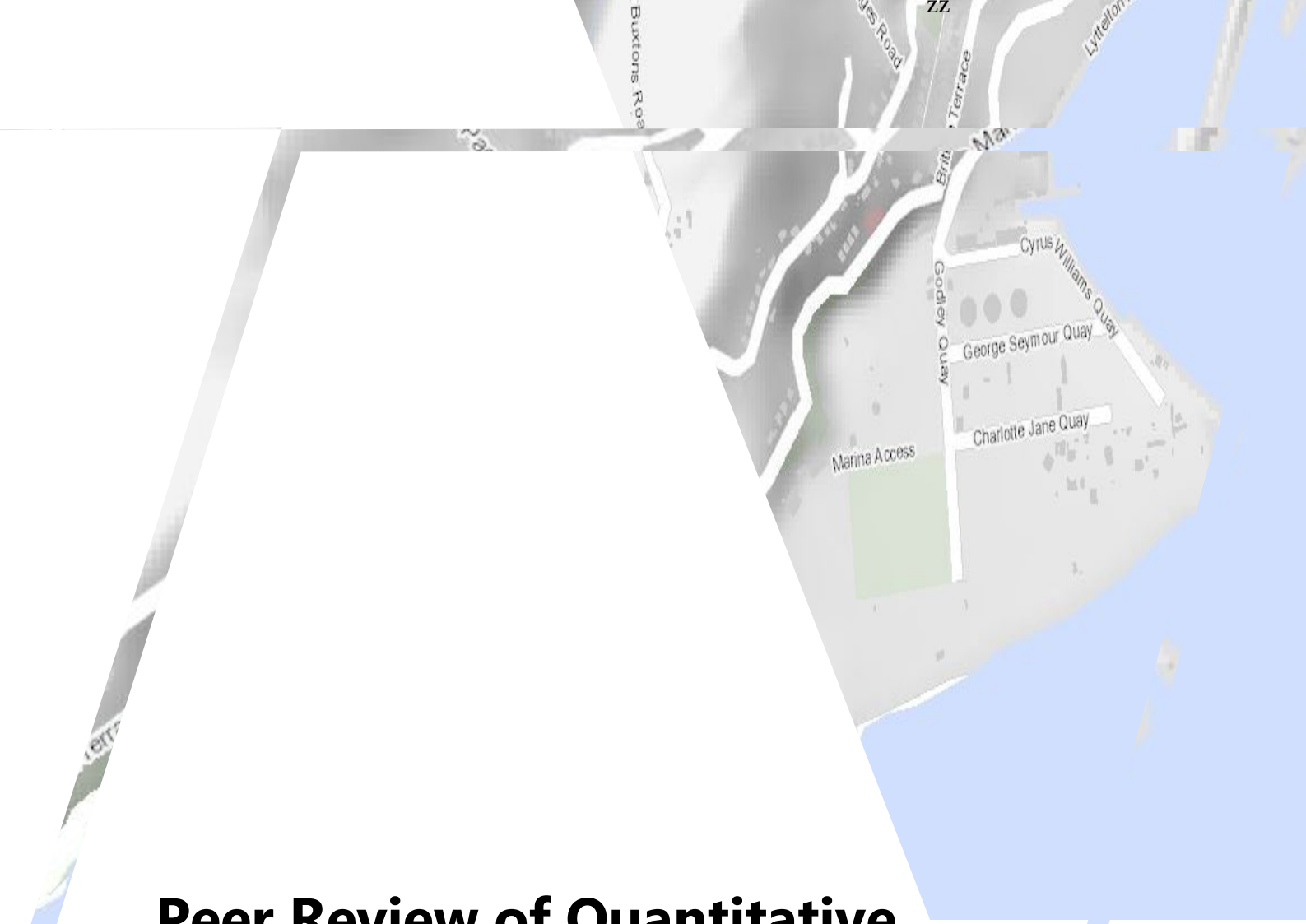

Peer Review of Quantitative Risk Analysis Report

Bulk Storage Facilities, Lyttelton Port

November 2016

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170396-RPT-X0001-R1.

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Project No: 170396-RPT-X0001-R1 – Peer Review of Quantitative Risk Analysis Report: Naval Point Bulk Storage Facilities, Lyttelton Port

Rev	Description	Author	Review	Advisian Approval	Date
0	Approve for Use	Donna Wong	Joseph Micallef	Kristin Hoskin	10/2016
1	Re-issued for use	Donna Wong	Joseph Micallef	Kristin Hoskin	11/2016

Table of Contents

Executive Summary

The Christchurch City Council, with support from the Lyttelton Port Company Limited and lessees of the bulk liquid storage facilities, has committed to developing a quantitative risk assessment, to be completed within nine months of gazettal of the Recovery Plan. A steering group with representatives of these parties was formed, and agreement was reached that Sherpa would be commissioned through Burton Planning, as the representative of the Oil Companies, to complete the required QRA.

Advisian (WorleyParsons) was selected by Christchurch City Council to conduct an independent review on the Bulk Storage Facilities, Lyttelton Port cumulative QRA. This report details the findings of that peer review.

The peer review identified that:

- The cumulative QRA report was prepared as per good industry practice and was based on the agreed database, information and assumptions. However, the calculated risk was seen to be on a caution side due to the assumptions and selected database.
- Flash fire event should have been considered for a delayed ignition for pumps and process piping and associated fittings, flanges and etc.
- It is unclear what input was used in determining the fatality probability for toxicity assessment. Modelling Parameters stated that an averaging time of 10 minutes was used and referenced to TNO yellow book; however a 30 minutes exposure using AEGL 3 concentration was also referenced. A confirmation is required on the actual information used in the QRA.
- The escalation between sites criterion used in the QRA is aligned with the HIPAP 4. This is acceptable in this QRA context as the Christchurch City Council has yet to define acceptable risk criteria.
- It was noted that the receptor height for flash fires in Table C.3 and the downwind distance to LFL receptor height presented in Table D.6 and D.7 were inconsistent. It is recommended that the receptor height that was used be confirmed and report updated.
- Consideration of natural hazards as initiating events increasing both the likelihood of damage and extent of probable damage is generalised. The second sensitivity in the QRA doubles the ignition probability to account for an earthquake initiated major loss of containment. Note that, that the occurrence of an earthquake leading to loss of containment is in the frequency of 0.001 to 0.002 per year and only a fraction of equipment will likely experience loss of containment in the event.

1. Background

Beginning in 2010 significant seismic activity has occurred in Canterbury. Most notably, in February 2011 an earthquake centered 2km from Lyttelton resulted in extensive damage throughout Christchurch and to the Lyttelton area. In June 2014 a Direction to Develop a Lyttelton Port Recovery Plan was issued. During consultation concern was raised that quantitative assessment of risk related to current and future planning at Naval Point was not in place. In formalising the Lyttelton Port Recovery Plan an action was included that

Christchurch City Council, with support from the Lyttelton Port Company Limited and lessees of the bulk liquid storage facilities, has committed to developing a quantitative risk assessment, to be completed within nine months of gazettal of the Recovery Plan.

(Lyttelton Port Recovery Plan - 3.11 Potential Off-site hazards from bulk storage liquids storage at Naval Point)

A steering group with representatives of the identified parties was formed, and agreement was reached that Sherpa would be commissioned through Burton Planning, as the representative of the Oil Companies, to complete a QRA. In order to ensure objectivity an independent peer reviewer for the work carried out by Sherpa was commissioned through Christchurch City Council. Advisian (WorleyParsons) was selected to conduct that peer review.

The Peer Review process included opportunity to observe steering group meetings and comment on assumptions, methodology and draft QRA documents during the project. This report is an assessment of the quality and completeness of the work carried out by Sherpa as documented in Quantitative Risk Assessment Report Document Number 21026-RP-002 Revision 0 Issued 20 September 2016 (hereafter referred to as the QRA report).

The peer review team consisted of:

- Kristin Hoskin – Project Lead
- Donna Wong – Technical Reviewer and Author
- Joseph Micallef –Subject Matter Expert and Internal Reviewer

This report documents the peer review findings.

2. Scope Definition Observations

2.1. Legislated Scope

Christchurch City Council, with support from the Lyttelton Port Company Limited and lessees of the bulk liquid storage facilities, has committed to developing a quantitative risk assessment, to be completed within nine months of gazettal of the Recovery Plan.

(Lyttelton Port Recovery Plan - 3.11 Potential Off-site hazards from bulk storage liquids storage at Naval Point)

2.2. Aim of commissioning a study

In the request for proposal aims were stated to define:

The most important aim is to produce a universally accepted Risk Assessment Report developed using best practise and providing recommendations against predetermined criteria. It is anticipated that these are likely to be the criteria developed by NSW Government Department of Planning (i.e. using relevant Hazardous Industry Planning Advisory Papers).

This study is intended to provide independent advice and recommendations that can be used as the basis upon which the local authorities and the Port Company can base planning decisions in relation to development proposals in the area through appropriate location, design and development. The study will need to consider both existing and future growth scenarios for the bulk storage facilities so that future bulk storage development can occur as and when required (i.e. within acceptable levels).

(Burton Planning Consultants, Risks Assessment Request for Proposal for Port of Lyttelton 14th May 2015)

The Sherpa report scope summarises its approach to meeting the defined requirements:

Two cases are presented in the cumulative QRA report:

- QRA baseline reflecting the cumulative risk from the current approved operations for all sites. This is referred to as the Current Case.
- QRA future growth case reflecting the cumulative risk for a future operations case for all sites (up to around 2026). This is referred to as the Future Case.

Estimates of current populations for the existing land uses, and future population growth reflecting potential land uses in the Port area have also been provided by CCC and LPC for use in the societal risk component of the QRA.

The QRA focused on the effects of potential major accident scenarios which may have fatality impacts outside the facility boundaries. It does not cover consequential losses such as asset damage or fuel supply interruption, or other risks such as long-term or chronic impacts, continuous small emissions or environmental impacts.

2.3. Extent to which report meets scope and aim definition

Because the Christchurch City Council has yet to define acceptable risk criteria it was not possible for this aspect of the request for proposal to be met. Instead Sherpa adopted a strictly analytical approach that could then be used to compare against risk criteria once these are set. Examples of risk criteria used in different jurisdictions around the world were included to assist in providing perspective on the tolerability of the risk exposures internationally.

In presenting risk exposure analysis a series of aerial photographs with overlays of risk contours were presented. Contours span 1x10-4 to 1x10-7 per year exposures. 1x10-4 is considered intolerable beyond facility boundaries in all the example jurisdictions. Risks of 1x10-8 per year are international accepted as considered negligible. The range of contours presented are therefore appropriate for assessing the tolerability/ intolerability of risk exposure against a yet to be defined criteria.

Risk exposure in the study is narrowly defined to the extent that only individual fatality and societal risk were analysed. These relate to a specific incident causing direct loss of life to people in areas surrounding the source. The likelihood and consequence of the considered incidents included some influence from natural hazards as contributors to initiating events.

It is usual for QRAs to have defined limits and to consider location based vulnerabilities that have the potential to exacerbate these risks. The major incident scenarios considered are consistent with the meaning of major incident as defined in the Health and Safety at Work (Major Hazard Facilities) Regulations 2016.

Both existing use and future use were considered. Constraints regarding these were well defined, with existing use being based on currently consented activities (rather than actual use for a given current period), and future use incorporating both desired changes in lessee activities and possible usage changes to the surrounding areas. Possible usage changes to the surrounding areas were less easily defined than for the lessee activities as these are less constrained by infrastructure. As a result, conservatism with respect to societal risk is likely reflected in the population distribution that was used to generate the risk contours.

When future use recreation areas that will have population density concentrated around them have their likely locations more specifically defined, consideration of updated modelling may be warranted.

3. Methodology

3.1. Expectations

A review of the QRA was done to give a sense check that the results are consistent with what would be expected from this type of study on a facility of this size, layout and age. The objective is being to determine if the QRA is robust and stands up to scrutiny. It was not intended that this would include a detailed review of all the modelling techniques and inputs into the QRA as the site specific QRAs were not made available to the peer reviewers. The focus of the peer review is determining whether suitable and sufficient analysis had been undertaken to support the current and future planning at Naval Point as required for the Recovery Plan.

The proposed methodology as shown in Figure 4.1 of the QRA report is aligned with the work scope required for a typical QRA. Since the risk evaluation criteria has not yet been defined by the Christchurch City Council, it was understood that the cumulative QRA excluded the risk acceptance criteria assessment and provided various risk results for information and comparison against different jurisdictions around the world.

Justifications and succinct explanation on assumptions / information used in the QRA should be provided so that readers can understand the basis for selecting the resources.

3.2. Methodology Review Comments

QRA Section 3.2.1 Scenarios, Table 4.1: Hazardous Incident Scenarios

The scenarios for loss of containment at all areas depend on the operating conditions such as temperature and pressure within the isolatable sections. If the operating conditions indicate that the isolatable sections operate at pressure beyond atmospheric conditions with hydrocarbon content of low flash point (normally under 60 degree Celsius), there is a possibility for the hydrocarbon to flash into vapour phase from the predefined hole sizes.

Note that, a piping or pipeline isolatable section could be subjected to overhead pressure from the storage tank that will cause the section to have pressure higher than atmospheric condition. Consideration should be made to include releases under such conditions. Although isolations are provided when no offloading operations are being undertaken there is a possibility where the lines remained pressurized Then a Jet fire event should be considered unless the percentage of liquid rain-out indicates that the likelihood of having a pool fire event is higher than jet fire event due to lack of momentum.

It is advisable to consider and define the transition point at which spray releases change to liquid releases in the methodology.

The safeguards for tank storage area do not include ignition control and fire/gas detection.

A confirmation is required on availability of the ignition control such as whether the electrical equipment and instrumentations located at the tank storage area are rated as per the hazardous area classification.

Generally firewire is installed on the tank to detect temperature increase and heat rise due to tank fires or fire impingement from external sources located within the vicinity of the tank.

A Low level alarm was not included as a barrier / safeguards for the tank storage. In the event of a tank rupture, the low level alarm will notify personnel that process upsets or leaks have occurred from the storage tank. An early warning is important to prevent full surface liquid formation inside the bund.

Flash fire event was not considered as a typical consequence for tank leaks. Vaporization of the flammable hydrocarbon could occur due to flashing of the fluid when released to atmosphere (phase change from a liquid phase to vapour phase) and pool vapourization in the event of a spill or liquid pool formed inside a bund. Flash fire events should only be discarded if no people are likely to get caught in any vapour cloud formed that could ignite.

Section 3.2.2 Scenarios, Table 4.2 Scenario Summary

The full bund pool fire scenario has not considered the extent of lower flammability limit (LFL). In the event personnel are present within the 100% flammable cloud and if ignition occurs, the fatality risk to personnel is assumed to be 100%

Flash fire event should be considered for a delayed ignition for pumps, process piping and associated fittings, flanges and etc.

Two types of consequences are credible for delayed ignition events i.e. pool fire and flash fire. This was also reflected in the event tree as attached in Appendix D2.

Section 3.2.3 Vulnerability

The fatality probability for toxicity assessment i.e. Ethyl Mercaptan and Methanol are based on personnel exposure both in concentration and duration. Table C3 Modelling Parameters stated

that an averaging time of 10 minutes was used and was referenced to TNO yellow book; however a 30 minutes exposure using AEGL 3 concentration was reported in the Table B2 Representative Hazardous Material Classifications and Properties in QRA report.

A confirmation is required on the actual toxicity information used in the QRA.

Section 3.2.4 Probability of Ignition

The ignition probability developed by Cox, Lees and Ang was used in this QRA and has been seen as reliable information to determine the risk associated with ignited loss of hydrocarbon.

This reference was prepared in 1990 and should be replaced with a more rigorous approach.

The International Association of Oil and Gas Producers (OGP) has issued a risk assessment data directory on ignition probabilities, Report No. 434-6.1 in March 2010 stating that formulation attributed to Cox, Lees and Ang was widely used and gained acceptance largely because of the proportion of analysts using it rather than because of the rigour of the theory underlying it. The ignition probabilities predicted by Cox, Lees and Ang were relatively easy and pragmatically quick to be applied, but it is also possibly lacking sensitiveness relevant to Plant-specific factors.

Note that, the immediate ignition probabilities used for this QRA is of approximately 10 times higher than what was recommended by OGP and hence could have significant impact on the risk calculation.

The differentiation between immediate and delayed ignition probabilities is provided in the IP Research Report, Ignition Probability Review, Model Development and Look Up Correlations, Energy Institute, London, Jan 2006. The report stated that for QRA purposes, the common practice to assume a 50:50 or 30:70 distribution between early and delayed ignitions appears to be reasonable. The immediate ignition probability in Cox, Lees and Ang is more than 70% which leads to higher probability of immediate event.

Justification of using higher immediate ignition probabilities should be provided.

Section 3.2.5 Effect of Safeguards

It should be noted that the availability and effectiveness of the hardware safeguards such as instrumentation and automatic trip system depends on the SIL level assigned for the system. As the site specific QRA was not made available for peer review, the probability of success for each of the safeguard considered in the event trees is not known.

A table of bowtie risk analyses drawn upon would need to be supplied in order to review this aspect of the QRA.

Section 3.2.6 Escalation between sites

The radiation levels of 8 – 12 kW/m2 were not used in fatality estimation in the QRA and the heat radiation used to assess escalation to equipment was 23kW/m2. An average radiation level of 10kW/m2 was used to determine the requirement for tank cooling system but does not have any impact in QRA risk calculation.

In general, the radiation used to assess the structural impairment leading to an escalation is between 37.5kW/m2 and 250kW/m2 depending on the selected criteria for a QRA. For example,

The Centre for Marine and Petroleum Technology (CMPT) used 37.5 kW/m2 and fire impingement, whilst OGP used 250kW/m2 for structural impairment assessment.

The criterion used in the QRA is aligned with the HIPAP 4 which is acceptable in this QRA context.

Section 3.2.7 Equipment Covered

The occurrences of the natural hazards leading to scenarios with low probability, high consequences have been considered in the QRA but have excluded the scenarios with high probability, low consequences. This assumption could possibly under estimate the risk due to natural hazards as leaks normally occur at piping or flange connections to the tanks or pipe rack depending on the supports available on site and ductility of the materials of construction.

It was understood that structural assessment has been excluded from this QRA but it is worth considering leaks from all credible releases.

4. Analysis

The risk analysis is a technique used to determine whether the risk results obtained from the QRA fall within the acceptance criteria. Because the Christchurch City Council has yet to define acceptable risk criteria it was not possible for this risk analysis to be met.

4.1. Analysis Presentation Comments

Section 4.1.1 Acceptance of Risk

Consideration to assess the risk acceptance criteria in the next phase for decision making and communication with the affected parties on options evaluation, and mitigation measures to reduce the risk to As Low As Reasonably Practicable (ALARP) is required. The risk acceptance criteria assessment helps in planning and decision making / discussion when future development is in the pipeline.

Although this is a cumulative QRA, the individual or site specific QRA should include recommended mitigation measures for risk reduction. There should be an initiative to reduce the existing / current risk levels with the Operators and CCC involvement such that the risk level is accepted by all parties.

It is acceptable for Sherpa to analyse the risk levels based on the risk criteria used in different jurisdictions around the world and provide a comparison against HIPAP 4.

Appendices

Table A.1 Population Data

The population data used for P04 area for societal risk calculation was based on the temporary population of 2,600 instead of the permanent population as provided in the Table A1.

An incremental societal risk should be provided due to the changes in manning from permanent to temporary population.

Table B.2 Representative Hazardous Material Classifications and Properties

It was stated in the main report that Ethyl Mercaptan and Methanol are toxic and that the risk is within the immediate area of exposure. Due to the unknown location of where the Ethyl Mercaptan and Methanol are used and stored, a detailed comment could not be made for the risk associated with toxic gas releases. Note that, if the above substances are located at the boundary of the tank facilities next to the public sites, a toxic gas release could potentially cause fatality which depends on the concentration of the substance at the public sites. Based on the QRA report, it is assumed that the toxic gas will not reach offsite / public sites.

A statement with respect to toxic gas reaching/not reach offsite/public sites is recommended. Note that, Table B2 needs to reflect that Methanol is a toxic substance.

Table C.2 Modelling Parameters

It was noted that the receptor height was taken as 1m for flash fires based on the verification of software models against empirical data as per Phast technical manual. However, the downwind distance to LFL presented in Table D.6 and D.7 were based on 1.5m receptor height.

D5 Pool Fires

As the site specific QRA and detailed calculations were not made available for peer review, it is assumed that the calculation of the pool equivalent diameter has discounted the area of the tank within the bund.

D6 Flash Fires

The hole size release for flash fire resulted from pool evaporation should be for hole sizes > 22mm instead of < 22mm.

A confirmation on whether there is a typing error made on the flash fire assessment summary (refer to second bullet point) should be obtained.

E8 Online Time

Information of the offline time and hydrocarbon inside piping / pipeline sections have presumably been taken into account in the site specific QRAs.

A consideration of the online time for piping / pipeline needs to be included in the QRA to account for the inventory within the piping / pipeline under static overhead pressure from the tank which could be above atmospheric condition.

5. Results

Risk results will be compared with the risk acceptance criteria and identifying the major risk contributors for each sensitive locations.

The analysis should cover the overall risk results which are the base case and both Future Cases for Bulk storage Facilities at Lyttelton Port. It is expected that the risk results are presented using risk contours with clear comparison for all 3 cases and incremental risk from sensitivity analysis is covered in this section.

5.1. Results Comments

Section 5.1.1 Existing Land Uses

The individual fatality risk for the public roads requires a clear distinction between the current and the future cases. The individual fatality risk for the public roads (Charlotte Jane Quay and George Seymour Quay) running east-west between the different storage facilities are exposed to risk levels well above $1x10^{-5}$ per year which applies for future case. The individual risk for these public roads under current case is within the $1x10^{-5}$ per year contour.

Section 5.1.2 Sensitivity of Risk Results to Natural Hazards

The second sensitivity done in the QRA was doubling the ignition probability to account for an earthquake initiated major loss of containment. Note that, the occurrence of an earthquake leading to major loss of containment is in the frequency of 0.001 to 0.002 per year (depending on the design criteria used by each Operator) and only a fraction of equipment will have loss of containment.

Section 5.1.3 Future Case

There is an error in this section where the QRA report states that Figure 6.3 (Future Case 2, all export increase via road tanker) shows a similar effect as Future Case 1 to the contours around the bulk storage facilities.

The Future Case 2 should state all export increase via pipeline instead of road tanker.

Section 5.1.4 Risk Contributors

It was mentioned in the QRA report that the nearer field risks (for example at the sports oval or around Naval Point tanks) are dominated by tank top fires, pool fire events in bunds or road tanker loading bays nearby. A similar consequence event has been conducted in the past for similar facilities by another consultant indicated that the heat radiation levels generated from a tank top fire will not have sufficient heat radiation level to cause personnel fatality at 1.5 m height from ground level. However, the radiation level from one tank could escalate to another tank depending on the separation distances.

The risk contributors for Future Case 2 were provided in the report without justification or explanation. However, it was noted that the Future Case 2 will have lower risk profile than the Future Case 1.

A review of the individual risk contours shows that there is a similarity between Future Case 1 and Case 2 although the mode of transporting the hydrocarbon inventory is different. It is understandable that the increased risk levels at Analysis Point 3 are associated with the reinstatement of the existing 5 tanks for Mobil. However, the unloading failure frequency (depending on the types of prevention systems used by the Operators) is higher than pipeline leak

frequency. The risk results from the Future Case 1 should be higher than Future Case 2 based on the failure rate alone.

Justification or explanation of risk contributors for Future Case 2 requires elaboration.

6. Quality Assessment of QRA

Peer Review Summary Table

QRA. Ref.	Aspect	Completeness	Issues	Recommendations
	Alignment with Objectives	The cumulative QRA report captured the main objectives in identifying the risk exposure to the sensitive receivers i.e. proposed developments occurring as part of the Lyttelton Port Recovery Plan.		
	Assumptions	High level assumptions have been incorporated in the report. Some specific assumptions were not provided in the QRA report e.g. the isolatable sections, inventories, operating conditions, probabilities for event trees.	This could possibly be due to site specific QRA information that could not be disclosed. Verification on the assumptions used could not be determined through the cumulative QRA report.	Site specific QRA to be made available for review if deemed required by CCC.
	Natural Hazard	The extent of	Assumptions in	Greater clarity on the

QRA. Ref.	Aspect	Completeness	Issues	Recommendations
	Considerations	influence natural hazards present as risk contributors is unusual.	increasing risk exposure due to natural hazard events appear disproportionate to the likely impact scenarios natural hazards present.	influence of natural hazards in magnifying risk is warranted.
	Choice of Tools	The selection of software used for the QRA is appropriate for this study.	Verification of the models and inputs used are excluded from this peer review as these were not made available.	
	Depth of Analysis	In general, the analysis covers hazards associated with flammable fluids, toxic gas and natural hazards. Risk assessment could not be conducted as Christchurch City Council has yet to define acceptable risk criteria.	There was no recommendation being made in the cumulative QRA report as mitigations could not be proposed to reduce the risk levels to meet the risk criteria.	The site specific QRA should include risk reduction measures as the risk contributors for the site specific could be narrowed down to the causal factors.
	Risk Consolidation	The risk contours have taken into consideration all hazards associated with the bulk storage facilities.	Verification in terms of suitability and accuracy of the risk contours could not be made.	

QRA. Ref.	Aspect	Completeness	Issues	Recommendations
	Interpretation	Risk exposures to the sensitive receivers were presented in the report for current case and future cases. Risk contributors are provided in the report. Assessment of the risk results were done against international typical range of land use planning risk criteria values adopted in other locations.	The risk interpretation is limited by the level of information provided in the cumulative QRA.	Consideration to assess the risk acceptance criteria in the next phase for decision making and communication with affected parties on options evaluation and mitigation measures to reduce the risk to ALARP. This helps CCC in decision making / discussion with regards to future development.
	Alignment with Good Practice	The QRA report is prepared as per good industry practice and references were made to state where the information was obtained.	A mixture of references from different publications and relatively old references were used in the risk calculation. The calculated risk level was seen to be on a higher / caution side due to the assumptions and selected database.	A further refinement of the QRA could be made by conducting a sensitivity analysis with reduction of total ignition probability and lower immediate ignition probability.
	Presentation of Findings	The risk results were presented using risk contours and	High level risk contributors were presented in the report.	Communication and alignment on forward plan to prioritise mitigation measures

QRA. Ref.	Aspect	Completeness	Issues	Recommendations
		overlay onto a layout. This is a good presentation as it is an easy way to communicate results to a wider audience. Risk results at specific analysis points were presented as order of magnitude levels i.e. from $1x10^{-4}$ to $1x10^{-7}$ per year and an assessment against HIPAP 4 was provided in Appendix G.	The main causal factor could not be determined as the cumulative QRA lacks in site specific information.	implementation and development are required between CCC and all Operators.

7. Conclusions

7.1. Conclusion

This review has concluded that:

- The cumulative QRA report was prepared as per good industry practice and was based on the agreed database, information and assumptions. However, the calculated risk was seen to be on a caution side due to the assumptions and selected database.
- Flash fire event should have been considered for a delayed ignition for pumps and process piping and associated fittings, flanges and etc. Two types of consequences are credible for delayed ignition events i.e. pool fire and flash fire. This was reflected in the event tree in the QRA Appendix D2.
- The fatality probability for toxicity assessment i.e. Ethyl Mercaptan and Methanol are based on personnel exposure both in concentration and duration. Table C3 Modelling Parameters stated that an averaging time of 10 minutes was used and referenced to TNO yellow book; however a 30 minutes exposure using AEGL 3 concentration was reported in the Table B2 Representative Hazardous Material Classifications and Properties in QRA report. A confirmation is required on the actual information used in the QRA.

- The escalation between sites criterion used in the QRA is aligned with the HIPAP 4 which is acceptable in this QRA context as the Christchurch City Council has yet to define acceptable risk criteria.
- It was noted from Table C.3 Modelling Parameters that the receptor height was taken as 1m for flash fires based on the verification of software models against empirical data as per Phast technical manual. However, the downwind distance to LFL presented in Table D.6 and D.7 were based on 1.5m receptor height.
- The second sensitivity done in the QRA was doubling the ignition probability to account for an earthquake initiated major loss of containment. Note that, the occurrence of an earthquake leading to loss of containment is in the frequency of around 0.001 to 0.002 per year (depending on the design criteria used by each Operator) and only a fraction of equipment will have loss of containment.