6. Preliminary Risk Assessment

The objective of the Preliminary Risk Assessment (PRA) process is to identify expected major hazards and risks associated with normal operation of the proposed urea plant. The risk assessment is intended to generate risk measures which can be compared with established guidelines to determine the acceptability of the plant at the proposed location. In addition, the risk assessment is expected to identify the key factors affecting offsite risk so they can be addressed during subsequent project design and planning phases.

The scope of the study is to assess and report the offsite risk in the form of individual risk contours. The study has additionally assessed societal risk. The societal risk is depicted in form of f-N curves. These approaches are described below and in more detail in Appendix J.

6.1 Planning Requirements

A preliminary risk assessment was conducted to determine off-site individual risk and the results compared with prescribed Individual Risk criteria, set by EPA, for developments in populated areas. The EPA has set the following off-site individual risk criteria for hazardous industrial plant:

0.5×10^{-6} per year

A risk level in "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments, of one half in a million per year or less is so small as to be acceptable to the EPA.

0.5×10^{-6} to 1.0×10^{-6} per year

A risk level within the grounds of a “sensitive development” can exceed the risk level of one half in a million per year up to a maximum of one in a million per year, for areas that are intermittently occupied, such as garden areas and car parks.

1×10^{-6} per year

A risk level in residential areas of one in a million per year or less is so small as to be acceptable to the EPA.

5×10^{-6} per year

A risk level for commercial developments, including offices, retail centres, showrooms, restaurants and entertainment centres, located in buffer areas between industrial facilities and residential areas, of five in a million per year or less, is so small as to be acceptable to the EPA.

10×10^{-6} per year

A risk level for any non-industrial activity or active open spaces located in buffer areas between industrial facilities and residential areas of ten in a million per year or less is so small as to be acceptable to the EPA.

50×10^{-6} per year

Risk levels from industrial facilities should not exceed a target of fifty in a million per year at the site boundary for each individual industry.

100 x 10^{-6} per year

The cumulative risk level imposed upon an industry should not exceed a target of one hundred in a million per year.

6.1.1 Types of Hazards and Risks

Hazard and Risk

A hazard is an item of equipment or process which could lead to harm, i.e. it is the thing which presents the risk, e.g. a fuel tank or pipeline containing a hazardous substance.

Risk is a measure of the specified level of harm occurring or being realised. Risk is a numerical measure; such as the chance of an injury per year.

Individual Risk

Individual risk is a measure of the chance of a particular individual incurring a specified level of harm (e.g. fatality). For Land Use safety Planning purposes, Individual Risk is generally calculated assuming there are individuals at any and all population centres, such as a member of a residential population.

Societal Risk

Societal risk is a more complex measure, which reflects the likelihood of numbers of persons (beyond the operating plant limits) being affected in a particular event. The societal risk can be characterised in a number of ways:

» f-N curve – A graph which shows the cumulative frequency (f) of all events that could lead to N or more people being affected. The graph is interpreted by considering Tolerable and Intolerable threshold. The band between these regions in known as the As Low as Reasonably Practicable (ALARP) region.

» Scaled Risk Integral (SRI) – SRI is an approximate measure of societal risk devised in the UK for considering specific land use and developments. The measure takes account of the number of persons potentially exposed to hazards, the risk of exposure and the land area of a development. SRI is a useful comparison with other societal risk measures.

6.2 Hazard Identification

A Risk Assessment workshop was held to assist in identifying hazards and risks for the project. Attending were key Project Managers from PCF and Risk Assessment consultants from GHD.

PCF provided a list of the hazardous chemicals that will be stored and handled at site. It was agreed by the study, and confirmed at the risk assessment workshop, that ammonia storage represents the dominant major hazard and that any sustained loss of containment event resulting in a significant spill of anhydrous ammonia could present a major risk to the workforce and areas adjacent to the proposed plant.

Due to high minimum ignition energy (100 MJ), ignition of ammonia is unlikely; the study has therefore considered the hazard consequences from ammonia releases to only have toxic effects.

Further details on this assessment and the hazardous properties of anhydrous ammonia are summarised in Appendix I.

6.3 Risk Assessment Software

The PRA has been conducted using PHAST hazard consequence modelling software combined with an in-house GHD risk assessment technique termed ^{PQ}RISK+.

6.4 Characteristic Hazards

The severity of consequence, once the released has occurred, will depend on the size of the leak. The risk assessment approach applied for the PCF plant has considered the total plant risk to be a combination of three characteristic hazards:

6.4.1 Major Pipe Failure

Major failure from bottom outlet flange (300 mm diameter emission) of 10,000 tonne ammonia storage tank:

- Entire tank inventory drains out, no isolation possible
- Pool spreading, flashing and dense gas dispersion close to point of release
- No bund provided, site kerbing will provide containment to prevent offsite spills
- Fatalities due to toxic effect of ammonia
- No ignition unlikely due to cold temperatures, high LEL and large minimum ignition energies
- Release continues until tank empties; partial flashing resulting in vapour/ liquid aerosol which is initially denser than air and slumps to ground close to the release point. Gas disperses as neutral density or marginally lighter-than-air plume beyond zone of flow establishment.

6.4.2 Small Pipe Leak or Seal Failure

25 mm equivalent diameter release, e.g. small pipe work leak, pump seal failure or accident following shutdown and inspection

- 25 tonne loss of containment.
- Release results in onsite gas plume which maintains a toxic concentration at population centres for more than 10 minutes
- Flashing and spray close to release source; small running pool for larger emissions, potential for asphyxiation close to source of release
- Ammonia released as cold flashing gas with liquid drop out, gas disperses as dense, ground hugging cloud

6.4.3 Rupture of Storage Tank

Instantaneous loss of contents from ammonia storage tank ; wholesale rupture of vessel due to major quality/ manufacture defect or mechanical impact event:

- Rapid loss of entire tank inventory drains, 10,000 tonnes
- Pool spreads to margins of plan
- Fatalities due to toxic effect of ammonia

» Partial flashing resulting in vapour/ liquid aerosol which is initially denser than air and slumps to ground close to the release point; gas disperses as denser than air, ground hugging cloud.

6.5 Non-Major Hazards

Onsite risk and non-major hazards and risks, such as workplace and transport risks, were not quantified by the study. These risks can be assessed when the project is further developed.

6.6 Initiating Event Frequencies

6.6.1 Risk Assessment Workshop

Initiating event frequencies were allocated, calculated and addressed during the risk assessment workshop, with the agreement of all attendees. Agreed frequencies were estimated using a combination of qualitative and quantitative techniques; including comparisons with case histories combined with generic failure rate data, Table 20.

Table 20 Initiating Event Frequencies

Leak	Leaks/ year Per leak source
Catastrophic failure (whole vessel, > 150 to 200 mm diameter)	3.42E-06
Large releases (50 to 150 mm diameter)	1.14E-05
Moderate releases (15 to 50 mm diameter)	1.69E-05
Small releases (5 to 15 mm diameter)	1.90E-05
Minor releases (< 5 mm diameter):	5.29E-05

6.7 Event Trees

The risk assessment applied Event Trees to account for incident mitigations with the potential to result in non-hazardous outcomes; the following mitigation branches were defined for each characteristic hazard:

» Hazard mitigated by high rainfall or high wind speed: wind speed dilutes release below fatal concentration or dispersion prevented by extreme rainfall event;

» Hazard mitigated by active barrier, e.g. deluge;

» Site response team arrests leak by Vetter bags; and

» Other Mitigations: e.g. ventilation dilution, forestry barrier.

The likelihoods/ effectiveness of mitigations was addressed during the risk assessment workshop and allocated with the agreement of all attendees.

6.8 Offsite Populations

6.8.1 Population Centres

Offsite populations at risk from major ammonia releases were defined by reviewing site drawings and various published information, and by discussion with Perdaman operations; these were discussed and agreed at the risk workshop and confirmed by subsequent research. The following population centres were defined:

» Griffin ash dumping station at 600 metres from closest plant boundary: intermittent trucking over assumed 24 hour operation.

» Bluewater's power station at 4,500 metres from closest plant boundary. 24 hour manning, all year round.

» For the tank rupture hazard only (due to distance from site); Collie town outskirts at 7.5 km from the closest plant boundary.

» Premier coal handling, including administration/ head office located at 2.2 km from the closest plant boundary.

» The risk assessors were informed that there is a resident "Hermit" living in the vicinity of the plant. This 24 hour presence of a single person has been considered by inclusion as an additional person present in the vicinity of the Premier site.

» Stockton Lake recreational area at 1 km from the nearest plant boundary and 1.6 km from the proposed ammonia storage tank position. Transient population with peak numbers at weekends and in the summer; lake used for water skiing and other water sports. Various year round motor cross events and public events are organised with short term attendances up to 500 to 2,000 persons.

6.9 Offsite Fatal Risk Assessment

Offsite fatalities have been assessed by estimating firstly, the likelihood that each populating is exposed to an ammonia hazard. Three measures of offsite risk have been assessed:

» Individual Risk contours; including wind-affected risk contours;

» Societal risk, expressed as an f-N curve, compared with accepted tolerability criteria; and

» Scaled Risk Integral (SRI).

The three measures are checked against each other to ensure a consistent understanding of the impact of the ammonia plant hazards and risks. No assessment has been made of onsite risk exposure or non-major risks.

6.10 Dispersion Modelling and Hazard Ranges

Hazard ranges for each hazard scenario have been derived from the combination of consequence modelling to estimate the concentration at a given distance and use of probits for estimating the fatality likelihood. Dispersion modelling was completed using PHAST software, with special attention given to the dispersions distances relating to ground or centreline concentrations of 10,000 ppm, 6,500 ppm and 4,500 ppm.

6.11 Risk Assessment Results

The specific methodologies, formula and calculations used to assess potential risks from the Urea Plant are detailed in Appendix J. A summary of the results is provided below.

6.11.1 Individual Risk Contours

Assessment of wind effects

Risk predictions have taken account of the Collie area wind direction profile.

The sensitivity to wind speed distribution has been assessed using guidance provided in Table 21 and Table 22: 'Severity 6' is considered highly sensitive to wind speed; 'Severity 0' is considered insensitive to wind speed.

Table 21 Source Parameters Affecting Sensitivity to Wind Directions

Severity	Hazard type	Toxicity	Dispersal	Source quantity
6	Toxic release.	Extreme	Slow	Large
5	Toxic release	High	Slow to moderate	Large
4	Toxic release	Moderate	Slow to moderate	Moderate to large
3	Toxic release	Moderate	Moderate	Moderate to large
2	Toxic, major VCE or flash fire	Minor to moderate	Moderate to rapid	Moderate
1	Toxic, VCE, flash fire	Minor	Rapid	Minor to moderate
0	Fire, explosion, release of pressure, mechanical	None	Any	Any

Table 22 Environmental Parameters Affecting Sensitivity to Wind Directions

Severity	Wind speeds	Direction	Terrain	Buildings	Weather, climate	Flora
6	High	Very directional, distinct channels	Flat, no barriers	None	Fine, sunny	Grass, low shrubs
5	High	Very directional	Some slopes	No large buildings	Fine, sunny	Grass, low shrubs

Severity	Wind speeds	Direction	Terrain	Buildings	Weather, climate	Flora
4	High to moderate	Very directional	Some hills or valleys	No large buildings	Mostly fine	Shrubs, low trees
3	Moderate	Directional	Undulating	Some buildings	Some rain	Some trees
2	Moderate	Some distinct directionality	Hilly areas	Some buildings	Some fog	Woodland
1	Low to moderate	Typical	Any	Any	Any	Any
0	Low to moderate	Typical	Any	Any	Any	Any

6.11.2 Results

1.0×10^{-7} per year

1.0×10^{-6} per year

1.0×10^{-5} per year

Figure 21 Wind affected Individual Risk contours

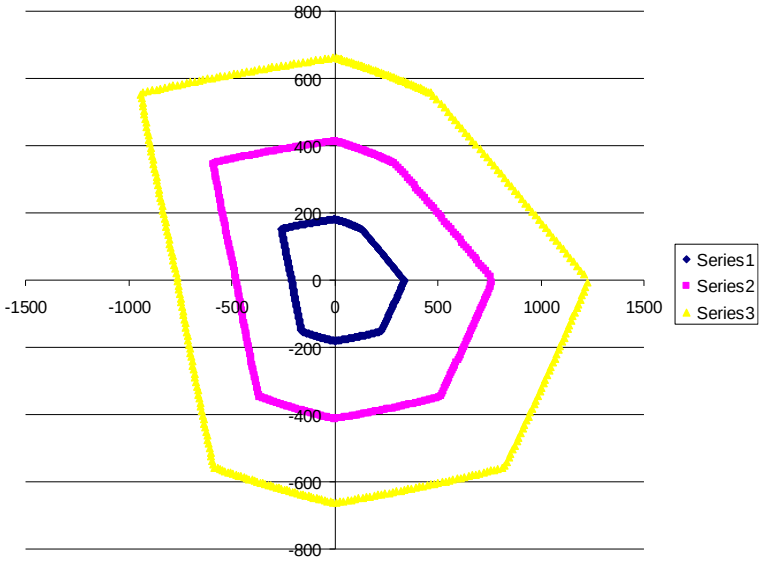


Figure 22 Individual Risk contours – not wind affected

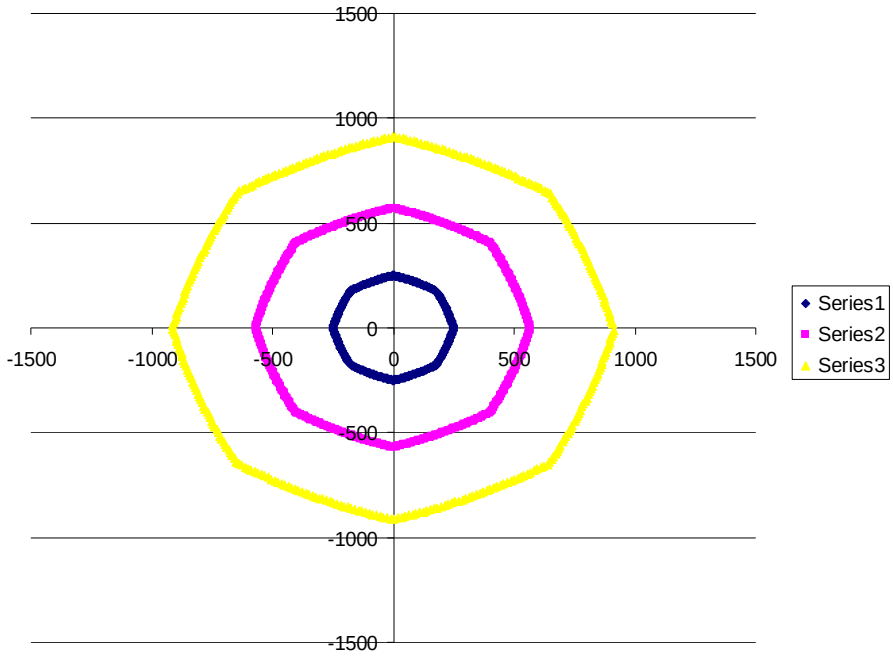


Figure 23 Individual Risk contours – maximum wind effect

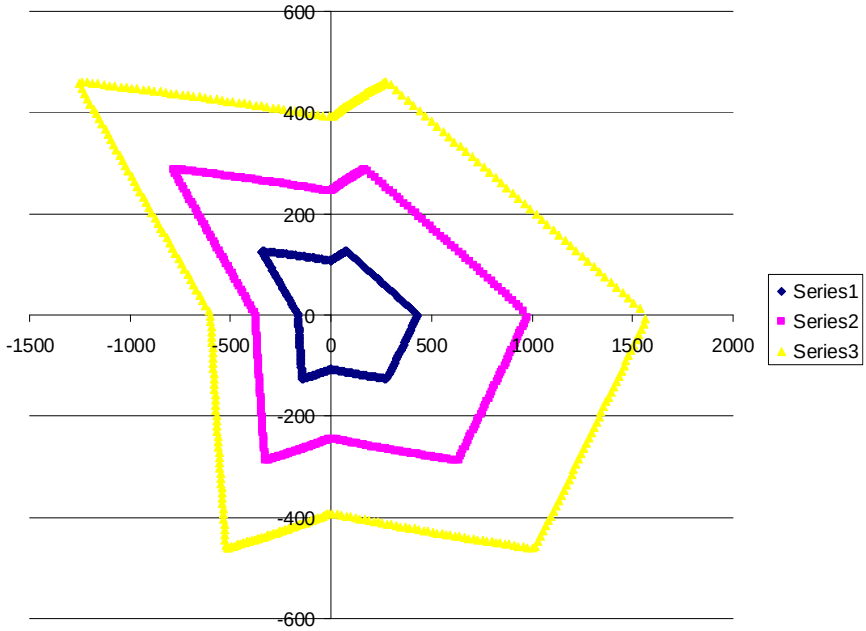
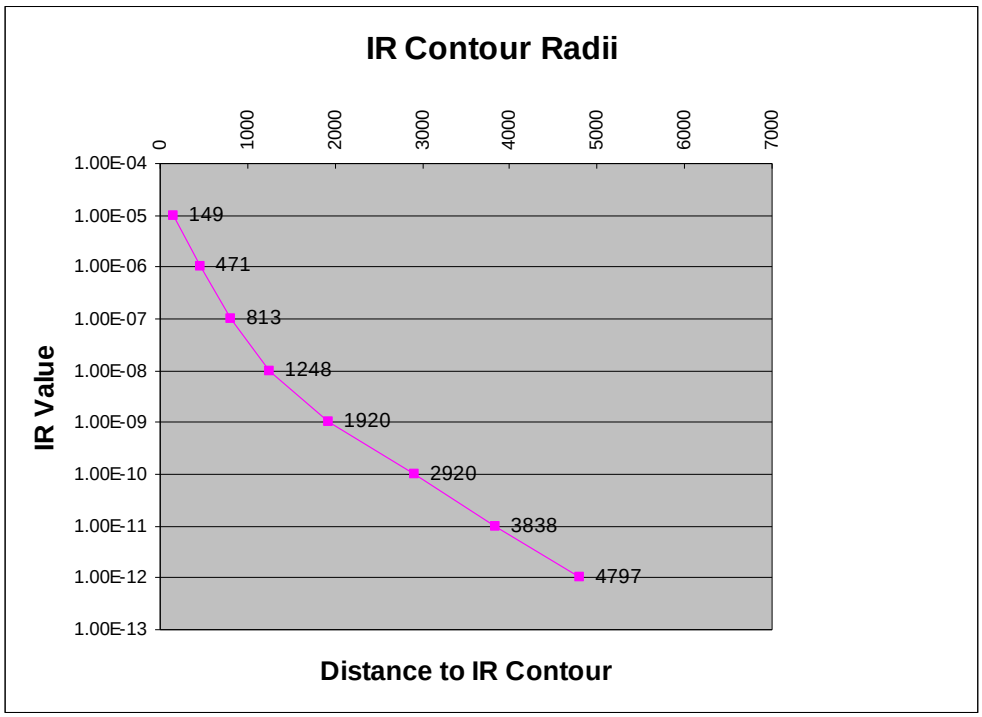


Figure 24 Distance to Individual Risk Contours



6.11.3 Conclusion

The extent of Individual Risk contours from 1x 10^{-5} per year to 1x 10^{-12} per year has been assessed by the study. It is predicted that the 1x 10^{-7} per year contour will be within a 1 km radius of the plant boundaries and that the area within this 1 km zone does not encompass any residential developments or sensitive developments.

The hazard ranges, represented as IR contours, are not greatly affected by the annual wind condition directions.

6.12 Societal Risk (f-N curve)

6.12.1 Introduction

Societal risk can be presented in the form of an 'f-N curve', which expresses the predicted frequency of occurrence (f) of a range of incidents with different magnitudes (N) of offsite fatalities. f-N curves express societies aversion to single incidents resulting in large numbers of fatalities (e.g. rail crashes, building collapse), compared to more frequent fatal incidents (notably traffic incidents).

Societal risk has been calculated as described in Appendix J.

6.12.2 Results

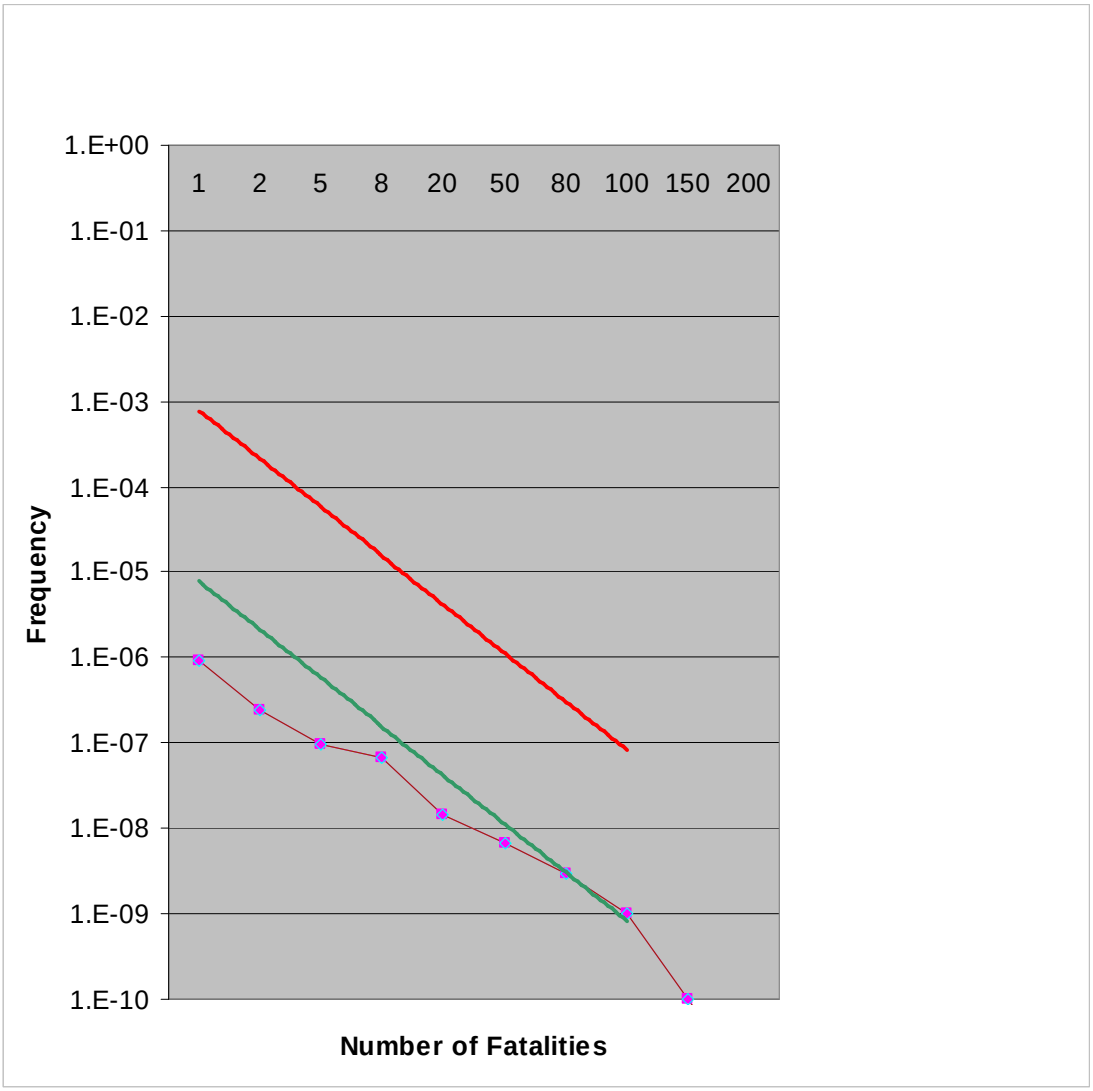
Intolerable band[§]

Broadly tolerable band[§]

Prediction

[§] The area between these bands is the ALARP region

Figure 25 f-N curve for proposed Perdaman site



6.12.3 Conclusion

The societal risk assessment has predicted an f-N curve which is comfortably within typical risk tolerability thresholds. Societal risk has been calculated making conservative population and manning

assumptions; with a typical population of up to 120 persons present within 4.5 km of the proposed plant. the Risk Assessment study for this project also modelled for peak population events at Stockton Lake)

The f-N curve flattens towards the right hand side, beyond the 8 to 20 person group fatality bands. This 'flattening' reflects the low risk of exposure of larger populations towards Collie as a result of the extreme hazard case of instantaneous loss of full vessel contents. Nevertheless, the risk is predicted to be broadly acceptable even though the hazard assessment has made a series of highly conservative assumptions.

The calculation of Individual Risk for Land Use Safety Planning does not strictly require specific offsite population centres to be considered; however, societal risk in form of f-N curves has been considered to provide additional insight into the nature of hazard and will assist PCF to optimise safe operation of the plant and during stakeholder engagements.

6.13 Scaled Risk Index (SRI)

The UK Health and Safety Executive (HSE) has defined a coarse estimator for societal risk known as the Scaled Risk Integral (SRI). The SRI calculation is intended as a screening tool, for use at the very early stage of project planning, prior to engineering development. One application of SRIs is to give guidance on qualitative estimates, such as those allocated during early safety in design activities. Although SRI is a simple metric, the HSE refers to SRI predictions in Land Use Safety Planning (LUSP) documentation and provides guidance concerning the calculation methodology and interpretation of results.

6.13.1 Formulation

$SR = P \times IR_{HSE} \times T / A$

Where:

P Population factor, defined as (N + N2)/ 2

N Number of persons affected by a development - can be estimated as: number of residential units x 2.5, plus 0.25 x commercial and industrial workers impacted by a development

IR_{HSE} Fatalities per million years due to major hazard exposure

T Proportion of time development is occupied by N persons

A Surface area affected by major hazard (km^2)

6.13.2 Typical Interpretation

Table 23 Typical Interpretation

SRI	Guidance
<30000	Will not take steps to prevent development proceeding
30000 to 100000	May advise against development but will not take steps to prevent
100000 to 500000	Not unreasonable, further safety justification required
500000 to 750000	Very likely to be considered intolerable

SRI	Guidance
>750000	Intolerable

6.13.3 Perdaman Study

There are a number of interpretations and approaches for estimating SRIs. The assessment below has been used because offsite populations have been defined.

The "Affected population" is assumed to be all residences and businesses within 5 km of the proposed site, estimated as 120 persons including Stockton Lake recreational area. Based on this information, the SRI is calculated to be:

SRI (120 persons) = **38,500**

6.13.4 Conclusion

The risk assessments undertaken for this study indicate that site location is satisfactory in relation to a major industrial facility as proposed by PCF, in accordance with UK HSE planning guidelines, for the current population density surrounding the plant. Risk and safety measures, and ultimately the location of the plant, would need to be re-assessed with any significant increase (200 to 250 persons or more) in residential development within 1 to 2 km of the plant. This conclusion agrees with the findings from the offsite IR calculation and with societal risk, f-N curve.

6.14 Comparison of Risk Results

All risk measures are in reasonable agreement and indicate that, with the current expected offsite population centres, the Shotts Industrial Park location is a suitable site with respect to offsite hazards and risks.

6.15 Conclusions

The PRA has determined that the dominant hazard from the proposed plant would be large or continuous emissions from the ammonia storage area and associated plant. No other significant offsite hazards were identified.

The risk assessment has suggested three characteristic storage tank hazards and assessed their consolidated impacts and risks using comprehensive dispersion modelling and the quantification of three separate offsite risk measures. All risk measures indicate that the Shotts Industrial Park location is a suitable site with respect to offsite hazards and risks.

At an appropriate stage in the project PCF will embark on a formal risk reduction process identifying opportunities which can:

- *Remove hazards entirely?*
- *Reduce the likelihood of occurrence?*
- *Reduce hazardous consequences?*
- *Minimise exposed populations (on-site and off-site)?*

» *Reduce the risk of fatality of an exposed person?*

All actions raised will be recorded and managed in accordance with appropriate action tracking and project change management procedures.

No design recommendations, other than essential requirements inferred by the risk results, were raised during the PRA.