APPENDIX I QRA PEER REVIEW KAPUNI J WELLSITE – ENVIRONMENTAL RISK SOLUTIONS

TODD ENERGY LTD

KAPUNI J WELLSITE

QRA REVIEW

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CONTENTS

FRONT PAGE
REVISION RECORD
CONTENTS
ABBREVIATIONS & DEFINITIONS

1. SUMMARY 1

2. INTRODUCTION 3

3. OBJECTIVE 3

4. SCOPE 3

4.1 Scope Inclusions 3

4.2 Scope Exclusions 3

5. METHODOLOGY 4

6. RISK CRITERIA 4

6.1 WorleyParsons QRA Criteria 4

6.2 Recommended QRA Criteria 5

7. QRA REVIEW FINDINGS 5

7.1 Risk Assessment Methodology 5

7.2 Parts Count 6

7.3 Holes Size Selection 10

7.4 Failure Frequency 11

7.4.1 Use of Offshore Data for Onshore Facilities 11

7.4.2 Alternative Failure Frequency Databases 12

7.4.3 Failure Frequency – Modification of failure frequencies 16

7.4.4 Failure Frequency – Confidence Levels 18

7.4.5 Failure Frequency – Review of TE Failure Data 20

7.5 Ignition Probability 20

7.6 Consequence Assessment 21

7.7 Analysis of Results 21

7.7.1 Bench Marking 21

8. GENERAL 23

9. CONCLUSION 23

10. REFERENCES 24

LIST OF TABLES

Table 7-1 Comparison of parts count 8
Table 7-2 Comparison of differences in total leak frequencies due to different parts count 9
Table 7-3 Impact of Different Methods for Hole Size Selection (50 mm – 150 mm range)........ 10
Table 7-4 Key Differences of Leak Frequencies between DNV & OGP Databases 14
Table 7-5 Release Frequency Modifications for Different Flange Types 17
Table 7-6 Benchmarking Assumptions between Different QRAs 22

LIST OF FIGURES

Figure 7-1 Parts count undertaken for comparison with WorleyParson values 7
Figure 7-2 Uncertainties in applying curve to data (Ref. 7 ‘Failure Frequency Guidance, Process Equipment Leak Frequency Data for Use in QRA’)........ 11
Figure 7-3 Ratio of frequencies – DNV data to Netherlands tabulation (Ref. 7 ‘Failure Frequency Guidance, Process Equipment Leak Frequency Data for Use in QRA’) 19

ABBREVIATIONS AND DEFINITIONS

AEE	Assessment of Environmental Effects
ANSI	American National Standards Institute
BLEVE	boiling liquid expanding vapour explosion
CO_2	carbon dioxide
COMAH	Control of Major Accident Hazards
DNV	Det Norske Veritas
ERS	Environmental Risk Solutions Pty Ltd
FERA	Fire and Explosion Risk Analysis
FB	full bore
FRED	Failure Rate and Event Data
HAZID	Hazard Identification (study)
HAZOP	Hazard and Operability (study)
HCRD	Hydrocarbon Release Database
HIPAP	Hazardous Industry Planning Advisory Paper
km	kilometre
LOC	loss of containment
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MF	management factor
mm	millimetre
mm^2	square millimetre
MMPS	Mckee-Mangahewa Production Station
N/A	not applicable
NCS	Norwegian Continental Shelf
NSW	New South Wales
NZ	New Zealand
OGP	Oil and Gas Producers
PFD	process flow diagram
PHA	process hazard analysis
P&ID	piping and instrument diagram
PLOFAM	Process leak for offshore installations frequency assessment model
PML	Petroleum Mining Lease
QRA	quantitative risk assessment
RADD	Risk Assessment Data Directory

ABBREVIATIONS AND DEFINITIONS

Rec	recommendations
Ref	reference
RF	raised flange
RMA	Resource Management Act 1991
RTJ	ring type joint
SBF	small bore fittings
SOW	scope of work
STDC	South Taranaki District Council
TE	Todd Energy Limited
UKCS	United Kingdom Continental Shelf
UK HSE	United Kingdom Health and Safety Executive
UKOOA	United Kingdom Offshore Operators Association
%	percent
“	inch

1. SUMMARY

Todd Energy Limited (TE) propose to install a new wellsite, the Kapuni J Wellsite on land zoned as rural near Palmer Road, approximately 2.5 kilometres southeast from Kaponga, South Taranaki and within Petroleum Mining Lease (PML) 38839.

Todd Energy has contracted WorleyParsons to undertake the Hazardous Substance Risk Assessment. Worley has drafted the, ‘Kapuni J Wellsite, Hazardous Substances Risk Assessment’, Doc. No. 620035-RPT-R0001, Dec. 2018. The report includes a quantitative risk assessment (QRA).

Todd Energy requested a third-party review of the WorleyParsons QRA which is the subject of this report.

QRAs have confidence levels that are limited by input data ranging from limitations on accuracy of parts counts, generic failure frequencies, ignition probabilities, modelling capability, consequence probits and other consequence criteria and management factors. The extent of these limitations has led to regulators in some jurisdictions, for example South Australia for major oil and gas facility, not requiring a QRA as a prerequisite for safety management through to some regulators being sceptical of the results of QRAs, as has occurred in the United Kingdom. This is not to say that QRAs do not have a purpose with regard to understanding hazardous events and risk drivers; however, the actual numerical risk levels are considered to be at best within an accuracy of two orders of magnitude.

Typically, a QRA is undertaken using conservative assumptions and if the results meet guidance criteria on risk levels, further refinement is not undertaken. Normally, where criteria are not met, refinement to the assumptions and consequently the model is undertaken until further refinement results in negligible change to the contours. WorleyParsons’ QRA is considered to be conservative and the following refinements are considered options that will show risk levels that are more representative of the Kapuni J Wellsite (note, some of the following recommendations will be superseded should there be a decision to change the frequency database which itself is a recommendation coming out of this report):

Recommendations to Reduce the Calculated Level of Risk

- **use the geometric mean for hole diameter**: to represent a range in hole sizes as this approach has a mathematical basis and will reduce the mass emission rate. Additionally, this will reduce the ignition probability (which is linked to the mass emission rate) (Rec. 4).
- **enhance accuracy associated with the modelling including**:
  - change the modelling of small bore fittings (SBF) to reflect a maximum hole size of 20 millimetre (mm) as current modelling indicates that hole sizes go up to 100 mm for a 50 mm SBF and 30 mm for a 25 mm SBF which is physically not possible (Rec. 5).
  - for pipework ≥150 mm, limit the maximum hole size for a flange to 20 mm from current assumptions that include hole sizes of up to 100 mm and full bore as a release is normally limited to a segment of a gasket between bolts (Rec. 6).
- **change generic database from current Det Norske Veritas database to OGP (Oil and Gas Producers) or UK HSE (United Kingdom Health and Safety Executive) published databases**: may result in up to an order of magnitude difference in the results as the latter two databases are more representative of onshore developments. Note, OGP data is considered to be the better of the two databases with regard to more comprehensive details on size, range of equipment and hole sizes (Rec. 7).

Recommendations to Improve the QRA Presentation

- **include in the QRA a review of historical incidents**: to assist in decision-making on whether the failure frequency data should be revised (Rec. 11).
- **Develop a TE QRA guidance document**: as this will assist in ensuring that there is consistency in the QRA reports that may be developed by different consultants to ensure representative assumptions (Rec. 2 and 3)
- **include in the QRA a section on the confidence levels associated with a QRA**: to highlight that what is considered the best and most rigorous QRA methodology has limitations on the confidence level due to limitations on the confidence level in the input data and methodology (Rec. 8).
- **separate the QRA report from the 'Hazardous Substances Risk Assessment' report**: so that there is not an associated assumption that the understanding and confidence levels of the QRA are the same as that for hazardous substances and to ensure that any potential security-related confidential information is not made public (Rec. 14).
- **develop a TE-specific database for failure frequencies**: to enable future risk assessments to be based on actual failure data specific to TE (Rec. 10).

2. INTRODUCTION

Todd Energy Limited (TE) own and operate Kapuni field which includes the Kapuni Production Station that is fed by underground pipelines from 12 currently active Kapuni field wells located in surrounding farmland on seven wellsites.

The Kapuni field is located in New Zealand (NZ) in the shadow of Mount Taranaki, near the small Kaponga township, some 65 kilometres (km) south of New Plymouth, and 10 km west of Eltham.

Todd Energy propose installing a new wellsite, the Kapuni J Wellsite, on land zoned as rural near Palmer Road, approximately 2.5 km southeast from Kaponga, South Taranaki within Petroleum Mining Lease (PML) 38839.

In order for the project to progress, a Land Use Consent from the South Taranaki District Council (STDC) will need to be obtained. Under the *Resource Management Act (RMA) 1991* (Ref. 1) an Assessment of Environmental Effects (AEE), incorporating a Hazardous Substances Risk Assessment, must be completed to facilitate this consenting process.

Todd Energy has contracted WorleyParsons to undertake the Hazardous Substance Risk Assessment, required under legislation. WorleyParsons has drafted the, 'Kapuni J Wellsite, Hazardous Substances Risk Assessment', Doc. No. 620035-RPT-R0001, Dec. 2018 (Ref. 2). The report includes a quantitative risk assessment (QRA), which is not explicitly prescribed as a requirement under relevant legislation.

Todd Energy recognises if the methodology is not representative, there is the potential to overestimate the level of risk. This may have significant implications with regard to raising unnecessary perception of the level of risk by owners of land surrounding wellsites and production facilities.

TE has requested a third-party review of the WorleyParsons' QRA which is the subject of this report.

3. OBJECTIVE

The objectives of the QRA review are to assess the assumptions used in the QRA and determine whether the interpretation of the results is representative of the potential hazards and associated levels of risk.

4. SCOPE

4.1 Scope Inclusions

The scope of work (SOW) for this review included the draft report 'Kapuni J Wellsite, Hazardous Substances Risk Assessment' 620035-RPT-R0001, December 2018 (Ref. 2).

4.2 Scope Exclusions

The SOW for this review excluded other TE wellsites, production facilities and transport operations, including road and pipeline.

The scope of the Worley Hazardous Substance Risk Assessment is stated as including:

- initial drilling
- well clean-up

- production testing
- hydrocarbon production.

Each of the above has different risk profiles and the report states that two modes of operation were subject to a QRA; namely, drilling and normal production.

Risk criteria are considered to apply to normal operations as opposed to drilling operations for which there are separate hazards and associated risks. Drilling operations are expected to take approximately 30 days per well of which a small time is associated with the potential for an incident involving shallow gas or reservoir fluids. Risk criteria are not normally associated with short term higher risk activities and other process hazard analysis (PHA) methods, such as a Hazard Identification (HAZID) study may be more appropriate for this activity. As the '1-in-a-million' contour is contained within the site boundary, review of this risk assessment was not undertaken.

The SOW also excluded explicit modelling of scenarios within risk or consequence software to cross-check model outputs as provided in the WorleyParsons report.

The SOW excluded risks to the workforce and associated risk assessment methodology with regard to criteria and risk reduction.

The SOW excluded a review of the methodology with regard to reducing risks to so far as is reasonably practicable.

5. METHODOLOGY

The methodology involved a systematic desktop review of the QRA report. A site inspection was not warranted for this review.

Specifically, the desktop review included:

- review of risk criteria used in the assessment
- technical review of the QRA assumptions, including:
  - parts count methodology
  - hole size selection
  - failure frequency database
  - ignition probabilities
  - explosion methodology
  - consequence modelling

6. RISK CRITERIA

6.1 WorleyParsons QRA Criteria

Section 6.2.2 of the QRA, 'Representation of Offsite Risk', refers to NSW Government Department of Planning in the Hazardous Industry Planning Advisory Paper No.4 (HIPAP 4) (Ref. 3) with a statement that "there are at present no standard risk criteria which have been developed for the New Zealand context. Therefore, the site has been assessed against risk criteria suggested in HIPAP 4. The WorleyParsons' QRA addresses only fatality risk. Note, whilst there is a statement in the QRA that Phast QRA software accounts for injurious effects in the individual fatality risk calculations, this does not address the criteria detailed in HIPAP 4.

The '50-in-a-million' contour is considered appropriate for industrial areas and is considered by some regulators as the maximum level of acceptable risk at the boundary of a property within an industrial estate. Further details on the application of the criteria is recommended to provide an understanding of how this contour is used with regard to land use planning.

6.2 Recommended QRA Criteria

If a QRA is undertaken as a TE initiative or potentially a regulatory requirement in the future, then consideration should be given to providing details of the types of risk that are detailed in HIPAP 4, namely, fatality, injury, property damage and environmental together with societal risk.

Recommendation 1

Include in future QRAs the determination of risk levels associated with fatality, injury, property damage and environmental together with societal risk as this will implement the full requirements of HIPAP 4. Note, WorleyParsons' QRA only addresses fatality risk.

7. QRA REVIEW FINDINGS

7.1 Risk Assessment Methodology

WorleyParsons' methodology generally follows normal procedure and an improvement would be to include a flow diagram showing the process. Key aspects of a standard QRA methodology are listed below with a brief comment on the approach taken by Worley and suggested improvements:

- Hazard Identification: no specific methodology included. There is an assumption that the methodology included a review of the piping and instrumentation diagrams (P&IDs). Further aspects that should be considered include:
  - review of historical incidents from TE's experience and from the oil and gas industry generally
  - review of any HAZOP or HAZID studies undertaken
  - review of external influences and natural hazards that may affect the site
  - security considerations
- Frequency Analysis: refer below with regard to further details on frequency database, parts count and ignition probability
- Consequence Analysis: Phast was used for the consequence analysis. There is reference to consequences associated with methanol and carbon dioxide (CO_2); however, details of how these are incorporated into the assessment was not transparent. Improvement would be to include details on all the consequences as would be undertaken in a FERA, i.e. explosion overpressure, BLEVE and fireball radiation and missile distances, jet fire, flash fire
- Risk Calculation: Phast used
- Risk Analysis: consists of comparing fatality results to HIPAP 4 criteria. Refer below to the use of other criteria. An improvement would be to provide an expanded discussion the risk drivers and opportunities for risk reduction.

7.2 Parts Count

WorleyParsons' parts count methodology included marking up P&IDs showing the segments of equipment that corresponded to the parts count detailed in Worley's Excel spreadsheet on the same. Det Norske Veritas (DNV) failure frequencies were then used to determine the overall failure frequency for hole sizes. The parts count is not transparent with regard to what equipment has been included, with **Figure 7-1** showing details of the parts count undertaken as a cross-check for the gas side of the Low Pressure Separator, V-2742.

Recommendation 2

Develop a QRA methodology and include in that methodology, a requirement for the parts count to be marked-up on P&IDs to enable transparency.

Table 7-1 provides the difference in the parts count, with significant differences attributable in part due to the rule sets that may or may not have been used. WorleyParsons' assumptions for the parts count are not fully transparent and assumptions used by Environmental Risk Solutions (ERS) as a cross check included:

- HCRD states "Includes small-bore connections for flow, pressure and temperature sensing. The scope includes the instrument itself plus up to two valves, four flanges, one fitting and associated small-bore piping, usually 25 mm diameter or less."
- normally closed valves are assumed to isolate the fluids and any equipment downstream of the valve is not included in the parts count, i.e. typically such an arrangement would include one valve and one flange.

Consideration should be given to providing a 'rule-set' to be used for the parts count.

Recommendation 3

Develop a QRA methodology and include in that methodology, a requirement for 'rule-sets' to enable transparency of how the parts were counted.

The impact of differences in parts count may be significant. **Table 7-2** shows that the estimated frequency for hole sizes in the range of >150 mm is approximately 14% higher (2.36E-4 vs 2.07E-4). This variation reflects the need to ensure an accurate as possible parts count, and also that there are limits to the overall confidence level for a QRA depending on the analyst.

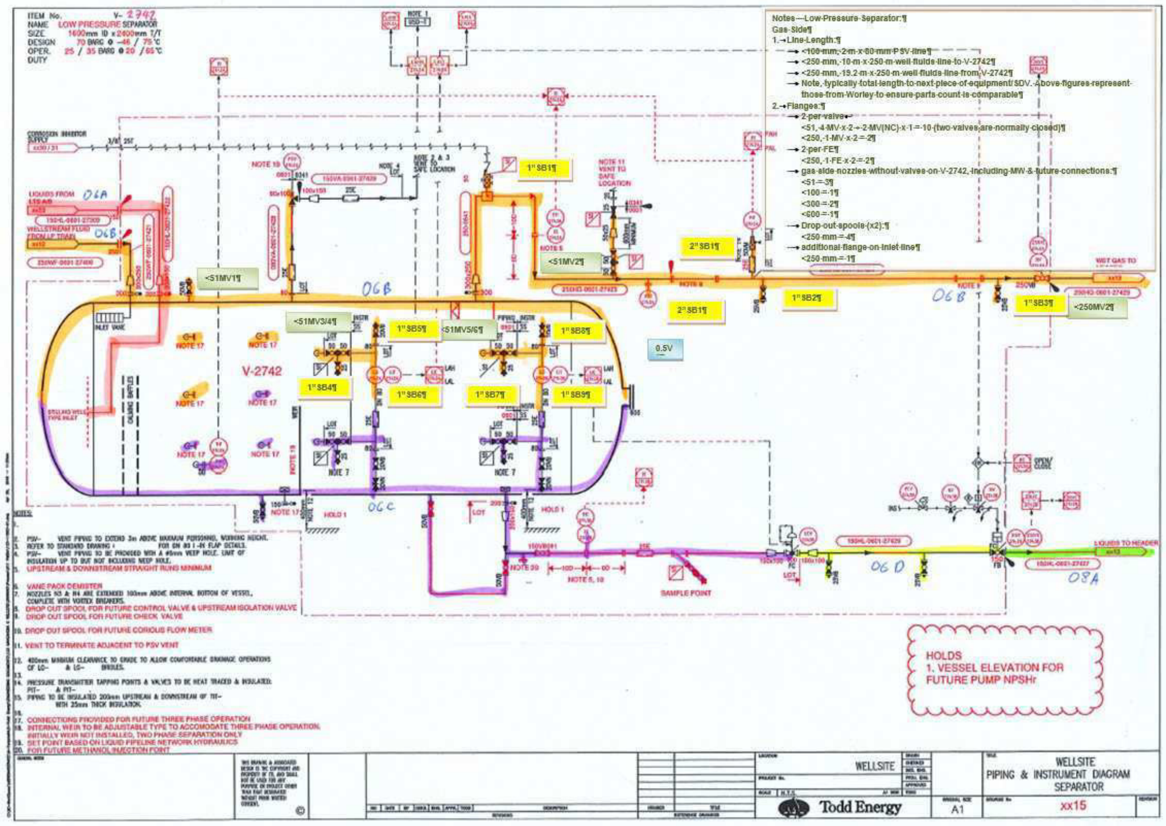

Figure 7-1 Parts count undertaken for comparison with WorleyParson values

Table 7-1 Comparison of parts count

Equipment	Size (inch)	Parts Count		Diff.[1]
		Worley	ERS	(%)
Process Vessel	6	0.5	0.5	0
Manual Valves	1	7	0	(700)
	2	4	6	150
	10	2	2	0
Small Bore Fittings	1	2	9	450
	2	3	2	(50)
Process Pipe	2	2	3	150
	10	29.2	20	0
Flange	1	3		N/A
	2	10	13	30
	4	0	1	100
	10	16	11	(30)
	20	1	1	0

Note [1] Where no entries were made the percentage difference was based on minimum of one.

Table 7-2 Comparison of differences in total leak frequencies due to different parts count

Equipment	Size	Parts Count		Diff.(1)	Hole Size Distribution (mm)					Total Leak Frequency (Worley Parts Count)					Total Leak Frequency (ERS Parts Count)				
	(inch)	Worley	ERS	(%)	1 - 3	3 - 10	10 - 50	50 - 150	>150	1 - 3	3 - 10	10 - 50	50 - 150	>150	1 - 3	3 - 10	10 - 50	50 - 150	>150
Process Vessel	6	0.5	0.5	0	7.80E-04	4.09E-04	2.24E-04	6.18E-05	5.93E-05	3.90E-04	2.05E-04	1.12E-04	3.09E-05	2.97E-05	3.90E-04	2.05E-04	1.12E-04	3.09E-05	2.97E-05
Manual Valves	1	7	0	-700	5.26E-05	2.28E-05	1.48E-05			3.68E-04	1.60E-04	1.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	2	4	6	150	5.34E-05	2.32E-05	1.02E-05	4.81E-06		2.14E-04	9.28E-05	4.08E-05	1.92E-05	0.00E+00	3.20E-04	1.39E-04	6.12E-05	2.89E-05	0.00E+00
	10	2	2	0	1.18E-04	5.13E-05	2.26E-05	4.97E-06	4.46E-06	2.36E-04	1.03E-04	4.52E-05	9.94E-06	8.92E-06	2.36E-04	1.03E-04	4.52E-05	9.94E-06	8.92E-06
Small Bore Fittings	1	2	9	450	3.00E-04	1.29E-04	7.64E-05			6.00E-04	2.58E-04	1.53E-04	0.00E+00	0.00E+00	2.70E-03	1.16E-03	6.88E-04	0.00E+00	0.00E+00
	2	3	2	-50	3.00E-04	1.29E-04	5.60E-05	2.04E-05		9.00E-04	3.87E-04	1.68E-04	6.12E-05	0.00E+00	6.00E-04	2.58E-04	1.12E-04	4.08E-05	0.00E+00
Process Pipe	2	2	2	0	1.03E-04	3.61E-05	1.24E-05	6.10E-06		2.06E-04	7.22E-05	2.48E-05	1.22E-05	0.00E+00	2.06E-04	7.22E-05	2.48E-05	1.22E-05	0.00E+00
	10	29.2	29.2	0	3.69E-05	1.29E-05	4.43E-06	7.38E-07	3.37E-06	1.08E-03	3.77E-04	1.29E-04	2.15E-05	9.84E-05	1.08E-03	3.77E-04	1.29E-04	2.15E-05	9.84E-05
Flange	1	3		N/A	3.77E-05	1.32E-05	1.07E-05			1.13E-04	3.96E-05	3.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	2	10	13	30	4.23E-05	1.48E-05	5.08E-06	6.27E-06		4.23E-04	1.48E-04	5.08E-05	6.27E-05	0.00E+00	5.50E-04	1.92E-04	6.60E-05	8.15E-05	0.00E+00
	4	0	1	100	5.13E-05	1.80E-05	6.16E-06	6.54E-06		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.13E-05	1.80E-05	6.16E-06	6.54E-06	0.00E+00
	10	16	11	-30	7.80E-05	2.73E-05	9.36E-06	1.56E-06	5.78E-06	1.25E-03	4.37E-04	1.50E-04	2.50E-05	9.25E-05	8.58E-04	3.00E-04	1.03E-04	1.72E-05	6.36E-05
	20	1	1	0	1.22E-04	4.26E-05	1.46E-05	2.44E-06	6.22E-06	1.22E-04	4.26E-05	1.46E-05	2.44E-06	6.22E-06	1.22E-04	4.26E-05	1.46E-05	2.44E-06	6.22E-06
Total										**5.90E-03**	**2.32E-03**	**1.02E-03**	**2.45E-04**	**2.36E-04**	**7.11E-03**	**2.87E-03**	**1.36E-03**	**2.52E-04**	**2.07E-04**

7.3 Holes Size Selection

Hole size selected for a range of hole sizes for which a failure frequency applies varies in different QRAs as detailed in **Table 7-6** ranging from the maximum of the range to the geometric mean of the respective diameters. **Table 7-3** provides an example of the approaches for the selection of a hole size and effect on mass emission rates which has a significant effect on potential consequences and hence overall level of risk.

Geometric mean is normally used for numbers which are exponential in nature, as applies to a mass emission rate whereby the rate is proportional to the square of the diameter. This approach is considered to have a mathematical basis and hence, is recommended as this will give a more representative scenario for Kapuni J Wellsite.

Recommendation 4

Use the geometric mean for hole diameter to represent a range in hole sizes as this approach has a mathematical basis that aligns with numbers that are exponential in nature such as is the case for hole sizes whereby the consequence is dependent on the area of the hole size or square of the diameter.

Table 7-3 Impact of Different Methods for Hole Size Selection (50 mm – 150 mm range)

Method	Hole Diam. (mm)	Hole Area (mm^2)	Effective Change in Mass Emission (%)
Use mean (Worley)	(150 + 50)/2 = 100	7,850	0
Use upper value of diameter range	150	17,700	225
Use geometric mean of diameters	$(50 * 150)^{0.5}$ = 87 (~85)	5,670	72

Other aspects associated with the parts count is that for 2” SBF, a hole size has been allocated as being in the 50 mm to 150 mm range and hence modelled as a 100 mm hole which is not credible with the inventory being from one side.

The release hole size from a flange failure includes hole sizes of 100 mm to FB for some pipework sizes which some analysts would consider as not credible as the release is normally limited to a segment of a gasket between bolts, as reflected in UK HSE ‘Failure Rate and Event Data for use within Risk Assessments (28/06/2012)’ (FRED) Ref. 6). A recommendation has been made to limit the hole size, however, if an alternative database is used, consideration to be given to the recommendations in that database.

Recommendation 5

Change modelling of SBF to reflect the maximum hole size of 20 mm as current modelling indicates that hole sizes may be 100 mm for a 50 mm SBF and 30 mm for a 25 mm SBF, which is physically not possible.

Recommendation 6

For pipework ≥150 mm, limit the maximum hole size for a flange to 20 mm from current assumptions that include hole sizes of 100 mm and full bore (FB) as a release is normally limited to a segment of a gasket between bolts. Note, if an alternative database is used consideration to be given to using the recommendations of that database.

7.4 Failure Frequency

7.4.1 Use of Offshore Data for Onshore Facilities

Failure frequency data used in the draft QRA for the Kapuni J Wellsite is from the DNV 'Failure frequency guidance – Process equipment leak frequency data for use in QRA' (DNV database) (Ref. 7). This data is based on failure frequencies in the North Sea collected by the UK HSE, with approximately 4,000 recorded leaks over a period of 1992 to 2010. This base data is known as the Hydrocarbon Release Database (HCRD) (Ref. 8). Whilst DNV consider that the HSE offshore data provides the best available estimate of leak frequencies for both onshore and offshore process equipment, they also recognise that:

"in general the HSE data set gives higher leak frequencies than most of the onshore sources of data."

The DNV database provide an analysis of application of HCRD leak frequencies. The uncertainty in the data is reflected by the curve fitting that is used to obtain leak frequencies as shown in as shown in **Figure 7-2**. Whilst there may be a question on under-reporting of larger leaks, the data shows up to an order of magnitude difference between the curve and actual data, with the latter being lower for large leaks. This uncertainty is reflected in the following statement:

"The historical data related to releases from large hole sizes is very limited and the uncertainty related to estimation of such leaks is therefore considerable."

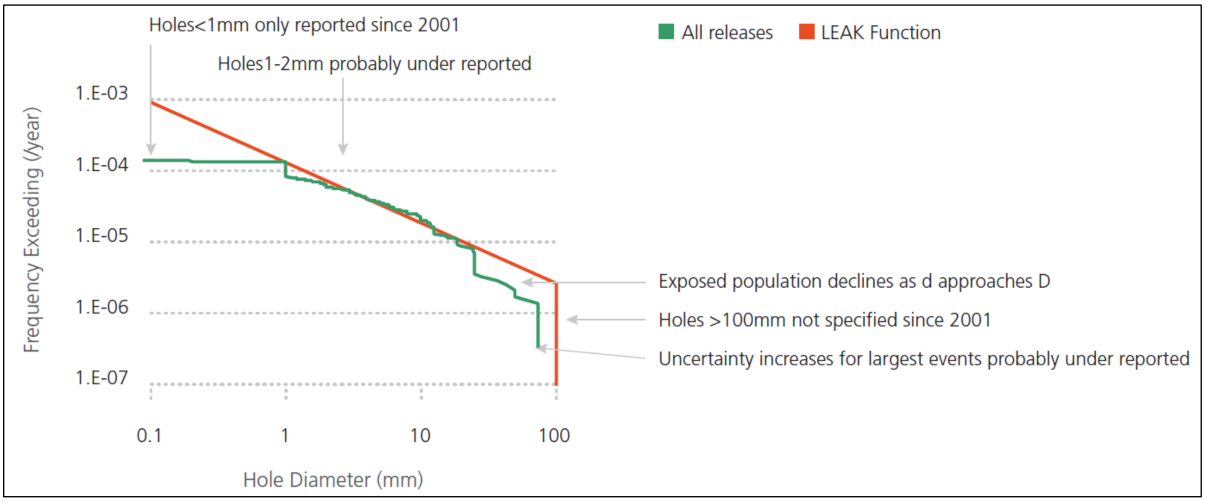

Figure 7-2 Uncertainties in applying curve to data (Ref. 7 'Failure Frequency Guidance, Process Equipment Leak Frequency Data for Use in QRA')

In a review of the HCRD database, Spouge (Ref. 9) concluded:

> *"Although becoming the standard for offshore industry, it* [HCRD] *has rarely been used in onshore QRAs because it would tend to give much higher risks than the established but largely judgmental onshore leak frequencies."*
>
> *"Despite the arguments for similarity in this paper, it remains undesirable to use offshore data for onshore QRA."*

The report 'The HCR Database – Its Potential for use at Above Ground Gas Facilities' DNV, 2010 (Ref. 10), states that:

> *"Consequently, HCRD does not contain appropriate data to derive leak frequencies for hole sizes in excess of 100mm for piping and flanges on onshore plant including gas treatment plants and compressor stations."*

The report 'Process leak for offshore installations frequency assessment model – PLOFAM', (Ref. 11) Lloyd's Register, March 2016 makes the following comments in relation to the existing leak models:

> *"that it overestimates the hydrocarbon leak frequencies compared to NCS [Norwegian Continental Shelf] experience, especially for large leaks."*
>
> *"HCRD has not been updated after 2005, which means that the estimated frequency for leaks extracted from HCRD will lead to an excessive estimate of the leak frequency even for installations located on the UKCS."*

Whilst the above report provides better data for large leaks, predicting 50-70% lower leak frequencies, the data is still for offshore installations and hence, is considered to still be overly conservative. The flow on from this further analysis has to date not reached other databases that have used the HCRD data as a basis, including that for onshore databases using the HCRD data. Hence, there is an expectation that future failure rates are likely to be lower.

Based on the above, the use of offshore database is likely to result in unrepresentative risk scenarios for Kapuni J Wellsite.

7.4.2 Alternative Failure Frequency Databases

<u>OGP</u>

The International Association of Oil & Gas Producers (OGP) have developed a Risk Assessment Data Directory (RADD) which includes that for 'Process Release Frequencies', Report No. 434-1, March 2010 (Ref. 12). The database has been developed to apply to both onshore and offshore facilities. Like the DNV database, the OGP database uses the HCRD as a basis with analysis of 3,824 releases between 1992 and 2006.

The relatively recent review of failure frequency sources, 'Offshore accident and failure frequency data sources – review and recommendations', UKHSE RR1114, 2017 (Ref. 13), recommended five data sources which included HCRD[1] and OGP, reflecting that OGP is regarded as being a reliable source for offshore failure frequencies, and corollary is that the data whilst may still be conservative, is also a reliable source for onshore failure frequencies.

[1] HCRD is considered to also include databases that used this base data including the DNV database and the OGP database, noting that the UKHSE RR1114 also specifically references the OGP database as one of the five recommended databases.

Whilst the OGP database is founded on the HCRD, the stated application is for both onshore and offshore facilities. The database is less conservative than that used by Worley and at the same time is a recognised and accepted database as indicated by the benchmarking of databases used in QRAs, refer **Table 7-6,** and in the UKHSE RR1114.

The OGP database provides frequencies for 'Full' releases, 'Limited' releases and 'Zero Pressure' releases. OGP guidance for the use of these releases in QRAs is that:

(i) 'Full' Releases

'Typical use in QRA:

These events should always be included in quantified risk assessments. They have the potential of developing into serious events endangering personnel and critical safety functions.'

(ii) 'Limited' releases

'Typical use in QRA:

- *Coarse QRAs*: Limited Releases should normally be included in the risk analysis, and treated as Full Releases with regards to the consequence modelling. This is a conservative approach, which normally is in line with the nature of Coarse QRA'.
- *Detailed QRAs*: Limited Releases could be considered for their expected (realistic) consequences. These events may be of concern for personnel risk, but it is less likely that they develop into any major concern for other safety functions, such as structural integrity, evacuation means, escalation, etc. Any consequence calculations should reflect that these events involve limited release volumes. If the consequences are not specifically assessed, the approach of a) above apply also for detailed QRAs.

There are two possible approaches to modelling these releases, depending on whether the limitation is on the duration (through prompt local isolation) or the flow (through a restriction). In the first case (limited duration), flow is likely to be at the same release rate as for a full release but reduced to a short duration (e.g. 30 seconds). In the second case, the release rate will be much lower than for the corresponding full release and the quantity released also smaller. In this case an approach previously suggested has been to model the flow rate as 8% of the full release rate and the duration as 6% of the full release duration.'

(iii) 'Zero Pressure' releases

Typical use in the QRA (but not limited to this example):

'These are events that typically are excluded from QRA assessments. Most likely there are no serious consequences and if so, the contribution to the overall risk level is considered insignificant. These events are mainly included for consistency with the original HSE data.

The event is likely to result in release of a small quantity of hydrocarbon. This could be taken as the inventory of the system hydrocarbon full at atmospheric pressure.'

Based on the above, and also benchmarking, refer below, OGP 'Full' frequency data should be used and, at the discretion of the analyst, the 'Limited' data may be used with or without modification to the consequence assessment methodology. If the 'Limited' data is used, and there is no change to the consequence methodology the results would be conservative.

Benchmarking approaches, there is use of only the 'Full'. release frequency by some consultants, including in the following risk assessments which are available on the web:

- 'Quantitative Risk Analysis Report, Bulk Storage Facilities, Lyttelton Port', Sherpa Consulting, 20th Sept 2016 (note, the QRA was peer reviewed by Worley Parson without comment on the use of 'Full' frequency data)
- 'Arrow Energy Bowen Gas Project, Preliminary Hazard Analysis', Sherpa Consulting, Oct. 2012
- 'CLP Power Hong Kong Ltd', ERM, June 2018
- 'Caltex Refineries (NSW) Pty Ltd, Proposed Kurnell Product Terminal, Preliminary Hazards Analysis', R4Risk, 15 May 2013

Table 7-4 provides a summary of some key differences between the DNV database and the OGP database ('Full' release frequency) with OGP frequencies range from 25% - 75% lower to in the case of SBFs showing that a 50–150 mm hole size as not being credible.

Table 7-4 Key Differences of Leak Frequencies between DNV & OGP Databases

Equipment	DNV	OGP ('Full' Frequency)	Difference (%)
1 – 3 mm			
10" Manual Valves	1.18E-04	4.30E-05	36
2" Process Piping	1.03E-04	5.50E-05	53
20" Flange	1.22E-04	8.30E-05	68
3 – 10 mm			
1" Manual Valves	2.28E-05	7.70E-06	34
2" Manual Valves	2.32E-05	7.70E-06	33
1" Small Bore Fittings	1.29E-04	6.80E-05	53
2" Small Bore Fittings	1.29E-04	6.80E-05	53
10" Process Pipe	1.29E-05	7.60E-06	59
1" Flange	1.32E-05	7.60E-06	58
2" Flange	1.48E-05	7.60E-06	51
10 – 50 mm			
1" Manual valves	1.48E-05	4.9E-06	33
2" Manual Valves	1.02E-05	4.9E-06	48
2" Process Piping	1.24E-05	7.00E-06	56
1" Flange	1.07E-05	4.00E-06	37
50 – 150 mm			
10"/12" Manual Valves	4.97E-06	1.2E-06	24
10"/12" Process Piping	7.38E-07	3.7E-07	50
2" Small Bore Fittings	2.04E5	Nil	Not credible
10"/12" Flange	1.56E-6	6.1E-7	39

<u>FRED</u>

Another alternative to the DNV is the UK HSE 'Failure Rate and Event Data for use within Risk Assessments (28/06/2012)' (FRED) Ref. 6). This data set is noted by the UK HSE as being:

> *'intended for use on Land Use Planning cases'*

As a primary purpose of the QRA is for land use planning, then the use of the FRED is considered appropriate.

The UK HSE also note that:

> *"They were NOT originally intended for use in COMAH Safety Report Assessment because they do not necessarily take account of all factors that could be relevant and significant at particular installations."*

There is a need to recognise that the driver for the QRA is that of land use planning and hence, FRED would be considered to be appropriate if there is no specific database of information available for TE's wellsites and if other data sources are considered to be too conservative.

Specifically, FRED has been used for onshore QRAs for many installations in the UK and other parts of the world with regard to land use planning and as such, there is a level of acceptance of this database for QRAs for onshore facilities. Additionally, taking into account this database has not been withdrawn, there is the implication that there is a current ongoing level of acceptance of use for land use planning considerations. This is also reflected in the dates of publication for the DNV database and FRED, being 2010 and 2012 respectively.

FRED provides guidance on the need for an analyst to adjust data according to the facility under consideration with specific reference to the 'derivation' section in the database as a basis for those considerations:

> *"For rates that have ranges the derivation also contains a brief guide on what factors may affect the value."*

> *"The assessor needs to decide whether or not the generic failure rates are appropriate for their assessment; if the generic failure rate is inappropriate, then further work is required to derive a suitable specific failure rate."*

> *"The assessor needs to decide whether or not the generic failure rates are appropriate for their assessment; if the generic failure rate is inappropriate, then further work is required to derive a suitable specific failure rate."*

<u>Overall Recommendation</u>

Both OGP and FRED are technically acceptable databases that may be used instead of the DNV database, and both would reduce the calculated levels of risk to levels where are more representative for onshore facilities. The reduction in the failure frequency for the parts count for the Separator using OGP database was to approximately 20% of the values determined using the DNV database.

Recommendation 7

Change the base frequency data from offshore HCRD to OGP or the UK HSE 'Failure Rate and Event Data for use within Risk Assessments (28/06/2012)' so as to remove the excessive conservatism associated with the use of the DNV database. Note, OGP data considered to be the better of the two databases with regard to being more comprehensive on details of size range of equipment and hole sizes.

7.4.3 Failure Frequency – Modification of failure frequencies

Generic failure frequencies are normally modified to account for differences that may exist for the facility under consideration. This may increase or decrease the frequency. There are a number of aspects associated with this approach, including:

- selecting the correct database(s)
- within the selected database, modifying specific failure frequencies according to the equipment under consideration, e.g. inter-unit piping
- modifying data according to site conditions which may change the data due to process fluids and/or external environment, including the following aspects identified by the OGP RADD:
  - design code
  - operating environment
  - process continuity
  - material of construction
  - cold or hot weather
  - stress cycling
  - fluid inside equipment
  - equipment age
  - welds
  - operating pressure
  - seismic activity
  - radiography
  - operating temperature
  - integrity status.

Worley have undertaken a sensitivity analysis with regard to FB ruptures stating that the 'frequency of release of FB rupture cases reduced by 20%'. There is uncertainty as to whether this applies to all FB ruptures or only to piping. Regardless, from the perspective of using the results for comparison to criteria, the Regulator will need clear advice on which contours are to be used. To this effect, where possible, modification factors should be included in the base case of the QRA, not as sensitivity analyses.

There are opportunities for modification of failure frequencies which are outlined below under respective headings. Typically, these modification factors are included in the 'Assumptions Register' for a QRA and form part of the base case frequencies used for the assessment.

(i) Release Frequency Modifications for Different Flange Types

Pipework will all be ANSI Raised Face (RF) except for the connection to the Wellhead Tree will be a Ring Type Joint (RTJ). **Table 7-5** shows the modification factors recommended by OGP RADD 'Process release frequencies' (Ref. 12) for RF flanges.

Table 7-5 Release Frequency Modifications for Different Flange Types

Flange Type	Hole Diameter Range (mm)	Modification (% of total flange release frequency)
ANSI RF	1 – 3	10
	3 - 10	10
	10 - 50	30
	50 - 150	30
	>150	20

(ii) Release Frequency Modifier for 'Inter-unit' Piping

The frequencies for piping are intended to apply within process units. For piping linking units, OGP RADD 'Process release frequencies' recommends a modification factor of 0.9.

DNV recognises for liquefied natural gas facilities that there is a level of uncertainty with inter-unit pipework/pipeline in that the application of process pipework failure data will tend to give overly conservative values with respect to longer inter-unit pipe segments. On this basis, DNV (Ref. 7) apply a factor of 10 reduction in pipework failure frequency for inter-unit piping.

Within the wellsites, there is also relatively long lengths of pipework for which a reduction of failure frequency may be applicable as the same principles with regard to inter-unit applicability. Specifically, there are sections of pipework that may be regarded as 'inter-unit', e.g. from wells to choke. As the risk driver is associated with large hole sizes, this may be significant.

In addition to the above consideration with regard to inter-unit frequency modifications, further modification should be made for the sections of pipework that are below ground in channels that are covered by a 200 mm concrete slab, with the level of reduction being a decision to be made by the analyst by reviewing the causes of LOC that may be removed with this arrangement.

(iii) Safety Management Factors

OGP RADD (Ref. 12) suggest that Management Factor (MF) may be appropriate and indicate that some studies suggest values between 0.1 and 10.0 (i.e. from 10 times better than average to 10 times worse than average). Whilst some QRAs have historically incorporated MFs in their analysis, there is a move away from this approach due to the subjectivity associated with the approach and also that the management may change with time. Hence a MF is recommended not to be included in the analysis.

Regardless, the above MF highlights another aspect that affects the overall confidence level that may be applied to a QRA.

7.4.4 Failure Frequency – Confidence Levels

DNV (Ref. 7) highlight the significant differences in alternate sources of leak frequency data which is shown in **Figure 7-3** with reference to Dutch data sources. **Figure 7-3** shows that the HCRD values are more than 100 times higher than the Dutch government.

The OGP RADD (Ref. 12) states that:

> *'No quantitative representations of the uncertainty in the release frequency results have yet been derived. Based on the sensitivity test that have been conducted and on previous analyses of the same dataset, the uncertainly in the results may be a factor or 3 (higher or lower) for frequencies of holes in the region of 1 mm diameter, rising to a factor of 10 (higher or lower) for frequencies of holes in the region of 100 mm diameter.'*

The above reflects the uncertainties in just one of the elements of a QRA and when combined with others such as accuracy of parts counts, generic failure frequencies, ignition probabilities, modelling capability, consequence probits and other consequence criteria, together with the MFs, the overall confidence limit that may be place on the numerical result of a QRA is considered to be within two orders of magnitude at best.

Recommendation 8

Include in the QRA, a section on the confidence level that may be given to the numerical/calculated results with the caveats that the QRA is considered to have been undertaken to best industry practice, however, due to limitations on confidence levels associated with QRA inputs and calculation methodologies, the overall calculated values have a relatively low confidence level and should be used for guidance in decision-making as opposed to being a decision maker and that despite a low confidence limit, the results may be used to identify risk drivers.

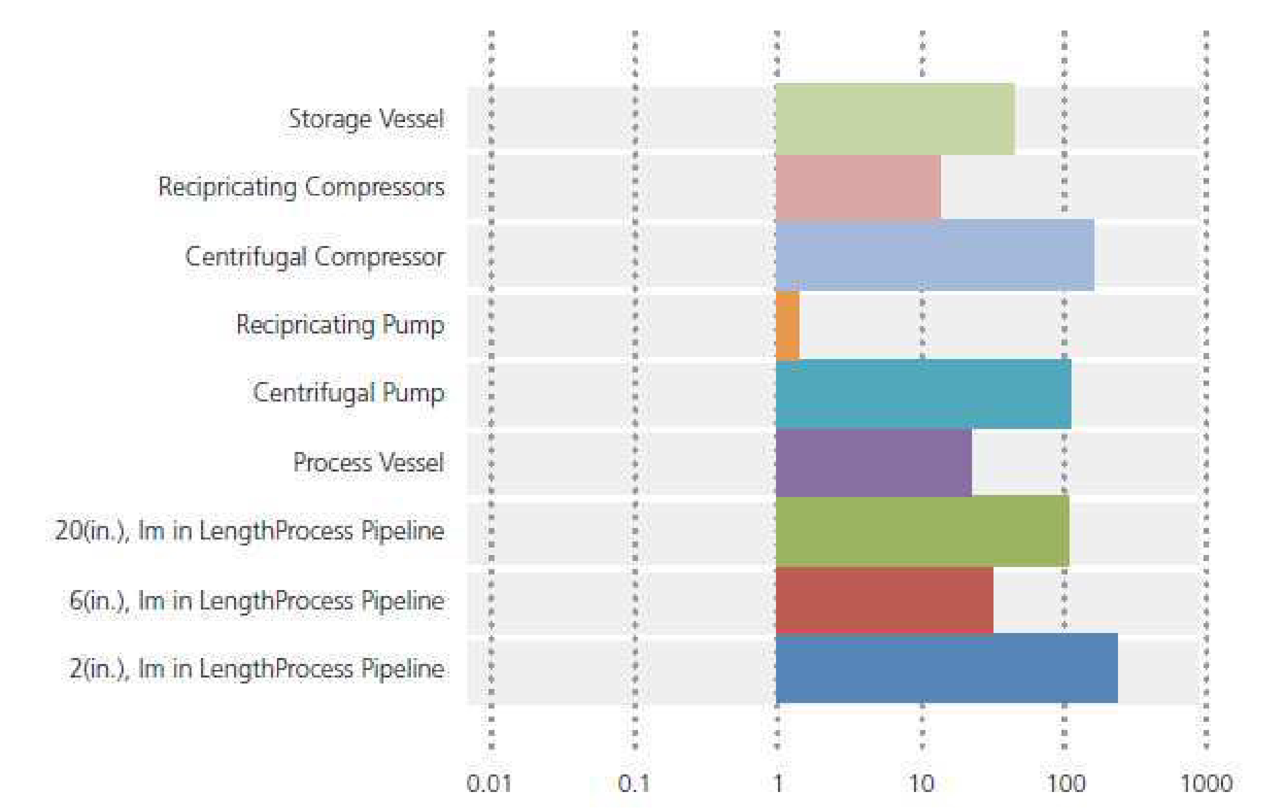

Figure 7-3 Ratio of frequencies – DNV data to Netherlands tabulation (Ref. 7 'Failure Frequency Guidance, Process Equipment Leak Frequency Data for Use in QRA')

A key aspect is that the QRA should be a separate report which may be referenced in the 'Hazardous Substances Risk Assessment'. The primary rationale is that by having a combined report, there is the implication that the level of calculated risk has the same confidence level in understanding hazardous chemicals and this is not the case. QRAs do not have high confidence levels. Additionally, the QRA often contains security confidential information and there may be a requirement to make the 'Hazardous Substances Risk Assessment' a public document and TE may not want such security sensitive information made public.

Note, this is typically the approach that is taken with regard to risk assessments that may be undertaken as part of an Environmental Impact Assessment whereby the risk assessment per se is a confidential document and only the contours and a high-level precis of the risk assessment is included in the public document.

Recommendation 9

Separate the QRA report from the 'Hazardous Substances Risk Assessment' report so that there is not an associated assumption that the understanding and confidence levels of the QRA are the same as that for hazardous substances and also to ensure that security related confidential information is not made public.

7.4.5 Failure Frequency – Review of TE Failure Data

Ideally, there should be a failure database that is specific to TE's wellsite operations that may be used in the QRAs. This data is not available, and consideration should be given to developing this data so as to provide a basis for realistic failure frequencies. Note, a corollary to this aspect is that all QRAs should review historical incidents both specific to the operator and on a broader regional/global scale so that there is recognition of and accounting for incidents that may have occurred in other facilities.

Recommendation 10

TE collates and record incident data with regard to LOC events so as to enable site-specific data to be used for undertaking QRAs.

Recommendation 11

Include in the Kapuni J Wellsite QRA and future QRAs, a review of incident data so as to recognise potential major incidents and to assist in the assessment of whether failure data should be modified to account either positively or negatively for these LOC events. Note, the inclusion of a review of historical incident data in a QRA is often a regulatory expectation.

7.5 Ignition Probability

Ignition probability is dependent on aspects including:

- mass emission rate of the release
- minimum ignition energy of the gas
- flammability limits of the gas
- ignition sources that may be present onsite.

The ignition probabilities in the QRA were calculated using the United Kingdom Offshore Operators Association (UKOOA)/Health and Safety Executive (HSE) mass release based, ignition probability look-up correlations from the IP Research Report (Ref. 14).

The correlations function generates a probability of ignition based on a release scenario and a mass discharge rate. The scenarios used from the IP report were #5 and #6, which correspond to "Small Plant Gas LPG (gas or LPG release from small onshore plant)" and "Liquid release from small onshore plant". These are considered suitable as they are representative of the Kapuni J Wellsite although as noted in the QRA, these are considered conservative.

Whilst conservative, further reduction in ignition probability should be considered once the other modifications to the method for calculating risk levels recommended in this report have been undertaken and the calculated risk contours refined. Any further modification to ignition probability will need to consider LOC causing the ignition through either physical impacts or there being increased activity onsite with associated increased ignition sources.

7.6 Consequence Assessment

The report is not transparent on the isolatable inventories, their volumes and process conditions. An improvement would be to show the same on a Process Flow Diagram (PFD) or schematic. Appendix 7 states that the "release scenarios and the respective operating conditions to be used in the Risk Assessment are given in Table 2-4" and Table 2-4 provides inventories that would not correspond to the isolatable inventory.

Recommendation 12

Confirm that the 'isolatable inventories' were use in the assessment and show the same on a marked-up schematic or PFD.

Consequence assessment was undertaken using DNV GL Phast Risk version 6.7. Whilst Phast is a recognised and accepted consequence modelling tool, the version used is outdated and hence the improvements have not been included. Consideration should be given to use of the latest version of Phast or provide a statement that the latest revision would not significantly change the calculated results.

Recommendation 13

Consideration should be given to use of the latest version of Phast or provide a statement that the latest revision would not significantly change the calculated results.

7.7 Analysis of Results

The purpose of the QRA is for assist in understanding the level of offsite risk. To assist in this goal consideration should be given to providing an understanding of the risk drivers so that best use of resources may be made to minimise the level of risk

Normally, an analysis would review the risk drivers so that there is an understanding of the same and this may allow for risk management to review resources that may be able to reduce the level or risk. Typically, this is in the form of a pie chart at specific locations to show the major risk contributors. This aspect is particularly important for this QRA as the risk drivers are likely to be those associated with large releases, and, if so, additional consideration may be given to assessing whether there is the opportunity to reduce the assumed failure rates.

Recommendation 14

Provide 'pie charts' or similar to show what are the key risk drivers at selected locations around the wellsite to enable an understanding of the same and hence the ability to assess whether further risk reduction measures may be focused on those drivers.

7.7.1 Bench Marking

Table 7-6 provides benchmarking with regard to databases and other factors that various consultants have used in QRA. The information has been sourced from the web and is only as sample of QRAs to provide a level of understanding of the wide variation in approaches that is taken with regard to QRAs. Of note, is that the OGP database is used in a number of QRAs and the Worley QRA, whilst using the DNV database for the majority of the process equipment, uses the OGP database for well blowouts.

Table 7-6 Benchmarking Assumptions between Different QRAs

Aspect	Consultancy/Government				
	Worley	**URS**	**Singapore Govt.**	**R4Risk**	**Sherpa**
Date	2019	2009	2016	2013	2016
Type of Facility	Wellsite	BOC Westbury LNG	All Risk Assessments	Caltex Product Terminal	Bulk Storage Facilities
Country	New Zealand	Australia	Singapore	Australia	New Zealand
Failure Database	HCRD	Cox, Lees and Ang	FRED	OGP (storage, pumps, flanges, valves, instruments) FRED (storage) E&P Forum (piping) Cox, Lees and Ang (ign prob.) TNO used for distribution of frequencies	OGP supplemented with specific data for storage tanks, pipelines and road transport Cox, Lees and Ang (ign. prob.)
Database Tailored	No	Yes, material defects and corrosion etc removed	Allowed	Considered but no particular aspect justified a change	Yes
Hole Size Selection	1 – 3 mm: 2 mm 3 – 10 mm: 7 mm 10 – 50 mm: 30 mm 50 – 150 mm: 100 mm >150 mm: FB	9 mm, 20 mm, 50 mm, FB	1 – 15 mm: 10 mm 16 – 49 mm: 25 mm >50 mm: 75 mm Cast/FB	<5 mm: 5 mm 5 – 20 mm, 20 mm 20 – 50 mm, 50 mm 50 – 150 mm: 100 mm >150 mm: FB	1 – 3 mm: 2 mm 3 – 10 mm: 6 mm 10 – 50 mm: 22 mm 50 – 150 mm: 85 mm >150 mm: FB
Risk Criteria	HIPAP 4 (fatality only)	HIPAP 4	50E-6 at boundary and others	HIPAP 4	HIPAP 4
Other Aspects	Report under review	Flange leak hole size = 9 mm, instrument leak hole size 20 mm	Singapore government prescribes a failure frequency database to provide consistency in results	Flange hole size limited to 20 mm OGP 'Full' frequencies used	OGP 'Full' frequencies used

8. GENERAL

There were a number of general observations made during the review which are captured below with regard to general improvements that may be considered.

Reference is made to the MB Century Environmental, Health, Safety and Risk Matrix which may be appropriate for the drilling, clean-up and testing phases. However, for the production phase, reference should be made to the TE risk matrix.

Wording is important with regard to understanding and potential objection to a report. Two areas of potential improvement would be to:

- replace 'acceptable' with 'tolerable' with regard to risk levels. The rationale is that from a corporate culture, regulatory environment and affected parties, the imposition of any risk may be considered as undesirable and hence 'unacceptable'.
- preface all reference to risk levels, where appropriate, with 'calculated': the idea behind this approach is to reinforce the concept that there is a certain level of confidence that applies to the level of risk.

Section 4.2, 'Site Selection' appropriately provides details on the risk reduction considerations for the selected site.

Remove from Table 4.1 the statement that 'Palmer Road runs directly adjacent to the western boundary of the wellsite' as Palmer Road is to west at a distance of approximately one kilometre.

Change the location of the 'star' on Figure 4-1 to closer represent the location of the proposed wells.

Consideration should be given to including the drawing 'Kapuni North Wellsite Consultation Plan', Dwg. 180000-GIS-101, with the details of land-owners removed to protect confidentiality.

Remove, for reasons of privacy, Section 4.4 which provides details of owners.

9. CONCLUSION

Overall there are a number of opportunities to more accurately reflect the calculated level of risk which have been detailed in a number of recommendations which are summarised in the Summary section of this report.

There are also a number of overall improvements to the QRA process, ranging from splitting the QRA from the Hazardous Substances Risk Assessment' through to TE developing their own QRA methodology through to incorporating all of the risk criteria detailed in HIPAP into the QRA. These overall recommendations are included in the Summary section of this report.

10. REFERENCES

1. New Zealand Government, *Resource Management Act (RMA) 1991*
2. Worley Parsons ‘Kapuni J Wellsite, Hazardous Substances Risk Assessment’, Doc. No. 620035-RPT-R0001, Dec. 2018
3. NSW Government, ‘Hazardous Industry Planning Advisory Paper No 4, Risk Criteria for Land Use Safety Planning’
4. NSW Government, ‘Hazardous Industry Planning Advisory Paper No 10, Land Use Safety Planning’
5. UK HSE, ‘HSE’s Land Use Planning Methodology’
6. UK HSE, ‘Failure Rate and Event Data for use within Risk Assessments (28/06/2012)’
7. DNV, ‘Failure frequency guidance – Process equipment leak frequency data for use in QRA’
8. UK HSE, ‘Hydrocarbon Release Database’
9. Spouge, ‘New Generic Leak Frequencies for Process Equipment’
10. DNV, ‘The HCR Database – Its Potential for use at Above Ground Gas Facilities’
11. Lloyd’s Register, ‘Process leak for offshore installations frequency assessment model – PLOFAM’
12. International Association of Oil & Gas Producers, ‘Risk Assessment Data Directory (RADD), Process Release Frequencies’, Report No. 434-1, March 2010
13. UK HSE, ‘Offshore accident and failure frequency data sources – review and recommendations’, RR1114, 2017
14. Energy Institute, ‘Ignition Probability Review, Model Development and Look-Up Correlations’, January 2006