum rate Inventory (60s x 1.5 kg/s)	490	Assume limited to 25m diameter (building width)
11.01b	HOSE FAILURE_isolation	RUPTURE	CI2	L	1	700	-34	0	-	1517	399	330	2780	525	426	25	90	12.5	21	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.02a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	1	700	-34	0	0.21	354	80	67	3161	379	293	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.02b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	1	700	-34	0	-	364	82	68	1927	316	251	25	90	12.5	450	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.03a	HOSE CONNECTION FAILURE_no isolation	RUPTURE	CI2	L	1	700	-34	0	4.61	1818	376	313	16200	2748	2145	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.03b	HOSE CONNECTION FAILURE_isolation	RUPTURE	CI2	L	1	700	-34	0	-	1517	399	330	2780	525	426	25	90	12.5	21	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.04	PIPING	RUPTURE	CI2	L	1	700	-34	0	11.17	2913	578	483	16642	3817	3009	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.05	PIPING	13 mm HOLE	CI2	L	1	700	-34	0	3.56	1574	330	276	15323	2386	1836	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.06	PIPING	3 mm HOLE	CI2	L	1	700	-34	0	0.21	354	80	67	3161	379	293	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
11.07	PIPING	GASKET	CI2	L	1	700	-34	0	3.56	1574	330	276	15323	2386	1836	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
CLP-12: Cylinder Filling																						
12.01a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	1	700	-34	0	4.60	1818	376	313	16200	2748	2145	25	50000	12.5	3600	Inventory (60s x 0.64)	490	Assume limited to 25m diameter (building width)
12.01b	HOSE FAILURE_isolation	RUPTURE	CI2	L	1	564.7	19	0	-	1517	399	330	2780	525	426	25	38	-	8	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.02a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	1	700	-34	0	0.21	354	80	67	3161	379	293	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.02b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	1	564.7	19	0	-	364	82	68	1927	316	251	25	38.4	-	192	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.03a	HOSE CONNECTION FAILURE_no isolation	RUPTURE	CI2	L	1	564.7	19	0	4.61	1818	376	313	16200	2748	2145	25	50000	-	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.03b	HOSE CONNECTION FAILURE_isolation	RUPTURE	CI2	L	1	700	-34	0	-	1517	399	330	2780	525	426	25	38.4	12.5	8	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.04	PIPING	RUPTURE	CI2	L	1	700	-34	0	11.17	2913	578	483	16642	3817	3009	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.05	PIPING	13 mm HOLE	CI2	L	1	700	-34	0	3.56	1574	330	276	15323	2386	1836	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.06	PIPING	3 mm HOLE	CI2	L	1	700	-34	0	0.21	354	80	67	3161	379	293	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
12.07	PIPING	GASKET	CI2	L	1	700	-34	0	3.56	1574	330	276	15323	2386	1836	25	50000	12.5	3600	Limited to pump maximum rate	490	Assume limited to 25m diameter (building width)
CLP-13: Parked Road Tanker																						
13.01	ROAD TANKER	RUPTURE	CI2	L	1	578	19	1	-	9103	2349	2004	18886	3108	2512	-	13000	N/A	n/a instantaneous		490	Assume limited to 25m diameter (building width)
13.02a	ROAD TANKER	50 mm HOLE	CI2	L	1	578	19	1	47.76	6686	1405	1162	23042	3977	3209	-	13000	N/A	3600		490	Assume limited to 25m diameter (building width)
13.02b	ROAD TANKER	50 mm HOLE	CI2	V	0	578	19	1	2.00	1183	259	217	6165	1118	895	-	13000	N/A	3600		490	Assume limited to 25m diameter (building width)
13.03a	ROAD TANKER	13 mm HOLE	CI2	L	1	578	19	1	3.27	1513	321	270	14746	2237	1728	-	13000	N/A	3600		490	Assume limited to 25m diameter (building width)
13.03b	ROAD TANKER	13 mm HOLE	CI2	V	0	578	19	1	0.19	342	77	65	3059	372	290	-	13000	N/A	3600		490	Assume limited to 25m diameter (building width)
CLP-14: Storage and Handling of Filled Drums (NORMAL)																						
14.01	DRUM FAILURE	RUPTURE	CI2	L	1	564.7	20	1	-	2903	808	692	5447	975	788	-	920	N/A	n/a instantaneous		490	Assume limited to 25m diameter (building width)
14.02	DRUM FAILURE	20 mm PLUG	CI2	L	1	564.7	20	1	7.61	2422	568	474	6610	1197	956	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.03	DRUM FAILURE	6 mm VALVE	CI2	L	1	564.7	20	1	0.69	657	146	124	5480	799	604	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.04	DRUM FAILURE	3 mm HOLE	CI2	L	1	564.7	20	1	0.17	323	73	62	2811	332	254	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.05	CYLINDER FAILURE	RUPTURE	CI3	L	1	564.7	20	1	-	1018	292	250	1672	314	254	-	70	N/A	n/a instantaneous		491	Assume limited to 25m diameter (building width)
CLP-14: Storage and Handling of Filled Drums (CONTINGENT)																						
14.01	DRUM FAILURE	RUPTURE	CI2	L	1	564.7	20	1	-	2903	808	692	5447	975	788	-	920	N/A	n/a instantaneous		490	Assume limited to 25m diameter (building width)

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LIQ FRAC	OP PRESS	TEMP	RELEASE HEIGHT	Release Rate	AEGL2	D8.4 AEGL3	1% Fatality	AEGL2	F1.4 AEGL3	1% Fatality	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	COMMENTS	BUND SIZE	ASSUMPTIONS
14.02	DRUM FAILURE	20 mm PLUG	Cl2	L	1	564.7	20	1	7.61	2422	568	474	6610	1197	956	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.03	DRUM FAILURE	6 mm VALVE	Cl2	L	1	564.7	20	1	0.69	657	146	124	5480	799	604	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.04	DRUM FAILURE	3 mm HOLE	Cl2	L	1	564.7	20	1	0.17	323	73	62	2811	332	254	-	920	N/A	3600		490	Assume limited to 25m diameter (building width)
14.05	CYLINDER FAILURE	RUPTURE	Cl3	L	1	564.7	20	1	-	1018	292	250	1672	314	254	-	70	N/A	n/a instantaneous		491	Assume limited to 25m diameter (building width)
CLP-15: Chlorine Vapour to Scrubber System																						
15.01	VAPOUR PIPELINE TO SCRUBBER	Scrubber breakthrough	Cl2	V	0	0	20	19	0.58	582	-	-	6848	629	462	500	50000.00	0.58	300	Assumed the scrubber is failed and chlorine goes out of the stack.	-	N/A Gas release
15.02	VAPOUR PIPELINE TO SCRUBBER	500 mm RUPTURE	Cl2	V	0	0	20	1	5.50	174	47	41	246	50	41	500	120.00	-	300	Limited to scrubber design flowrate Assumed 10 m piping and 5 flanges	-	N/A Gas release
15.03	VAPOUR PIPELINE TO SCRUBBER	50 mm HOLE	Cl2	V	0	0	20	1	0.06	165	39	31	237	43	36	500	120.00	-	300	Limited to scrubber design flowrate Assumed 10 m piping and 5 flanges	-	N/A Gas release
15.04	VAPOUR PIPELINE TO SCRUBBER	13 mm HOLE	Cl2	V	0	0	20	1	0.01	49	7	6	189	29	24	500	120.00	-	900	Limited to scrubber design flowrate Assumed 10 m piping and 5 flanges	-	N/A Gas release
15.05	VAPOUR PIPELINE TO SCRUBBER	3 mm HOLE	Cl2	V	0	0	20	1	0.01	7	-	-	49	5	-	500	120.00	-	900	Limited to scrubber design flowrate Assumed 10 m piping and 5 flanges	-	N/A Gas release
15.06	VAPOUR PIPELINE TO SCRUBBER	GASKET	Cl2	V	0	0	20	1	0.01	49	7	6	189	29	24	500	120.00	-	900	Limited to scrubber design flowrate Assumed 10 m piping and 5 flanges	-	N/A Gas release
NH3-01: Ammonia (Refrigeration Unit)																						
16.01	DRUM FAILURE	RUPTURE	NH3	L	1	VP	20	1	-	450	135	143	748	158	172	-	180	N/A	n/a instantaneous	Confirm inventory - nominal	20	Assumed limited by Refrigeration Canopy
16.02	DRUM FAILURE	3 mm HOLE	NH3	L	1	VP	20	1	0.13	82	19	21	317	31	36	-	180	N/A	3600	Confirm inventory - nominal	20	Assumed limited by Refrigeration Canopy

APPENDIX I. FREQUENCY ANALYSIS

I1. Overview

The focus of this Appendix is on the CLP scenarios. The same methodology and base frequencies as the most recent CAP QRA study, Refs [4, 5], were used for this study where applicable.

I2. Base frequencies

I2.1. Generic equipment failure

The base frequencies are usually expressed on a per m of pipe or per equipment item basis per year or per million operating hours.

Piping and equipment mechanical failures frequencies were mainly sourced from data compiled for internal use by ICI, Ref [9], from frequency estimates published by the Institution of Chemical Engineers, Ref [10], or the CCPS and compared with more recently published data (UK HSE, Ref [11]). Data adopted for this study is summarised in Table I.1.

The preliminary PIDs were used to estimate the number of flanges and equipment, and pipe lengths were estimated from layout and information provided by IXOM.

Table I.1: Generic equipment failure frequencies

Type of Failure	Failure Rate (x 10 ⁶ per year)	Reference	Comments
Piping			
3 mm hole	9/m	ICI Mond	-
13 mm hole	3/m		
50 mm hole	0.3/m		
Gasket (13 mm hole equivalent)	5/joint		
Guillotine fracture (full bore): < 50 mm > 50 mm but < 200 mm > 200 mm	0.6/m 0.3/m 0.1/m		
Bellows			
Fracture (full bore)	4000/bellow		Used for hydrogen chloride (HCl) plant only
Pressure Vessels			
6 mm hole	24	ICI Mond	Used for liquid chlorine storage tanks and liquefier separator
13 mm hole	6		
25 mm hole	3		
50 mm hole	3		
Catastrophic failure	1		

Type of Failure	Failure Rate (x 10 ⁶ per year)	Reference	Comments
Atmospheric Tanks			
Catastrophic failure – Non-metallic atmospheric tanks	0.021	CCPS	Lower end used. HCl tanks well maintained, inspected protected from impact. Appropriate mats of construction (fibreglass).
Canned Pump			
3 mm hole	50	TNO Purple Book	-
Catastrophic failure	10		
Compressor			
3 mm hole	12000	UK HSE	-
13 mm hole	270		
50 mm hole	2.9		
Catastrophic failure	2.9		
Road Tanker (pressurised)			
13 mm hole	5.7	UK HSE	Frequency split between liquid and vapour release (50%/50%) for non-rupture scenarios.
50 mm hole	0.5	TNO Purple Book	
Catastrophic failure	0.5		

12.2. Cylinder, drum and road tanker filling

The frequencies of incidents due to hose failure during cylinder, drum or road tanker filling were obtained from TNO Purple Book, Ref [12], as below:

- Hose minor leak (3 mm): 4 x 10⁻⁵ per hour
- Hose rupture: 4 x 10⁻⁶ per hour.

12.3. Drum and cylinder failure storage and handling

Drum failure rates are based on a study conducted by ICI UK into failures associated with chlorine drum storage and handling operations, Ref [13, 14].

Table I.2: Drum and cylinder failure frequencies

Type of failure	Failure rate
Static Drum Failures	
Catastrophic failure – drum	0.1 x 10 ⁻⁶ per year/drum
3mm hole – drum	5 x 10 ⁻⁶ per year/drum
Catastrophic failure – cylinder	0.1 x 10 ⁻⁶ per year/cylinder
Drum Handling Failures	
Probability of dropping drum during transfer	1 x 10 ⁻⁶ /transfer
Probability of valve damage per drop	0.001/drop
Probability of plug damage per drop	0.002/drop

13. Online probability

The online time factor reduces the leak frequency based on the proportion of time that the equipment is used. It is assumed that all process equipment is always un-isolated and pressurised, and hence the online probability of 1 is applied to all sections except for the following:

- Cylinder filling: online probability of 0.01, equivalent to 2 hours per week (Contingent Case only, assumed to occur all year).
- Drum filling: online probability of 0.01, equivalent to 2 hours per week Contingent Case only, assumed to occur all year).
- Road tanker filling: online probability of 0.07, equivalent to 12 hours per week.
- Parked road tanker: online probability of 0.5, equivalent to half the time.

14. Effect of safeguards

The effect of control measures factored into the QRA are summarised in Table I.3.

Table I.3: Control measures failure on demand

Description	PFDavg	Comments
Detection and isolation (ESD) – automatic	0.1	Cl ₂ detection and shutdown (transfer equipment in buildings such as feed to storage tank, pumps for tanker/drum filling) - automatic by chlorine detection
Detection and isolation (ESD) – operator	0.1	Cl ₂ detection and shutdown (transfer equipment in buildings such as feed to storage tank, pumps for tanker/drum filling) - by operator
Containment building and scrubber	0.05	Building/scrubber 'unavailability' has been estimated from the time that the building will be open for vehicles moving in and out (1.3% of time normal case, 3% of time contingent case) and an allowance for ventilation and scrubber failing. The overall design target for the building and scrubber containment system 'unavailability' is 5% and this will be verified in detailed design. The event tree developed to cover potential failure modes of this system indicates that this is achievable Refer to APPENDIX F for event tree. This is accounted for in the QRA as a frequency modification factor, i.e. for 5% of the time the building has no containment effect on any scenario in the liquefaction building, which is equivalent to all releases from the CLP occur inside a containment building and do not result in significant release outside the building 95% of time.
Emergency response	1	The QRA does not factor in emergency response actions such as sheltering in place or evacuation. These are highly dependent on human response and by convention are not accounted for in land use safety planning risk calculations.

15. CLP incident frequencies

The frequencies for scenarios included in the QRA model for the CLP are summarised in the following table.

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LINE DIAM (mm)	LIMITING INVENTORY (kg)	LIMIT TO LEAK RATE (kg/s)	MAX LEAK DURATION (sec)	FAIL FREQ. (x 10e6)	PROB ONLINE	FAILURE PROB OF MITIG. (probab.)	RELEASE FREQUENCY (x 10e6)	Frequency Stationary equipment (per year)	Inside Containment Building?	Riskcurves Frequency (per year)	Normal/Contingent Case?	Comments	
CLP-00: Chlorine Supply (Extension from CAP-Outside Liquefaction Building)															Unavailable factor:	0.05		
00.01	SUPPLY PIPELINE (OUTSIDE)	80 mm RUPTURE	Cl2	V	80	4200.0	0.58	300	9.0	1.00	1.00	9.0	9.00E-06	No	9.00E-06	Both		
00.02	SUPPLY PIPELINE (OUTSIDE)	50 mm HOLE	Cl2	V	80	4200.0	0.58	300	9.0	1.00	1.00	9.0	9.00E-06	No	9.00E-06	Both		
00.03	SUPPLY PIPELINE (OUTSIDE)	13 mm HOLE	Cl2	V	80	4200.0	0.58	900	90.0	1.00	1.00	90.0	9.00E-05	No	9.00E-05	Both		
00.04	SUPPLY PIPELINE (OUTSIDE)	3 mm HOLE	Cl2	V	80	4200.0	0.58	900	270.0	1.00	1.00	270.0	2.70E-04	No	2.70E-04	Both		
00.05	SUPPLY PIPELINE (OUTSIDE)	GASKET	Cl2	V	80	4200.0	0.58	900	5.0	1.00	1.00	5.0	5.00E-06	No	5.00E-06	Both		
CLP-01: Chlorine Supply (Inside Liquefaction Building)																		
01.01	SUPPLY PIPELINE (INSIDE)	80 mm RUPTURE	Cl2	V	80	4200.0	0.58	300	7.5	1.00	1.00	7.5	7.50E-06	Yes	3.75E-07	Both		
01.02	SUPPLY PIPELINE (INSIDE)	50 mm HOLE	Cl2	V	80	4200.0	0.58	300	7.5	1.00	1.00	7.5	7.50E-06	Yes	3.75E-07	Both		
01.03	SUPPLY PIPELINE (INSIDE)	13 mm HOLE	Cl2	V	80	4200.0	0.58	900	75.0	1.00	1.00	75.0	7.50E-05	Yes	3.75E-06	Both		
01.04	SUPPLY PIPELINE (INSIDE)	3 mm HOLE	Cl2	V	80	4200.0	0.58	900	225.0	1.00	1.00	225.0	2.25E-04	Yes	1.13E-05	Both		
01.05	SUPPLY PIPELINE (INSIDE)	GASKET	Cl2	V	80	4200.0	0.58	900	5.0	1.00	1.00	5.0	5.00E-06	Yes	2.50E-07	Both		
CLP-02: Chlorine Liquefier																		
02.01	SEPARATOR	RUPTURE	Cl2	L	-	2492.8	N/A	n/a instantaneous	1.0	1.00	1.00	1.0	1.00E-06	Yes	5.00E-08	Both		
02.02	SEPARATOR	50 mm HOLE	Cl2	L	-	2492.8	N/A	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both		
02.03	SEPARATOR	25 mm HOLE	Cl2	L	-	2492.8	N/A	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both		
02.04	SEPARATOR	13 mm HOLE	Cl2	L	-	2492.8	N/A	3600	6.0	1.00	1.00	6.0	6.00E-06	Yes	3.00E-07	Both		
02.05	SEPARATOR	6 mm HOLE	Cl2	L	-	2492.8	N/A	3600	24.0	1.00	1.00	24.0	2.40E-05	Yes	1.20E-06	Both		
CLP-03: LIQUID CHLORINE RUNDOWN																		
03.01	PIPING DOWNSTREAM OF LIQUEFIER	RUPTURE	Cl2	L	80	2492.8	N/A	n/a instantaneous	6.0	1.00	1.00	6.0	6.00E-06	Yes	3.00E-07	Both		
03.02	PIPING DOWNSTREAM OF LIQUEFIER	50 mm	Cl2	L	80	2492.8	N/A	3600	6.0	1.00	1.00	6.0	6.00E-06	Yes	3.00E-07	Both		
03.03	PIPING DOWNSTREAM OF LIQUEFIER	13 mm HOLE	Cl2	L	80	2492.8	N/A	3600	60.0	1.00	1.00	60.0	6.00E-05	Yes	3.00E-06	Both		
03.04	PIPING DOWNSTREAM OF LIQUEFIER	3 mm HOLE	Cl2	L	80	2492.8	N/A	3600	180.0	1.00	1.00	180.0	1.80E-04	Yes	9.00E-06	Both		
03.05	PIPING DOWNSTREAM OF LIQUEFIER	GASKET	Cl2	L	80	2492.8	N/A	3600	30.0	1.00	1.00	30.0	3.00E-05	Yes	1.50E-06	Both		
CLP-04: TAIL GAS TO DEGAS REACTOR																		
04.01	TAIL GAS TO DEGAS REACTOR	50 mm HOLE	Cl2	V	50	2492.8	0.014	n/a instantaneous	6.0	1.00	1.00	6.0	6.00E-06	Yes	3.00E-07	Both		
04.02	TAIL GAS TO DEGAS REACTOR	13 mm HOLE	Cl2	V	50	2492.8	0.014	900	30.0	1.00	1.00	30.0	3.00E-05	Yes	1.50E-06	Both		
04.03	TAIL GAS TO DEGAS REACTOR	3 mm HOLE	Cl2	V	50	2492.8	0.014	900	90.0	1.00	1.00	90.0	9.00E-05	Yes	4.50E-06	Both		
04.04	TAIL GAS TO DEGAS REACTOR	GASKET	Cl2	V	50	2492.8	0.014	900	10.0	1.00	1.00	10.0	1.00E-05	Yes	5.00E-07	Both		
CLP-05: Storage Tanks																		
05.01	STORAGE TANK	RUPTURE	Cl2	L	-	50000	N/A	n/a instantaneous	1.0	1.00	1.00	1.0	1.00E-06	Yes	5.00E-08	Both		
05.02	STORAGE TANK	50 mm HOLE	Cl2	L	-	50000	N/A	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both		

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	FAIL FREQ.	PROB ONLINE	FAILURE PROB OF MITIG.	RELEASE FREQUENCY	Frequency Stationary equipment	Inside Containment Building?	Riskcurves Frequency	Normal/Contingent Case?	Comments
05.03	STORAGE TANK	25 mm HOLE	CI2	L	-	50000	N/A	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both	
05.04	STORAGE TANK	13 mm HOLE	CI2	L	-	50000	N/A	3600	6.0	1.00	1.00	6.0	6.00E-06	Yes	3.00E-07	Both	
05.05	STORAGE TANK	6 mm HOLE	CI2	L	-	50000	N/A	3600	24.0	1.00	1.00	24.0	2.40E-05	Yes	1.20E-06	Both	
CLP-06: STORAGE RELIEF																	
06.01	STORAGE TANK RELIEF	50 mm HOLE	CI2	V	50	50000.0	0.8	n/a instantaneous	6.0	0.01	1.00	0.1	6.00E-08	Yes	3.00E-09	Both	
06.02	STORAGE TANK RELIEF	13 mm HOLE	CI2	V	50	50000.0	0.8	900	30.0	0.01	1.00	0.3	3.00E-07	Yes	1.50E-08	Both	
06.03	STORAGE TANK RELIEF	3 mm HOLE	CI2	V	50	50000.0	0.8	900	90.0	0.01	1.00	0.9	9.00E-07	Yes	4.50E-08	Both	
06.04	STORAGE TANK RELIEF	GASKET	CI2	V	50	50000.0	0.8	900	10.0	0.01	1.00	0.1	1.00E-07	Yes	5.00E-09	Both	
CLP-07 Pump Suction																	
07.01	PUMP SUCTION	100 mm RUPTURE	CI2	L	100	50000	N/A	n/a instantaneous	1.5	1.00	1.00	1.5	1.50E-06	Yes	7.50E-08	Both	
07.02	PUMP SUCTION	50 mm HOLE	CI2	L	100	50000	N/A	3600	1.5	1.00	1.00	1.5	1.50E-06	Yes	7.50E-08	Both	
07.03	PUMP SUCTION	13 mm HOLE	CI2	L	100	50000	N/A	3600	15.0	1.00	1.00	15.0	1.50E-05	Yes	7.50E-07	Both	
07.04	PUMP SUCTION	3 mm HOLE	CI2	L	100	50000	N/A	3600	45.0	1.00	1.00	45.0	4.50E-05	Yes	2.25E-06	Both	
07.05	PUMP SUCTION	GASKET	CI2	L	100	50000	N/A	3600	40.0	1.00	1.00	40.0	4.00E-05	Yes	2.00E-06	Both	
CLP-08: Storage Pumps																	
08.01	PUMP FAILURE	RUPTURE	CI2	L	80	50000	12.5	n/a instantaneous	10.0	1.00	1.00	10.0	1.00E-05	Yes	5.00E-07	Both	
08.02	PUMP FAILURE	3 mm HOLE	CI2	L	80	50000	12.5	3600	50.0	1.00	1.00	50.0	5.00E-05	Yes	2.50E-06	Both	
08.03	PUMP DISCHARGE	80 mm RUPTURE	CI2	L	80	50000	12.5	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both	
08.04	PUMP DISCHARGE	50 mm HOLE	CI3	L	80	50000	12.5	3600	3.0	1.00	1.00	3.0	3.00E-06	Yes	1.50E-07	Both	
08.05	PUMP DISCHARGE	13 mm HOLE	CI2	L	80	50000	12.5	3600	30.0	1.00	1.00	30.0	3.00E-05	Yes	1.50E-06	Both	
08.06	PUMP DISCHARGE	3 mm HOLE	CI2	L	80	50000	12.5	3600	90.0	1.00	1.00	90.0	9.00E-05	Yes	4.50E-06	Both	
08.07	PUMP DISCHARGE	GASKET	CI2	L	80	50000	12.5	3600	20.0	1.00	1.00	20.0	2.00E-05	Yes	1.00E-06	Both	
CLP-09: Road Tanker Filling (NORMAL)																	
09.01	TANKER FAILURE	RUPTURE	CI2	L	-	13000	N/A	n/a instantaneous	0.5	0.04	1.00	0.02	1.78E-08	Yes	8.90E-10	Normal	
09.02a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	50	50000	12.5	3600	35040.0	0.04	0.01	12.5	1.25E-05	Yes	6.24E-07	Normal	
09.02b	HOSE FAILURE_isolation	RUPTURE	CI2	L	50	108	12.5	9	35040.0	0.04	0.99	1235.5	1.24E-03	Yes	6.18E-05	Normal	
09.03a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	50	50000	12.5	3600	350400.0	0.04	0.01	124.8	1.25E-04	Yes	6.24E-06	Normal	
09.03b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	50	108	12.5	540	350400.0	0.04	0.99	12355.2	1.24E-02	Yes	6.18E-04	Normal	
09.04	HOSE FAILURE (TANKER OVERFILL TO CATCH POT)	RUPTURE	CI2	V	50	13000		3600	35040.0	0.04	1.00	1248.0	1.25E-03	Yes	6.24E-05	Normal	
09.05	HOSE FAILURE (TANKER OVERFILL LINE TO CATCH POT)	3 mm HOLE	CI2	V	50	13000		3600	350400.0	0.04	1.00	12480.0	1.25E-02	Yes	6.24E-04	Normal	
09.06	TANKER FILLING LINE	50 mm HOLE	CI2	L	50	50000	12.5	3600	6.0	0.04	1.00	0.2	2.14E-07	Yes	1.07E-08	Normal	
09.07	TANKER FILLING LINE	13 mm HOLE	CI2	L	50	50000	12.5	3600	30.0	0.04	1.00	1.1	1.07E-06	Yes	5.34E-08	Normal	
09.08	TANKER FILLING LINE	3 mm HOLE	CI2	L	50	50000	12.5	3600	90.0	0.04	1.00	3.2	3.21E-06	Yes	1.60E-07	Normal	
09.09	TANKER FILLING LINE	GASKET	CI2	L	50	50000	12.5	3600	30.0	0.04	1.00	1.1	1.07E-06	Yes	5.34E-08	Normal	
	ROADTANKER OVERFILL (RELIEF VALVE)	25 mm HOLE	CI2	V	50	13000	1.3		6.0	0.04	1.00	0.2	2.14E-07	Yes	1.07E-08	Normal	
9.10a	HOSE COUPLING ERROR_no isolation	50 mm HOLE	CI2	L	50	0	12.5	0	18.7	1.00	0.01	0.2	1.87E-07	Yes	9.36E-09	Normal	
9.10b	HOSE COUPLING ERROR_isolation	50 mm HOLE	CI2	L	50	0	12.5	9	18.7	1.00	0.99	18.5	1.85E-05	Yes	9.27E-07	Normal	
9.11	VACUUM CATCH POT FAILURE	RUPTURE	CI2	L	50	15		n/a instantaneous	1.0	1.00	1.00	1.0	1.00E-06	Yes	5.00E-08	Contingent	
CLP-09: Road Tanker Filling (CONTINGENT)																	
09.01	TANKER FAILURE	RUPTURE	CI2	V	-	13000	N/A	n/a instantaneous	0.5	0.04	1.00	0.02	2.13E-08	Yes	1.07E-09	Contingent	
09.02a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	50	50000	12.5	3600	35040.0	0.04	0.01	15.0	1.50E-05	Yes	7.48E-07	Contingent	
09.02b	HOSE FAILURE_isolation	RUPTURE	CI2	L	50	65	12.5	5	35040.0	0.04	0.99	1481.0	1.48E-03	Yes	7.41E-05	Contingent	

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	FAIL FREQ.	PROB ONLINE	FAILURE PROB OF MITIG.	RELEASE FREQUENCY	Frequency Stationary equipment	Inside Containment Building?	Riskcurves Frequency	Normal/Contingent Case?	Comments
09.03a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	50	50000	12.5	3600	350400.0	0.04	0.01	149.6	1.50E-04	Yes	7.48E-06	Contingent	
09.03b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	50	65	12.5	324	350400.0	0.04	0.99	14810.4	1.48E-02	Yes	7.41E-04	Contingent	
09.04	HOSE FAILURE (TANKER OVERFILL TO CATCH	RUPTURE	CI2	V	50	13000		3600	35040.0	0.04	1.00	1496.0	1.50E-03	Yes	7.48E-05	Contingent	
09.05	HOSE FAILURE (TANKER OVERFILL TO CATCH	3 mm HOLE	CI2	V	50	13000		3600	350400.0	0.04	1.00	14960.0	1.50E-02	Yes	7.48E-04	Contingent	
09.06	TANKER FILLING LINE	50 mm HOLE	CI2	L	50	50000	12.5	3600	6.0	0.04	1.00	0.3	2.56E-07	Yes	1.28E-08	Contingent	
09.07	TANKER FILLING LINE	13 mm HOLE	CI2	L	50	50000	12.5	3600	30.0	0.04	1.00	1.3	1.28E-06	Yes	6.40E-08	Contingent	
09.08	TANKER FILLING LINE	3 mm HOLE	CI2	L	50	50000	12.5	3600	90.0	0.04	1.00	3.8	3.84E-06	Yes	1.92E-07	Contingent	
09.09	TANKER FILLING LINE	GASKET	CI2	L	50	50000	12.5	3600	30.0	0.04	1.00	1.3	1.28E-06	Yes	6.40E-08	Contingent	
9.10a	HOSE COUPLING ERROR_no isolation	50 mm HOLE	CI2	L	50	50000	12.5	3600	22.4	1.00	0.01	0.2	2.24E-07	Yes	1.12E-08	Contingent	
9.10b	HOSE COUPLING ERROR_isolation	50 mm HOLE	CI2	L	50	108	12.5	5	22.4	1.00	0.99	22.2	2.22E-05	Yes	1.11E-06	Contingent	
9.11	VACUUM CATCH POT FAILURE	RUPTURE	CI2	L	50	15		n/a instantaneous	1.0	1.00	1.00	1.0	1.00E-06	Yes	5.00E-08	Contingent	
CLP-10: Drum/Cylinder Filling Supply Line																	
10.01	SUPLY LINE	50 mm HOLE	CI2	L	50	50000	12.5	3600	12.0	1.00	1.00	12.0	1.20E-05	Yes	6.00E-07	Contingent	
10.02	SUPLY LINE	13 mm HOLE	CI2	L	50	50000	12.5	3600	60.0	1.00	1.00	60.0	6.00E-05	Yes	3.00E-06	Contingent	
10.03	SUPLY LINE	3 mm HOLE	CI2	L	50	50000	12.5	3600	180.0	1.00	1.00	180.0	1.80E-04	Yes	9.00E-06	Contingent	
10.04	SUPLY LINE	GASKET	CI2	L	50	50000	12.5	3600	10.0	1.00	1.00	10.0	1.00E-05	Yes	5.00E-07	Contingent	
CLP-11: Drum Filling																	
11.01a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	25	50000	12.5	3600	35040.0	0.26	0.01	90.1	9.01E-05	Yes	4.51E-06	Contingent	
11.01b	HOSE FAILURE_isolation	RUPTURE	CI2	L	25	90	12.5	21	35040.0	0.26	0.99	8923.2	8.92E-03	Yes	4.46E-04	Contingent	
11.02a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	25	50000	12.5	3600	350400.0	0.26	0.01	901.3	9.01E-04	Yes	4.51E-05	Contingent	
11.02b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	25	90	12.5	450	350400.0	0.26	0.99	89232.0	8.92E-02	Yes	4.46E-03	Contingent	
11.03a	HOSE CONNECTION FAILURE_no isolation	RUPTURE	CI2	L	25	50000	12.5	3600	1622.4	0.26	0.01	4.2	4.17E-06	Yes	2.09E-07	Contingent	
11.03b	HOSE CONNECTION FAILURE_isolation	RUPTURE	CI2	L	25	90	12.5	21	1622.4	0.26	0.99	413.2	4.13E-04	Yes	2.07E-05	Contingent	
11.04	PIPING	RUPTURE	CI2	L	25	50000	12.5	3600	12.0	0.26	1.00	3.1	3.09E-06	Yes	1.54E-07	Contingent	
11.05	PIPING	13 mm HOLE	CI2	L	25	50000	12.5	3600	60.0	0.26	1.00	15.4	1.54E-05	Yes	7.72E-07	Contingent	
11.06	PIPING	3 mm HOLE	CI2	L	25	50000	12.5	3600	180.0	0.26	1.00	46.3	4.63E-05	Yes	2.32E-06	Contingent	
11.07	PIPING	GASKET	CI2	L	25	50000	12.5	3600	50.0	0.26	1.00	12.9	1.29E-05	Yes	6.43E-07	Contingent	
CLP-12: Cylinder Filling																	
12.01a	HOSE FAILURE_no isolation	RUPTURE	CI2	L	25	50000	12.5	3600	35040.0	0.26	0.01	90.1	9.01E-05	Yes	4.51E-06	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.01b	HOSE FAILURE_isolation	RUPTURE	CI2	L	25	38	-	8	35040.0	0.26	0.99	8923.2	8.92E-03	Yes	4.46E-04	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.02a	HOSE FAILURE_no isolation	3 mm HOLE	CI2	L	25	50000	12.5	3600	350400.0	0.26	0.01	901.3	9.01E-04	Yes	4.51E-05	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.02b	HOSE FAILURE_isolation	3 mm HOLE	CI2	L	25	38.4	-	192	350400.0	0.26	0.99	89232.0	8.92E-02	Yes	4.46E-03	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.03a	HOSE CONNECTION FAILURE_no isolation	RUPTURE	CI2	L	25	50000	-	3600	1622.4	0.26	0.01	4.2	4.17E-06	Yes	2.09E-07	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.03b	HOSE CONNECTION FAILURE_isolation	RUPTURE	CI2	L	25	38.4	12.5	8	1622.4	0.26	0.99	413.2	4.13E-04	Yes	2.07E-05	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.04	PIPING	RUPTURE	CI2	L	25	50000	12.5	3600	12.0	0.26	1.00	3.1	3.09E-06	Yes	1.54E-07	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.05	PIPING	13 mm HOLE	CI2	L	25	50000	12.5	3600	60.0	0.26	1.00	15.4	1.54E-05	Yes	7.72E-07	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.06	PIPING	3 mm HOLE	CI2	L	25	50000	12.5	3600	180.0	0.26	1.00	46.3	4.63E-05	Yes	2.32E-06	Contingent	Assumed to be the same as drums for time in use, probably a lot less
12.07	PIPING	GASKET	CI2	L	25	50000	12.5	3600	50.0	0.26	1.00	12.9	1.29E-05	Yes	6.43E-07	Contingent	Assumed to be the same as drums for time in use, probably a lot less
CLP-13: Parked Road Tanker																	

RC Scenario No	Description	Incident Type	MAT'L	PHASE (L/V)	LINE DIAM	LIMITING INVENTORY	LIMIT TO LEAK RATE	MAX LEAK DURATION	FAIL FREQ.	PROB ONLINE	FAILURE PROB OF MITIG.	RELEASE FREQUENCY	Frequency Stationary equipment	Inside Containment Building?	Riskcurves Frequency	Normal/Contingent Case?	Comments
13.01	ROAD TANKER	RUPTURE	Cl2	L	-	13000	N/A	n/a instantaneous	0.5	0.50	1.00	0.3	2.50E-07	Yes	1.25E-08	Both	Parked tanker has been included for consistency with CAP DA - probably conservative as tankers will be filled, warm up in building then leave to customer
13.02a	ROAD TANKER	50 mm HOLE	Cl2	L	-	13000	N/A	3600	0.3	0.50	1.00	0.1	1.25E-07	Yes	6.25E-09	Both	
13.02b	ROAD TANKER	50 mm HOLE	Cl2	V	-	13000	N/A	3600	0.3	0.50	1.00	0.1	1.25E-07	Yes	6.25E-09	Both	
13.03a	ROAD TANKER	13 mm HOLE	Cl2	L	-	13000	N/A	3600	2.9	0.50	1.00	1.4	1.43E-06	Yes	7.13E-08	Both	
13.03b	ROAD TANKER	13 mm HOLE	Cl2	V	-	13000	N/A	3600	2.9	0.50	1.00	1.4	1.43E-06	Yes	7.13E-08	Both	
CLP-14: Storage and Handling of Filled Drums (NORMAL)																	
14.01	DRUM FAILURE	RUPTURE	Cl2	L	-	920	N/A	n/a instantaneous	20.0	1.00	1.00	20.0	2.00E-05	Yes	1.00E-06	Normal	
14.02	DRUM FAILURE	20 mm PLUG	Cl2	L	-	920	N/A	3600	50.3	1.00	1.00	50.3	5.03E-05	Yes	2.52E-06	Normal	
14.03	DRUM FAILURE	6 mm VALVE	Cl2	L	-	920	N/A	3600	25.2	1.00	1.00	25.2	2.52E-05	Yes	1.26E-06	Normal	
14.04	DRUM FAILURE	3 mm HOLE	Cl2	L	-	920	N/A	3600	1000.0	1.00	1.00	1000.0	1.00E-03	Yes	5.00E-05	Normal	
14.05	CYLINDER FAILURE	RUPTURE	Cl3	L	-	70	N/A	n/a instantaneous	10.0	1.00	1.00	10.0	1.00E-05	Yes	5.00E-07	Normal	
CLP-14: Storage and Handling of Filled Drums (CONTINGENT)																	
14.01	DRUM FAILURE	RUPTURE	Cl2	L	-	920	N/A	n/a instantaneous	20.0	1.00	1.00	20.0	2.00E-05	Yes	1.00E-06	Contingent	
14.02	DRUM FAILURE	20 mm PLUG	Cl2	L	-	920	N/A	3600	54.1	1.00	1.00	54.1	5.41E-05	Yes	2.70E-06	Contingent	
14.03	DRUM FAILURE	6 mm VALVE	Cl2	L	-	920	N/A	3600	27.0	1.00	1.00	27.0	2.70E-05	Yes	1.35E-06	Contingent	
14.04	DRUM FAILURE	3 mm HOLE	Cl2	L	-	920	N/A	3600	1000.0	1.00	1.00	1000.0	1.00E-03	Yes	5.00E-05	Contingent	
14.05	CYLINDER FAILURE	RUPTURE	Cl3	L	-	70	N/A	n/a instantaneous	10.0	1.00	1.00	10.0	1.00E-05	Yes	5.00E-07	Contingent	
CLP-15: Chlorine Vapour to Scrubber System																	
15.01	VAPOUR PIPELINE TO SCRUBBER	Scrubber breakthrough	Cl2	V	500	50000.00	0.58	300	1.0	1.00	1.00	1.0	1.00E-06	No	1.00E-06	Both	
15.02	VAPOUR PIPELINE TO SCRUBBER	500 mm RUPTURE	Cl2	V	500	120.00	-	300	1.0	1.00	1.00	1.0	1.00E-06	No	1.00E-06	Both	
15.03	VAPOUR PIPELINE TO SCRUBBER	50 mm HOLE	Cl2	V	500	120.00	-	300	3.0	1.00	1.00	3.0	3.00E-06	No	3.00E-06	Both	
15.04	VAPOUR PIPELINE TO SCRUBBER	13 mm HOLE	Cl2	V	500	120.00	-	900	30.0	1.00	1.00	30.0	3.00E-05	No	3.00E-05	Both	
15.05	VAPOUR PIPELINE TO SCRUBBER	3 mm HOLE	Cl2	V	500	120.00	-	900	90.0	1.00	1.00	90.0	9.00E-05	No	9.00E-05	Both	
15.06	VAPOUR PIPELINE TO SCRUBBER	GASKET	Cl2	V	500	120.00	-	900	25.0	1.00	1.00	25.0	2.50E-05	No	2.50E-05	Both	
NH3-01: Ammonia (Refrigeration Unit)																	
16.01	DRUM FAILURE	RUPTURE	NH3	L	-	180	N/A	n/a instantaneous	1.0	1.00	1.00	1.0	1.00E-06	No	1.00E-06	Both	
16.02	DRUM FAILURE	3 mm HOLE	NH3	L	-	180	N/A	3600	5.0	1.00	1.00	5.0	5.00E-06	No	5.00E-06	Both	

APPENDIX J. RISK CONTRIBUTORS

J1. Analysis point locations

Analysis points have been selected at IXOM boundaries and at points in the Denison St residential area as shown below.



J2. Cumulative CAP and CLP Normal case risk contributors

Analysis point: 1. Denison st south				Analysis point: 2. High density nearest				Analysis point: 3. Ixom boundary (east)			
Total Individual risk at analysis point (X=335882,Y= 6.24118E6) is: 6.58E-08/yr				Total Individual risk at analysis point (X=335981,Y= 6.24135E6) is: 1.32E-08/yr				Total Individual risk at analysis point (X=335756,Y= 6.24129E6) is: 2.48E-0			
Individual risk Risk ranking				Individual risk Risk ranking				Individual risk Risk ranking			
Scenario	Contribution	Value		Scenario	Contribution	Value		Scenario	Contribution	Value	
09.02a Chlorine Road Tanker Hose Failure - 1 Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	31.4	2.06E-08		09.02a Chlorine Road Tanker Hose Failure - 1 Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	56.6	7.47E-09		Scenario 139 Mixing hypo & acid loadout 1 generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	22.5	5.57E-08	
Scenario 139 Mixing hypo & acid loadout 2 generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	17.2	1.13E-08		08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	21.4	2.83E-09		09.02a Chlorine Road Tanker Hose Failure - 2 Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	17.2	4.26E-08	
08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	14.2	9.36E-09		08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	14.3	1.88E-09		08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	11.9	2.94E-08	
08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	9.49	6.24E-09		13.01 Chlorine Parked Road Tanker - Rupture (13. [N/C] Parked Road Tanker)	1.59	2.10E-10		08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	7.92	1.96E-08	
Scenario 140 Mixing hypo & acid loadout 5 generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	8.43	5.55E-09		13.02a Chlorine Parked Road Tanker -50 mm (liquid) (13. [N/C] Parked Road Tanker)	1.27	1.67E-10		Scenario 140 Mixing hypo & acid loadout 5 generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	7.7	1.91E-08	
Scenario 026-350 Chlorine to Cooler Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	2.92	1.92E-09		09.10a Chlorine Road Tanker Coupling Error - 6 Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	0.847	1.12E-10		09.03b Chlorine Road Tanker Hose Failure - 6 3mm leak (isolation) (09. [N] Chlorine Road Tanker Filling)	6.91	1.71E-08	
Scenario 011-1500 Weak Brine Tank Gas RUP (Toxic) (Location IXM-002: 02 CAP brine)	1.3	8.56E-10		13.03a Chlorine Parked Road Tanker -13 mm (liquid) (13. [N/C] Parked Road Tanker)	0.833	1.10E-10		Scenario 141 Mixing hypo & acid loadout 7 generating Cl2 Gas (Toxic) ([CUMULATIVE] Location IXM-018: 19 Chemical loadout 3)	4.28	1.06E-08	
14.02a Drum Failure Plug - 20mm leak (liquid) (14. [N] Storage and Handling of Filled Drums)	1.19	7.85E-10		14.02a Drum Failure Plug - 20mm leak (liquid) (14. [N] Storage and Handling of Filled Drums)	0.728	9.60E-11		09.02b Chlorine Road Tanker Hose Failure - 8 Rupture (isolation) (09. [N] Chlorine Road Tanker Filling)	3.17	7.86E-09	
13.01 Chlorine Parked Road Tanker - Rupture (13. [N/C] Parked Road Tanker)	1.05	6.88E-10		09.07 Chlorine Road Tanker Filling Line - 13mm Leak (09. [N] Chlorine Road Tanker Filling)	0.722	9.53E-11		14.02a Drum Failure Plug - 20mm leak (liquid) (14. [N] Storage and Handling of Filled Drums)	3.02	7.47E-09	
Scenario 071-300 Dried Chlorine Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	0.813	5.35E-10		09.09 Chlorine Road Tanker Filling Line - 13mm Leak (Gasket) (09. [N] Chlorine Road Tanker Filling)	0.722	9.53E-11		Scenario 026-350 Chlorine to Cooler Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	1.32	3.28E-09	
	87.993	5.7834E-08			99.012	1.30656E-08			85.92	2.1271E-07	

Analysis point: 4. Ixom boundary (north)				Analysis point: 5. Ixom boundary (west)				Analysis point: 6. BIP boundary (south)			
Total Individual risk at analysis point (X=335531,Y= 6.24133E6) is: 1.22E-05/yr				Total Individual risk at analysis point (X=335569,Y= 6.24121E6) is: 1.44E-05/yr				Total Individual risk at analysis point (X=335785,Y= 6.24102E6) is: 1.39E-07			
Individual risk Risk ranking				Individual risk Risk ranking				Individual risk Risk ranking			
Scenario	Contribution	Value		Scenario	Contribution	Value		Scenario	Contribution	Value	
1 Scenario 141 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) ((CUMULATIVE) Location IXM-018: 19 Chemical loadout 3)	96.6	1.18E-05		1 09.03b Chlorine Road Tanker Hose Failure - 3mm leak (isolation) (09. [N] Chlorine Road Tanker Filling)	29.2	4.19E-06		09.02a Chlorine Road Tanker Hose Failure - 1 Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	17.3	2.41E-08	
2 09.02b Chlorine Road Tanker Hose Failure - Rupture (isolation) (09. [N] Chlorine Road Tanker Filling)	0.659	8.07E-08		2 09.02b Chlorine Road Tanker Hose Failure - Rupture (isolation) (09. [N] Chlorine Road Tanker Filling)	26.2	3.76E-06		Scenario 139 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	15.7	2.18E-08	
3 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	0.459	5.62E-08		3 14.04a Drum Failure - 3 mm leak (vapour) (14. [N] Storage and Handling of Filled Drums)	8.25	1.19E-06		Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	15.3	2.13E-08	
4 09.03b Chlorine Road Tanker Hose Failure - 3mm leak (isolation) (09. [N] Chlorine Road Tanker Filling)	0.456	5.58E-08		4 00.02 Vapour Supply Pipeline - 50mm Leak (00. [N/C] Chlorine Supply (Extension from CAP-Outside Liquefaction Building))	4.57	6.57E-07		08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	7.83	1.09E-08	
5 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [N] Chlorine Road Tanker Filling)	0.414	5.07E-08		5 00.03 Vapour Supply Pipeline - 13mm Leak (00. [N/C] Chlorine Supply (Extension from CAP-Outside Liquefaction Building))	3.59	5.16E-07		Scenario 026-350 Chlorine to Cooler Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	7.47	1.04E-08	
6 14.02a Drum Failure Plug - 20mm leak (liquid) (14. [N] Storage and Handling of Filled Drums)	0.356	4.36E-08		6 Scenario 141 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) ((CUMULATIVE) Location IXM-018: 19 Chemical loadout 3)	3.34	4.79E-07		Scenario 011-1500 Weak Brine Tank Gas RUP (Toxic) (Location IXM-002: 02 CAP brine)	6.7	9.30E-09	
7 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	0.306	3.74E-08		7 14.01 Drum failure - Rupture (14. [N] Storage and Handling of Filled Drums)	2.57	3.69E-07		08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	5.22	7.25E-09	
8 14.01 Drum failure - Rupture (14. [N] Storage and Handling of Filled Drums)	0.185	2.26E-08		8 Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	2.35	3.38E-07		Scenario NEW1-Chlorine Compressor Suction Pot RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	1.94	2.69E-09	
9 Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	0.0464	5.68E-09		9 00.01 Vapour Supply Pipeline - 80mm Leak (00. [N/C] Chlorine Supply (Extension from CAP-Outside Liquefaction Building))	2.33	3.35E-07		Scenario 066-760 Secondary Drying Tower Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	1.94	2.69E-09	
10 14.04a Drum Failure - 3 mm leak (vapour) (14. [N] Storage and Handling of Filled Drums)	0.0455	5.58E-09		10 14.02a Drum Failure Plug - 20mm leak (liquid) (14. [N] Storage and Handling of Filled Drums)	1.94	2.79E-07		Scenario 041-1800 Candle Filter Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	1.93	2.69E-09	
	99.5269	1.21583E-05			84.34	1.2113E-05			81.33	1.1312E-07	

J3. Cumulative CAP and CLP Contingent case risk contributors

Analysis point: 1. Denison st south				Analysis point: 2. High density nearest				Analysis point: 3. Ixom boundary (east)			
Total Individual risk at analysis point (X=335882,Y= 6.24118E6) is: 1.90E-0				Total Individual risk at analysis point (X=335981,Y= 6.24135E6) is: 5.20E				Total Individual risk at analysis point (X=335756,Y= 6.24129E6) is: 0			
Individual risk Risk ranking				Individual risk Risk ranking				Individual risk Risk ranking			
Scenario	Contribution	Value		Scenario	Contribution	Value		Scenario	Contribution	Value	
1 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	19.5	3.70E-08		1 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	22	1.14E-08		1 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	17.2	1.09E-07	
2 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	19	3.62E-08		2 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	21.9	1.14E-08		2 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	17.1	1.08E-07	
3 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [C] Chlorine Road Tanker Filling)	13	2.48E-08		3 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [C] Chlorine Road Tanker Filling)	17.2	8.96E-09		3 Scenario 139 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	8.81	5.57E-08	
4 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	8.82	1.68E-08		4 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	9.68	5.04E-09		4 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	8.45	5.34E-08	
5 Scenario 139 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	5.95	1.13E-08		5 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	5.44	2.83E-09		5 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [C] Chlorine Road Tanker Filling)	8.09	5.11E-08	
6 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	4.92	9.36E-09		6 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	3.62	1.88E-09		6 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	4.66	2.94E-08	
7 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	3.28	6.24E-09		7 12.05 Piping Failure - 13mm Leak (12. [C] Cylinder Filling)	2.46	1.28E-09		7 09.03b Chlorine Road Tanker Hose Failure - 3mm leak (isolation) (09. [C] Chlorine Road Tanker Filling)	3.23	2.04E-08	
8 Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	2.92	5.55E-09		8 11.05 Piping Failure - 13mm Leak (11. [C] Drum Filling)	2.45	1.27E-09		8 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	3.11	1.96E-08	
9 11.05 Piping Failure - 13mm Leak (11. [C] Drum Filling)	2.25	4.29E-09		9 12.04 Piping Failure - 25mm Leak (12. [C] Cylinder Filling)	2.07	1.08E-09		9 Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	3.02	1.91E-08	
10 12.05 Piping Failure - 13mm Leak (12. [C] Cylinder Filling)	2.2	4.19E-09		10 12.07 Piping Failure - 13mm Leak (Gasket) (12. [C] Cylinder Filling)	2.06	1.07E-09		10 12.05 Piping Failure - 13mm Leak (12. [C] Cylinder Filling)	2.12	1.34E-08	
	81.84	1.5573E-07			88.88	4.621E-08			75.79	4.791E-07	

Analysis point: 4. Ixom boundary (north)				Analysis point: 5. Ixom boundary (west)				Analysis point: 6. BIP boundary (south)			
Total Individual risk at analysis point (X=335531,Y= 6.24133E6) is: 1.31E-05				Total Individual risk at analysis point (X=335569,Y= 6.24121E6) is: 2.39E-05/yr				Total Individual risk at analysis point (X=335785,Y= 6.24102E6) is: 2.88E-05			
Individual risk Risk ranking				Individual risk Risk ranking				Individual risk Risk ranking			
Scenario	Contribution	Value		Scenario	Contribution	Value		Scenario	Contribution	Value	
1 Scenario 141 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) ([CUMULATIVE] Location IXM-018: 19 Chemical loadout 3)	90.3	1.18E-05		09.03b Chlorine Road Tanker Hose Failure - 1 3mm leak (isolation) (09. [C] Chlorine Road Tanker Filling)	20.9	5.00E-06		1 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	15.7	4.52E-08	
2 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	1.76	2.31E-07		09.02b Chlorine Road Tanker Hose Failure - 2 Rupture (isolation) (09. [C] Chlorine Road Tanker Filling)	18.8	4.49E-06		2 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	15	4.34E-08	
3 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	1.62	2.13E-07		3 11.03b Hose Connection Failure - 15mm Leak (isolation) (11. [C] Drum Filling)	8.31	1.99E-06		3 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [C] Chlorine Road Tanker Filling)	10	2.89E-08	
4 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	0.883	1.16E-07		4 14.04a Drum Failure - 3 mm leak (liquid) (14. [C] Storage and Handling of Filled Drums)	4.95	1.19E-06		4 Scenario 139 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-016: 17 Chemical loadout 1)	7.55	2.18E-08	
5 09.02b Chlorine Road Tanker Hose Failure - Rupture (isolation) (09. [C] Chlorine Road Tanker Filling)	0.735	9.63E-08		5 11.02a Hose Failure - 3mm Leak (no isolation) (11. [C] Drum Filling)	4.25	1.02E-06		5 Scenario 140 Mixing hypo & acid loadout generating Cl2 Gas (Toxic) (Location IXM-017: 18 Chemical loadout 2)	7.39	2.13E-08	
6 09.03b Chlorine Road Tanker Hose Failure - 3mm leak (isolation) (09. [C] Chlorine Road Tanker Filling)	0.508	6.66E-08		6 11.01a Hose Failure - 15mm Leak (no isolation) (11. [C] Drum Filling)	3.91	9.37E-07		6 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	6.9	1.99E-08	
7 09.02a Chlorine Road Tanker Hose Failure - Rupture (no isolation) (09. [C] Chlorine Road Tanker Filling)	0.464	6.08E-08		7 12.01a Hose Failure - 15mm Leak (no isolation) (12. [C] Cylinder Filling)	3.84	9.20E-07		7 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	3.77	1.09E-08	
8 08.05 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	0.429	5.62E-08		8 12.02a Hose Failure - 3mm Leak (no isolation) (12. [C] Cylinder Filling)	3.74	8.96E-07		8 Scenario 026-350 Chlorine to Cooler Gas RUP (Toxic) (Location IXM-004: 04 CAP dry, cool, compress)	3.6	1.04E-08	
9 14.02a Drum Failure Plug - 20mm leak (liquid) (14. [C] Storage and Handling of Filled Drums)	0.357	4.67E-08		9 00.02 Vapour Supply Pipeline - 50mm Leak (00. [N/C] Chlorine Supply (Extension from CAP-Outside Liquefaction Building))	2.74	6.57E-07		9 Scenario 011-1500 Weak Brine Tank Gas RUP (Toxic) (Location IXM-002: 02 CAP brine)	3.22	9.30E-09	
10 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	0.286	3.74E-08		10 10.02 Drum/Cylinder Filling Supply Line - 13mm Leak (10. [C] Drum/Cylinder Filling Supply Line)	2.28	5.47E-07		10 08.07 Pump Discharge - 13mm Leak (08. [N/C] Chlorine Storage Pumps)	2.51	7.25E-09	
	97.342	0.000012724			73.72	0.000017647			75.64	2.1835E-07	

APPENDIX K. ONSITE RISK BASIS

K1. Occupancy

Role: Day Plant Operator

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.65	0.60
Main admin	0.02	0.02
Maintenance workshop	0.02	0.02
Repack plant	0.00	0.00
Drum storage area	0.02	0.00
CAP plant area	0.15	0.15
Products Area	0.15	0.15
Liquefaction building	0.00	0.06

Role: Night Plant Operator

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.83	0.83
Main admin	0.00	0.00
Maintenance workshop	0.00	0.00
Repack plant	0.00	0.00
Drum storage area	0.00	0.00
CAP plant area	0.08	0.08
Products Area	0.08	0.08
Liquefaction building	0.00	0.00

Role: Maintenance Technicians

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.09	0.09
Main admin	0.00	0.00
Maintenance workshop	0.28	0.28
Repack plant	0.02	0.02
Drum storage area	0.02	0.02
CAP plant area	0.30	0.22
Products Area	0.30	0.22
Liquefaction (excluding transfer)	0.00	0.16

Role: Engineers/Planners

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.13	0.13
Main admin	0.13	0.13
Maintenance workshop	0.50	0.50
Repack plant	0.00	0.00
Drum storage area	0.00	0.00
CAP plant area	0.13	0.13
Products Area	0.13	0.13
Liquefaction building	0.00	0.00

Role: Technical/Quality

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.25	0.25
Main admin	0.50	0.50
Maintenance workshop	0.00	0.00
Repack plant	0.00	0.00
Drum storage area	0.00	0.00
CAP plant area	0.13	0.13
Products Area	0.13	0.13
Liquefaction building	0.00	0.00

Role: Operations

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.13	0.13
Main admin	0.50	0.50
Maintenance workshop	0.00	0.00
Repack plant	0.09	0.09
Drum storage area	0.03	0.03
CAP plant area	0.13	0.13
Products Area	0.13	0.13
Liquefaction building	0.00	0.00

Role: Admin staff

Location	Probability of presence (Current)	Probability of presence (Future)
CAP control room	0.04	0.04
Main admin	0.90	0.90
Maintenance workshop	0.01	0.01
Repack plant	0.00	0.00
Drum storage area	0.00	0.00
CAP plant area	0.03	0.03
Products Area	0.03	0.03
Liquefaction building	0.00	0.00

K2. IRPA results

Role: Day Plant Operator

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.65	0.60	6.83E-07	3.46E-06	1.21E-05	n/a	n/a	n/a
Main admin	0.02	0.02	0.00E+00	3.19E-10	1.32E-09	n/a	n/a	n/a
Maintenance workshop	0.02	0.02	-	-	-	n/a	n/a	n/a
Repack plant	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Drum storage area	0.02	0.00	8.85E-07	0.00E+00	0.00E+00	n/a	n/a	n/a
CAP plant area	0.15	0.15	1.86E-06	1.87E-06	2.01E-06	n/a	n/a	n/a
Products Area	0.15	0.15	1.52E-06	2.77E-06	8.74E-06	n/a	n/a	n/a
Liquefaction building	0.00	0.06	0.00E+00	2.84E-05	6.92E-04	n/a	n/a	n/a
Cumulative risk			4.95E-06	3.65E-05	7.15E-04	0.00E+00	0.00E+00	0.00E+00

Role: Night Plant Operator

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.83	0.83	n/a	n/a	n/a	2.43E-06	6.04E-06	1.80E-05
Main admin	0.00	0.00	n/a	n/a	n/a	0.00E+00	0.00E+00	0.00E+00
Maintenance workshop	0.00	0.00	n/a	n/a	n/a	-	-	-
Repack plant	0.00	0.00	n/a	n/a	n/a	0.00E+00	0.00E+00	0.00E+00
Drum storage area	0.00	0.00	n/a	n/a	n/a	0.00E+00	0.00E+00	0.00E+00
CAP plant area	0.08	0.08	n/a	n/a	n/a	1.06E-06	1.07E-06	1.15E-06
Products Area	0.08	0.08	n/a	n/a	n/a	8.71E-07	1.58E-06	4.99E-06
Liquefaction building	0.00	0.00	n/a	n/a	n/a	0.00E+00	0.00E+00	0.00E+00
Cumulative risk			0.00E+00	0.00E+00	0.00E+00	4.37E-06	8.69E-06	2.41E-05

Role: Maintenance Technicians

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.09	0.09	9.92E-08	5.37E-07	1.88E-06	n/a	n/a	n/a
Main admin	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Maintenance workshop	0.28	0.28	-	-	-	n/a	n/a	n/a
Repack plant	0.02	0.02	3.99E-08	4.02E-08	4.07E-08	n/a	n/a	n/a
Drum storage area	0.02	0.02	6.64E-07	1.09E-07	2.14E-07	n/a	n/a	n/a
CAP plant area	0.30	0.22	3.78E-06	2.80E-06	3.02E-06	n/a	n/a	n/a
Products Area	0.30	0.22	3.10E-06	4.16E-06	1.31E-05	n/a	n/a	n/a
Liquefaction (excluding transfer)	0.00	0.16	0.00E+00	1.02E-05	1.02E-05	n/a	n/a	n/a
Cumulative risk			7.69E-06	1.78E-05	2.84E-05	0.00E+00	0.00E+00	0.00E+00

Role: Engineers/Planners

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.13	0.13	1.32E-07	7.16E-07	2.51E-06	n/a	n/a	n/a
Main admin	0.13	0.13	0.00E+00	1.92E-09	7.94E-09	n/a	n/a	n/a
Maintenance workshop	0.50	0.50	-	-	-	n/a	n/a	n/a
Repack plant	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Drum storage area	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
CAP plant area	0.13	0.13	1.59E-06	1.60E-06	1.72E-06	n/a	n/a	n/a
Products Area	0.13	0.13	1.31E-06	2.38E-06	7.49E-06	n/a	n/a	n/a
Liquefaction building	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Cumulative risk			3.03E-06	4.69E-06	1.17E-05	0.00E+00	0.00E+00	0.00E+00

Role: Technical/Quality

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.25	0.25	2.65E-07	1.43E-06	5.02E-06	n/a	n/a	n/a
Main admin	0.50	0.50	0.00E+00	7.66E-09	3.18E-08	n/a	n/a	n/a
Maintenance workshop	0.00	0.00	-	-	-	n/a	n/a	n/a
Repack plant	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Drum storage area	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
CAP plant area	0.13	0.13	1.59E-06	1.60E-06	1.72E-06	n/a	n/a	n/a
Products Area	0.13	0.13	1.31E-06	2.38E-06	7.49E-06	n/a	n/a	n/a
Liquefaction building	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Cumulative risk			3.16E-06	5.42E-06	1.43E-05	0.00E+00	0.00E+00	0.00E+00

Role: Operations

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.13	0.13	1.32E-07	7.16E-07	2.51E-06	n/a	n/a	n/a
Main admin	0.50	0.50	0.00E+00	7.66E-09	3.18E-08	n/a	n/a	n/a
Maintenance workshop	0.00	0.00	-	-	-	n/a	n/a	n/a
Repack plant	0.09	0.09	2.40E-07	2.41E-07	2.44E-07	n/a	n/a	n/a
Drum storage area	0.03	0.03	1.33E-06	2.17E-07	4.27E-07	n/a	n/a	n/a
CAP plant area	0.13	0.13	1.59E-06	1.60E-06	1.72E-06	n/a	n/a	n/a
Products Area	0.13	0.13	1.31E-06	2.38E-06	7.49E-06	n/a	n/a	n/a
Liquefaction building	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Cumulative risk			4.60E-06	5.16E-06	1.24E-05	0.00E+00	0.00E+00	0.00E+00

Role: Admin staff

Location	Probability of presence (Current)	Probability of presence (Future)	Day time			Night time		
			Current operation	Future operation (normal case)	Future operation (contingent case)	Current operation	Future operation (normal case)	Future operation (contingent case)
CAP control room	0.04	0.04	3.97E-08	2.15E-07	7.53E-07	n/a	n/a	n/a
Main admin	0.90	0.90	0.00E+00	1.38E-08	5.72E-08	n/a	n/a	n/a
Maintenance workshop	0.01	0.01	-	-	-	n/a	n/a	n/a
Repack plant	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Drum storage area	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
CAP plant area	0.03	0.03	3.18E-07	3.20E-07	3.45E-07	n/a	n/a	n/a
Products Area	0.03	0.03	2.61E-07	4.75E-07	1.50E-06	n/a	n/a	n/a
Liquefaction building	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	n/a	n/a	n/a
Cumulative risk			6.19E-07	1.02E-06	2.65E-06	0.00E+00	0.00E+00	0.00E+00

APPENDIX L. BOTANY/RANDWICK SAFETY STUDY RECOMMENDATIONS (2001)

Recommendation	Comment
<p>Future developments within the Botany/Randwick industrial area should be subject to full risk assessment, following the seven-stage approval process. In addition, proposed developments should undergo comprehensive environmental impact assessment to conclusively demonstrate that the development will not produce off-site risks that are inappropriate for surrounding land uses.</p>	<p>As required by the SEARs the DA application includes a full QRA and evaluated the offsite individual and societal risk. i.e. the present QRA report fulfills the function of assessing offsite risk</p>
<p>Any future development in the vicinity of the Botany/Randwick industrial area should generally provide a buffer between the industrial area and surrounding residential zones. In assessing a proposed development, residential intensification should not be considered in the shaded region of Figure 1 until the new Orica chlorine plant is operational and bulk chlorine storage on the site has ceased. The Department should be consulted regarding proposed development within the 'consultation region' of Figure 1. It would also be prudent for the Department to be consulted regarding these regions after the replacement of the existing (pre-2001) Orica chlorine plant, at least during the early stages of plant operation.</p>	<p><u>Not applicable.</u> The 'new chlorine plant' is the current CAP commissioned in 2001. As required by the SEARs the DA application includes a full QRA and evaluated the offsite individual and societal risk including in the shaded region</p>
<p>As this study has not included the impacts of dangerous goods traffic along Stephen Road and Denison Street, or the operations of Port Botany and Sydney Airport, it is strongly recommended that these activities be taken into account in the assessment of any development in the Botany/Randwick area.</p>	<p>The transport risk has been reviewed. Refer to doc no 21383-RP-003 Sherpa Consulting</p>
<p>It is recommended that all facilities be investigated as part of this study review and strengthen safety management systems. These systems should be monitored by periodic independent compliance audits at intervals of not less than two years. As part of the review of safety management systems, incident/near miss reporting and follow-up procedures should be updated to be consistent with best practice. Training arrangements should be reviewed to ensure that a safety management system is supported by an employee understanding of operational hazards and emergency procedures.</p>	<p>As an MHF, IXOM submits a periodic Safety Case report to SafeWork NSW. The Safety Case reviews the SMS as well as all other recommended items and IXOM including the SMS is periodically audited as part of eth MHF licensing requirements. The CLP will be operated under the same SMS</p>
<p>Emergency procedures for facilities within the industrial area should be reviewed and updated with the aim of establishing greater consistency between the procedures at different sites. There should also be a greater level of integration between facilities in terms of regional emergency planning. An integrated emergency plan for the area should be developed and mutual aid agreements established.</p>	<p>The recommendation has been addressed for the existing facilities within BIP. The existing emergency procedures will be updated to account for the new facility post DA approval.</p>

Recommendation	Comment
<p>The community should be adequately informed about activities, associated risks and safety management measures adopted within the Botany/Randwick industrial area. A formal mechanism needs to be established to implement a community right-to-know program. Community Consultative Committees should be established for developments, or groups of developments, in the industrial complex to act as an interface between the community and industry. particularly in regard to safety issues.</p>	<p>This function was fulfilled by setting up the Botany Industrial Park Community Consultative Committee (BIPCCC) which meets periodically. Refer to the consultation section of the DA submission for consultation activities relating to the liquefaction project.</p>

APPENDIX M. REFERENCES

- [1] NSW Department of Planning, Hazardous Industry Planning Advisory Paper No. 6 (HIPAP 6) - Hazard Analysis, 2011.
- [2] NSW Department of Planning, "Hazardous Industry Planning Advisory Paper No.4 (HIPAP 4)- Risk Criteria for Land Use Safety Planning," 2011.
- [3] UK HSE, "Reducing Risks, Protecting People – HSE's Decision-Making Process (R2P2)," 2001.
- [4] Sherpa Consulting Pty Ltd, Quantitative Risk Assessment Report 2024, Chloralkali Facility, Document No 21972-RP-001, 2024.
- [5] DPHI, "Email Nick Hon DPHI to Ben Smith IXOM, Re: IXOM RFI on 2024 CAP QRA," 26 June 2025.
- [6] TNO Institute of Environmental Sciences, Yellow Book: Methods for the calculation of physical effects due to releases of hazardous materials (liquids and gases), 2005.
- [7] Gifford, Turbulent Diffusion-Typing Schemes: A Review, Nucl Saf, Vol.17, No. 1, Jan/Feb, 1961, pp.68-86, 1961.
- [8] Committee for the Prevention of Disasters, TNO Purple Book, Guidelines for Quantitative Risk Assessment, CPR 18E, 1st edition, 1999.
- [9] ICI Engineering Department, Process Safety Guide 14 - Reliability Data, ICI PLC (UK).
- [10] A W Cox, F P Lees and M L Ang, Classification of Hazardous Locations, Institution of Chemical Engineers, 1990.
- [11] UK Health & Safety Executives, Failure Rate and Event Data for use within Risk Assessments, 2012.
- [12] TNO, Purple Book: Guidelines for quantitative risk assessment (CPR 18E), PGS3 ed., TNO, 2005.
- [13] ICI Engineering UK, Chlorine Drum Hazard Analysis, Internal Orica (ICI Australia at that time) memo to DA Beattie, 1993.
- [14] Ixom Operations Pty Ltd (formerly Orica), Drum Failure Frequency Data for Chlorine Risk Assessments. Rev C.