coffey natural systems
SPECIALISTS IN PEOPLE AND PLACE

ENVIRONMENTAL ASSESSMENT

Newcastle Gas Storage Facility Project

Major Project Application Number 10-0133

Volume 5: Appendices 14 – 16

May 2011

Appendices

Volume 2

Volume 3

Volume 4

Volume 5

ENVIRONMENTAL ASSESSMENT

Newcastle Gas Storage Facility Project

Major Project Application Number 10-0133

Volume 5: Appendices 14 – 16

May 2011

CR 6023_8_v3

Coffey Natural Systems Pty Ltd ABN 61005041878
Level 1, 3 Rider Boulevard Rhodes NSW 2138 Australia
T (+61) (2) 9736 2400 F (+61) (2) 8765 0762
coffey.com

Project director	Carolyn Balint		
Project manager	Edward Niembro		
Version:	**Details:**	**Approved:**	**Date:**
CR 6023_8_v1	Initial draft to client	CB	14/02/2011
CR 6023_8_v2	Second draft to client and Department of Planning	CB	24/02/2011
CR 6023_8_v3	Final to client	CB	23/05/2011

Appendix 16

Preliminary Hazard Assessment

Addendum to PHA AGL Energy's NGSF

1. Introduction

This addendum has been compiled to respond to a request by the NSW Department of Planning (DoP) and the Major Hazard Branch at NSW WorkCover (WorkCover MHF Branch) for additional information on the Preliminary Hazard Analysis (PHA) of the Newcastle Gas Storage Facility (NGSF) (Ref [1]) which is proposed by AGL Energy in Tomago in NSW. The addendum and the PHA were compiled by Planager Pty Ltd (Planager) in accordance with the requirements for risk assessment of potentially hazardous development by NSW DoP.

To assist in the reading of this addendum, the questions / requests for information posed by the DoP and WorkCover MHF Branch have been included in the text below.

Ref [1]. Nilsson K, *Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales*, Planager Pty Ltd, 11 February 2011

2. Response to Requests by NSW DoP

2.1 How the design meets the Australian Standard AS2885

Q1: *Please clarify how the project will meet the standard?*

A1: The high pressure pipeline interconnecting the NGSF with the main Sydney to Newcastle pipeline will be designed and constructed to meet the requirements of AS2885.1-3.

Pipelines onsite meet other standards and codes, as listed in Appendix 2 of the PHA.

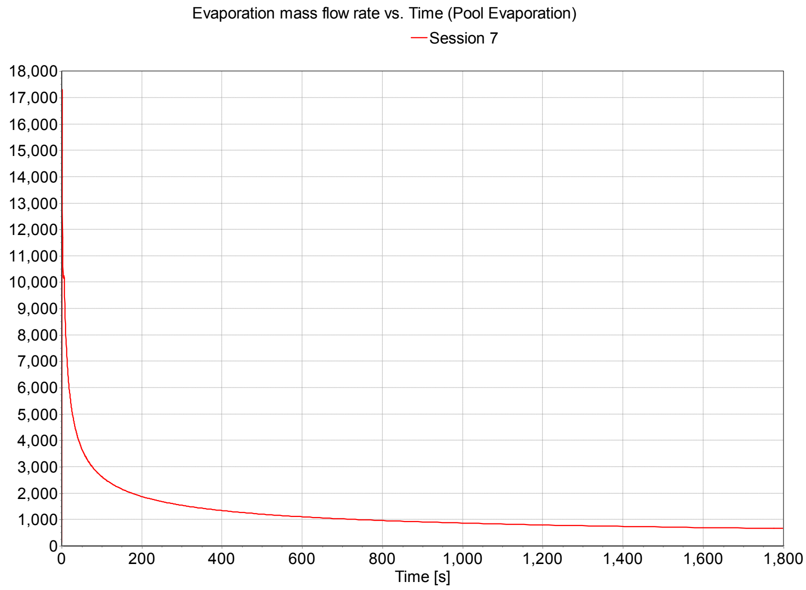
2.2 Details on the bund design under Section 4.2.1 Gas Plant

Q2: *It is noted that that the proposed size of the bund is 140 x140 m (Fig 6 of the draft EA). The following inconsistency in relation to the bund design of the LNG storage tank needs to be corrected. The PHA calculations of the bund fire are based on dimensions of 150 m x 100 m, as reported in Table 7 – Impoundment Systems Design. However, the dimensions of the pool on Fig 6 of the EA appears to be 140 x 140 m.*

A2: The dimensions used in the PHA for the bund refer to the bottom of the bund while those in the EA refer to the top of the bund.

The PHA calculations of the bund fire are a function of the surface area of the pool, not the shape of the bund. The surface area of the top of the proposed bund is 19,600 m^2 compared to the 15,000 m^2 (of the bottom of the bund) assumed in the PHA.

In case of a rupture of the storage tank the entire bund is likely to fill up to near the top (bund is designed for 110% of the volume), i.e. the pool is likely to cover the maximum surface area, as stated in the EA. The evaporation rate is therefore a function of surface area. The evaporation rate at this point is initially very large but as the ground cools down by the cold LNG the evaporation rate reduces very quickly, particularly in the first few seconds, as per the profile below:



The *representative* surface of the bund of 13,610m^2, as calculated using Effects, is reached after about 30 seconds. This is the bund surface which is used by Riskcurves to determine the risk from this scenario.

The representative surface of the bund is less than the total surface available in the bottom of bund and even less than the surface area of the top of the bund.

Hence, the somewhat larger bund surface area referred to in the EA would not affect the calculated risk results in the PHA.

2.3 Clarification on the end point for calculation of the dispersion distances

Q3. *Clarification on the end point for calculation of the dispersion distances. Section 5.2.4 Dispersion Distances of the PHA states that the dispersion modelling is estimated to ½ LFL. However, Appendix 3 of the PHA reports "Distance to LFL".*

A3. The QRA risk contours were modelled using the TNO Riskcurves software which uses the *½ LFL* as an end point for calculation of the dispersion distances. The consequence results provided in the Riskcurves model is not user friendly and therefore the TNO Effects software was run separately to populate the spreadsheet provided in Appendix 3 so as to provide the reader of the PHA with an understanding of the possible extent of the incident scenarios.

2.4 Point where LNG becomes lighter than air

Q4: *The MSDSs for LNG in the public domain report that the vapours of LNG become lighter than air above temperature of -88^{o}C. The PHA reports temperature of -107^{o}C. Reference to the source of information used should be provided as well as information on its relevance.*

A4: LNG composition varies depending on the source of the natural gas. Hence, the temperature where it can be said to become lighter than air will vary accordingly. The temperature of -107°C provided in the PHA is approximate for the LNG composition expected for the NGSF, however, this composition may vary over the years as the source gas composition varies.

The temperature at which the LNG becomes a lighter than air gas is not an input into Riskcurves, however the model predicts this point based on conditions of the release and dispersion characteristics. The approximate temperature of -107°C provided in the PHA was for information only.

2.5 Surface Emissive Power Value

Q5: *The value of the SEP for modelling of the pool fires should be provided.*

A5: The Surface Emissive Power (or SEP) is the heat flux due to heat radiation at the surface area of the flame (in W/m^2).

SEP is calculated by the Riskcurves software as per the TNO Yellow Book. SEP_{theo} is calculated in Riskcurves, using complex formulas provided in the Yellow Book. The relationship between the SEP_{theo} and the SEP_{max} is done by multiplying the SEP_{theo} with the *fraction of the generated heat radiated from the flame surface* (or F_s), also in Riskcurves.

Quoting the Yellow Book: *In [Roberts, 1982], the thermal radiation output from a fireball was characterised in terms of the fraction of combustion energy released through radiation, and its dependance on the release pressure. The following relationship was obtained:*

$F_s = c_6 \times (P_{sv})^{0.32}$

With:

F_s = *Fraction of the generated heat radiated from the flame surface*

$c_6 = 0.00325(N/m^2)0^{.32}$

P_{sv} = *Saturated vapour pressure before the release, in* N/m^2

2.6 Reliability of Automatic Response

Q6: *The information on the safeguard systems provided on page 36 of the PHA suggests SIL 2 for the instrumented protective systems, which results in probability of failure on demand of less than 0.01. Further in the PHA, Sec 5.2.2 Duration states that where an automatic response is designed into the plant, such response has been taken into account, with the relevant probability of failure of the trip. Clarification if SIL 2 for has been accounted for in the frequency analysis (i.e. was a probability of failure on demand of 0.01 used in the analysis) is needed.*

A6: The requirements in terms of instrumented protection are clearly defined in the Codes and Standards applicable for LNG:

- Overfilling
- Overpressure
- Underpressure

- Roll over

At least two (usually three) redundant levels of protection are required for each one of the above mentioned scenarios. This relates to a SIL of about 2 (further investigation of the SIL level will be done during SIL analysis at detailed design stage).

The result of each of the above mentioned scenarios (also the overfill scenario – refer Table 8 in the PHA) would be damage to the tank with possible release.

The frequency data for tank leaks and tank rupture used in the QRA for LNG tanks are assumed to incorporate the risk of maloperation of the tank provided the tank is designed and built to Code requirement (which is an underlying assumption in the QRA).

No other automatic protective systems have been considered. This is highly conservative as the plant will have fire and gas detection systems built in which would be linked into the Emergency Shut Down system. However, this conservatism is appropriate at this early design stage.

2.7 Likelihood Data for Pipeline Leaks

Q7: *Clarification on the likelihood of fracture of the NGSF pipeline, in particular if the likelihood has been reduced by factor of 2 as suggested in the EGIG report*

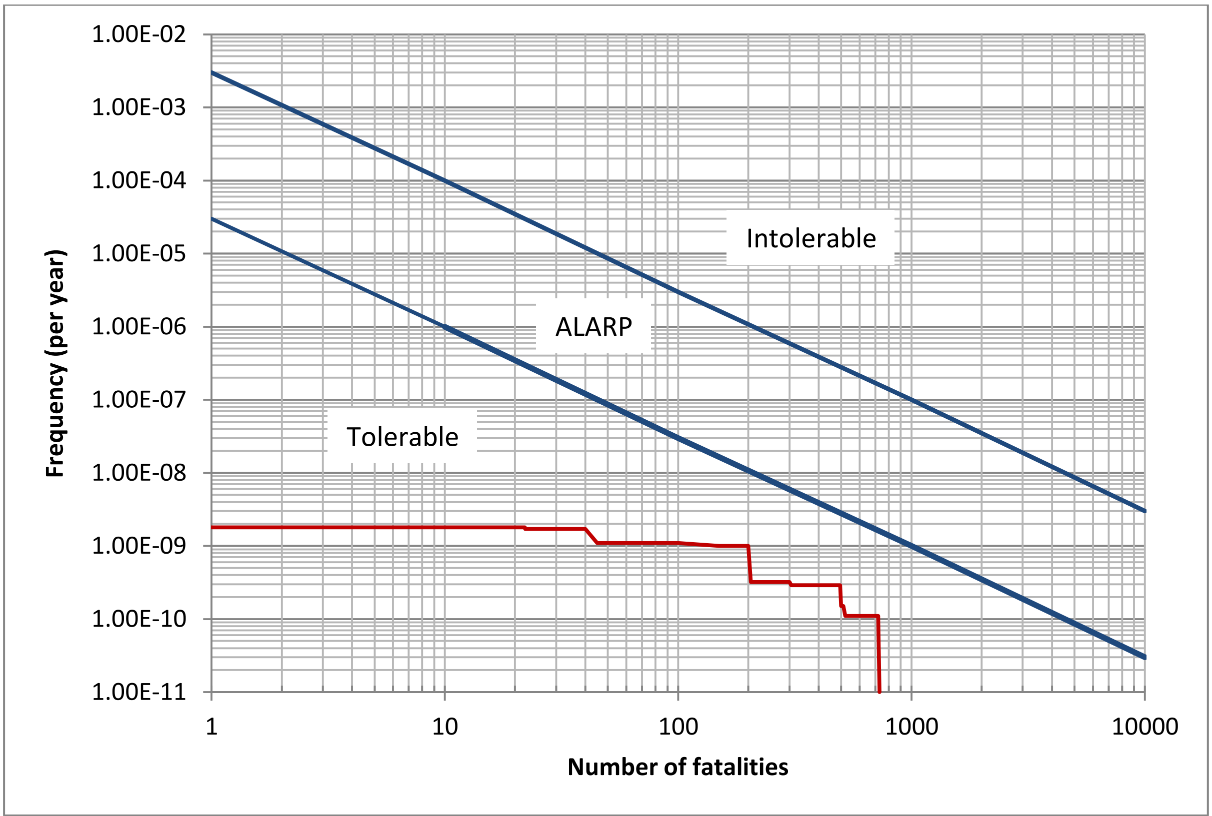
A7: The EGIG likelihood data has been used in the QRA as is, without any alteration to account for any additional protective features over and above the *average* pipeline.

The factor of two (2) discussed in the PHA refers to the fact that using the EGIG data without altering this data for a pipeline designed for *no rupture* (as is the case of the NGSF Pipeline) is conservative with (about) a factor of two (2).

2.8 Societal Risk

Q8: *It is recommended the societal risk graph to be amended in accordance with the suggested indicative societal risk criteria, published in HIPAP No 4 Risk Criteria for Land Use Safety Planning*

A8: The *Indicative Societal Risk Criteria* quoted in the HIPAP No 4 (January 2011) have been added to the societal risk figure below, replacing Figure 9 in the PHA. The societal risk has not been altered and the discussions and conclusions relating to societal risk in the PHA remain unchanged.



2.9 Set Back from Bush

Q9: *Note DoP criteria is 23KWm2 (31m) and European code is 15KWm2 (43m). How was set back determined? After discussions with Hazards section – the larger setback may still need to be adopted.*

A9: Refer Section 4.2.6 D in the PHA: Based on the proposed layout, the separation distance between the bush and the storage tank (about 75m) is such that the heat radiation resulting from a bush fire will not exceed the 15kW/m^2 and will in fact be about 6.2kW/m^2 (Ref 29), which is less than the maximum heat radiation allowed as per both the NSW DoP and the European LNG Code requirements (*EN 1473 - The European Norm standard EN 1473 Installation and equipment for Liquefied Natural Gas*).
In short, the set back was defined based on the more conservative European code of 15kW/m^2.

3.1 Consult with WorkCover

A10: Formal consultation carried out 31 March 2011.

3.2 Links of PHA into the Safety Case Report

Q11: *The safety report must demonstrate that both on site and off-site risks have been reduced to as low as reasonably practicable (ALARP).*

A11: The PHA is only one step in the development of the complete Safety Case for this project. The key purpose of the PHA is to ensure adherence with land use planning guidelines and criteria. It will be included in the Safety Case development but it is expected that further demonstration of adherence to ALARP principles will also need to be applied.

Appropriate measures will be taken to control and mitigate the consequences to protect personnel and assets, through application of Safety Management Systems. A multi-staged approach to hazard and risk management is and will be applied throughout the lifecycle of this project, from concept design to decommissioning.

The general form of hazard and risk management is to identify the hazards, assess their likelihood and consequences, control the process effectively with instrument and material protection and minimise the consequences of any loss of containment. The effectiveness of risk reduction measures will receive considerable attention. This allows the residual risk to be benchmarked against risk tolerability criteria, as well as to be minimised by considering alternative strategies until the risks are tolerable or As Low As Reasonably Practicable (ALARP). A hierarchy of engineering experience and methods are used throughout this decision making process, including:

- Codes and standards
- Assurance reviews
- Hazard Identification (HAZID) and Hazard and Operability (HAZOP) studies
- Physical effects modelling (consequence analysis)
- Quantitative Risk Assessment (QRA)
- Cost benefit analysis of risk reduction options
- Development of human factors programs and systems such as Emergency Response Plans, training plans, maintenance strategies, etc.

3.3 Flare and an ignition source

Q12: *PHA Appendix 5 - Ignition sources, should identify and consider the presence of the permanent sources such as the site flare and Tomago Aluminium.*

A12: Refer Table A5.1 in Appendix 5 of the PHA. The NGSF flare and the entire Tomago Aluminium (TAC) site were identified as permanent ignitions sources with a probability of 1 (100% if a released gas cloud was to pass in the direction of the flare or TAC). This was assumed regardless of the height of the cloud as it passed the flare or TAC (which is believed to be conservative). The location of the NGSF site flare may change during detailed design – however, due to the conservative assumptions in this regard, this is unlikely to have any major impact on the results of the risk assessment.

3.4 Roll over scenario

Q13: *PHA Clause 4.2.1 section C - Safeguard systems, describes the roll over scenario. Additional details should be included regarding the safeguards. For example,*

(a) does the down pipe have a sparge ring at the bottom?

(b) What measures are in place for times when there is no incoming liquid?

A13: The discussion in the PHA on roll over is based on preliminary designs for the tank. However, the roll over potential is well known and understood in LNG tank design and the management of risk associated with such a scenario is specified in relevant Codes. For example, the NSFP59A code specifies the need for prevention of stratification and vapour evolution that could result in rollover. The ability of the design to prevent a roll over scenario will be scrutinised during the design review and HAZOP study process. Also refer Section 2.6 above.

3.5 LFL Relationship with Temperature

Q14: *PHA clause 5.2.4 - Distance to Lower Flammable Limit (LFL) - states that the LNG will remain negatively buoyant until after LFL. PHA E 4 appears to say that the gas is buoyant below -107 deg C. Is there a relationship between LFL & temperature?*

A14: There is anecdotal evidence that the LFL coincides approximately with the point at which the cloud becomes lighter than air. This relationship is however never used in the risk calculations.

The concentration of the cloud and its state (dense gas, lighter-than-air gas etc.) is calculated within the Riskcurves program. So called *Event trees* and associated probabilities of immediate and delayed ignition have been prepared outside of Riskcurves and form part of the input information.

The approach used in this study (as per the Yellow Book methodology) is to determine the footprint of the cloud (to LFL) and then to estimate the probability of ignition depending on the wind direction. No attempt has been made to determine whether this cloud is at ground level or at height, and for natural gas this approach appears to be conservative as most ignition sources (bar the flare) are located relatively close to ground.

PRELIMINARY HAZARD ANALYSIS OF AGL ENERGY'S NEWCASTLE GAS STORAGE FACILITY PROJECT, NEW SOUTH WALES

Prepared for: AGL Energy
Document Number: AGLENE\06-B220
Revision E

Prepared by: Karin Nilsson

11 February 2011

PO Box 1497
Lane Cove NSW 2066
Telephone: [02] 9427 7851
Facsimile: [02] 9427 7851
Web: planager.com.au
Email: karin@planager.com.au

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Acknowledgment

The author would like to thank Alex Kennedy-Clark and Eric Thomason (AGL Energy), David Moss (IDM Partners) and David Miller and Les Cohen (Worley Parsons) for their assistance in preparing this report.

Disclaimer

This report was prepared by Planager Pty Ltd (Planager) as an account of work for AGL Energy. The material in it reflects Planager's best judgement in the light of the information available to it at the time of preparation. However, as Planager cannot control the conditions under which this report may be used, Planager and its related corporations will not be responsible for damages of any nature resulting from use of or reliance upon this report. Planager's responsibility for advice given is subject to the terms of engagement with AGL Energy.

Rev	Date	Description	Prepared By	Reviewed By	Authorised By
A	01/10/2010	Draft for Comments	Karin Nilsson	Maarten Tentij	Karin Nilsson
B	06/12/2010	Draft for Comments	Karin Nilsson	Maarten Tentij	Karin Nilsson
C	12/12/2010	Draft for Comments	Karin Nilsson	Maarten Tentij	Karin Nilsson
D	19/12/2010	Draft issued for comments to NSW DoP and TAC	Karin Nilsson	Maarten Tentij	Karin Nilsson
E	11/02/2011	Final Report	Karin Nilsson	Maarten Tentij	Karin Nilsson

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

E1 Overview

Preliminary hazard and risk assessment of the proposed LNG facility at Tomago in New South Wales has not identified any risks to public safety or to the biophysical environment from accidental releases of hazardous material associated with the proposed development beyond acceptable levels or that exceed legislative safety and risk guidelines.

From the point of view of adherence to generally accepted risk criteria, the proposed Tomago site is acceptable for the proposed development and the Development does not preclude further industrial development in the vicinity of the proposed site.

The gas storage facility will process, handle and store large inventories of LNG. AGL Energy is committed to reducing the health and safety risks to public, employees and contractors to levels that are as low as reasonably practicable. The potential for accidents is understood and the design of the plant and other facilities will emphasise minimisation of the probability of an accident happening and mitigating an accident if it occurs.

The construction, commissioning and operation of the facility will be subject to a rigorous management process, safeguarding delivery and operation of the Development in a manner that minimises the risk to workers and the community.

The safety, efficiency and stability of the proposed gas storage facility will be achieved through the use of high level safety systems, regular preventative maintenance programs, detection and protective measures. Security measures will include security patrols, protective enclosures, lighting and monitoring equipment.

E2 Background

To meet the peak gas market requirements over winter and to provide additional security of supply during supply disruption events, AGL Energy Limited (AGL) proposes to develop the Newcastle Gas Storage Facility (NGSF) at Tomago, New South Wales.

Due to the potentially hazardous nature of the natural gas used and stored, there is a requirement to review the hazards and risks associated with the proposed facility, as per the requirements by the NSW Department of Planning. The present assessment reviews the hazards and risks associated with the proposed facility, and compares these risks with the NSW Department of Planning criteria for landuse planning.

Further, the NGSF is likely to be classified as a *Major Hazard Facility* (MHF) as per the New South Wales *Occupational Health and Safety Regulation* 2001 Chapter 6B. The present report constitutes a first step towards meeting the requirements for hazard and risk assessment under these regulations.

As per the requirements by the Department of Planning, the risk analysis focused on those events shown to have off-site impacts or potential to escalate and cause off-site impacts.

Risk has been evaluated in terms of individual fatality and injury risk (which is the risk to a person at a given location exposed to the hazard 24-hours of the day and 365 days in the year), societal fatality risk and incident propagation to nearby facilities.

E3 Aim and Scope

The objectives of this hazard and risk analysis were to:

- Assess the operations phase risk of the proposed NGSF Project and compare this risk with risk criteria specified by the Department of Planning;
- Assist AGL selecting a concept with risk levels that are acceptable in terms of well recognised risk criteria;
- Identify significant risk contributors where future mitigation measures may be viable.

At the time this hazard and risk assessment was conducted, the design of the facility was in its preliminary stages. Detailed plant information was therefore not available for review. In situations where such information could impact on the results of the hazard and risk assessment, assumptions have been made which are intentionally conservative and these been stated in the report.

The scope of this analysis covers the operation of the plants and processes listed below.

- Pipeline linking the Jemena Gas Networks (NSW) Limited Wilton-Newcastle trunk pipeline (the Jemena pipeline) to the site (6 km), including receiving station;
- Pipelines distributing natural gas through the gas plant site;
- Liquefaction of natural gas to LNG (up to 180 tonnes per day (TPD));
- Storage of up to 63,000 m^3 (30,000 TJ) of natural gas as a cryogenic liquid (LNG);
- LNG tanker loading;
- LNG vaporisation; and
- Natural gas injection from the vaporisation unit back into the natural gas main to the point where it leaves the NGSF and returns to the interconnecting pipeline.

The risk associated with the construction and commissioning phases are not included in the present scope. This will form part of other hazard and risk reviews performed as part of the project development, following the internal AGL requirements (as per their Project Management framework) and the NSW Department of Planning requirements for new *Potentially Hazardous Development* as described in their Hazardous Industry Advisory Papers.

E4 Potential Hazards

The main hazard associated with the proposed development relates to the handling of natural gas and LNG.

Natural gas and LNG are mainly composed of methane gas. Methane gas is flammable if it is within the concentration range of 5.5-14% gas in air.

Hazards may arise in fixed plant, storage vessels and pipelines. The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;
- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include equipment not rated for hazardous areas, vehicles or other combustion engines, or flames some distance from the release;
- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (for example a so called jet fire or a pool fire) or a flash fire. If there is confinement, such as in the cramped plant area or inside a building, a vapour cloud explosion is possible.
- Finally, for there to be a risk, people or plant must be present within the harmful range (consequence distance) of the fire or explosion. How close the people or plant are will determine whether any injuries or fatalities result or whether a propagation incident results.

Natural gas is a buoyant, flammable gas which is held under pressure in pipelines and process plant pipes. It is lighter than air and, on release into the atmosphere, the non-ignited gas tends to rise rapidly at altitude where it will disperse to below hazardous concentrations without encountering an ignition source. Combustion and/or vapour cloud explosion is only possible with a concurrent source of ignition and with an air to methane ratio within the flammable region, i.e. between 5.5 to 14% methane gas in air.

LNG is natural gas which has been cooled down sufficiently to form a liquid. The gas is liquefied by reducing its temperature, not by being placed under pressure[1]. It is colourless, odourless, and non-toxic. It does not mix with water.

The hazards associated with LNG are similar to those of natural gas except for the fact that as a cryogenic liquid it is much cooler and therefore will form a much smaller gas cloud for the same leak dimensions.

---

[1] As is the case for, for example, LPG

As a cryogenic liquid, the risk of LNG exploding or burning is low.

In the unlikely event that LNG did escape from its storage containment to the environment, it would begin warming immediately and return to its gaseous form. As the gas warms up to -107ºC from -162ºC (the temperature at which it is liquid at atmospheric pressure), the vapours become lighter than air and would rise into the atmosphere and dissipate without leaving any residue.

The limiting conditions for a hazardous event to occur are an LNG release with and without immediate ignition. If the ignition was immediate or relatively soon after the start of the release, the fire size would be determined by the LNG release rate which fuels the fire. If the ignition was instead delayed, an LNG vapour cloud would develop and disperse as it would expand and/or travel downwind. If ignition occurred at this stage, the vapour cloud would burn back to the source. Depending on how ignition occurred, the result may result in a pool fire or, for delayed ignition, a flash fire or vapour cloud explosion (the latter would be possible only if there was confinement).

Other hazards associated with natural gas and LNG are from lack of oxygen (asphyxiation) and low temperatures (frostbite) which are only present in the immediate area of the release and would be confined to the site. Employees of the facility would be trained and instructed as to a safe course of action to follow in the event of an emergency as required by the codes covering the facility. The risks associated with asphyxiation and frost bite are therefore not included in the present hazard and risk assessment but will form part of other risk assessments at a later stage of this project (typically using job safety analysis and other similar methods).

Cold metal brittle fracture is a phenomenon where materials are exposed to lower temperatures than those for which they are designed (for example, carbon steel exposed to a release of LNG). This hazard is taken into account in material selection throughout the facility and in protecting structural supports in high hazard areas. The site is also designed so that a spill would drain away from other plant items and structural supports so as to minimise the risk of further damage in the case of a release of LNG on the ground.

Some mixed refrigerants such as methane, propane, ethylene, butane, i-pentane (and nitrogen) will be used in the liquefaction unit of the NGSF. These are flammable gases held under pressure. Common with natural gas, the primary hazard of these refrigerant gases is fire, either immediate upon vapour release or a delayed ignition of vapours which creates a potential hazard to the extent that the vapours are not dispersed below the lower flammable limit (LFL) concentration and which could result in a flash fire or an explosion. A Boiling Liquid Vapour Explosion (BLEVE) is also possible with these materials.

Notwithstanding the different behaviour of the LPG vapours, the risks are offset by much smaller inventories (less than 22 tonnes of refrigerants in storage compared with the 30,000 tonnes of LNG in storage). These materials are handled in everyday operations that are not different in any significant way in the context of being part of an LNG facility. Because the refrigerant volumes will be significantly smaller, the risk associated with these refrigerants would be much lower than the overall NGSF risk.

Nitrogen may also be used in the liquefaction unit. This is a common industrial gas with asphyxiation properties. Again, employees of the facility would be trained and instructed as to a safe course of action to follow in the event of an emergency as required by the codes covering the facility.

Some odorant will be stored at the NGSF. The odorant will most likely be either a liquid with flammable properties either similar to petrol or to diesel (i.e. a so called flammable or combustible liquid in accordance with the definition in the Australian Standard for the storage and handling of flammable and combustible liquids (AS1940). Provided the requirements from AS1940 are adhered to, the risk of a flammable incident involving the odorant stored and handled would be very small. The main hazard associated with such storage is the release of strong odours into the environment – such releases will be prevented through design.

Other materials that will be used for gas treatment include liquid amine and solid gas treatment material. These materials represent a minor health hazard and will be managed through appropriate safe operating procedures and permit to work.

E5 Safety and Acceptance Criteria

Individual risk at a given location is generally expressed as the peak individual risk, defined as the risk of fatality to the most exposed individual located at the position for 24-hours of the day and for 365 days of the year. Since residential areas tend to be occupied by at least one individual all the time, this definition would easily apply to residential areas. A person indoors would receive natural protection from fire radiation and hence the risk to a person indoors is likely to be lower than to one the in open air. In this study, the individual risk levels have been calculated for a person in the open air – note that this is a conservative assumption.

For land uses other than residential areas (that is, industrial, open space or commercial) where occupancy is not 100% of the time, individual risk is still calculated on the same basis. However, the criteria for acceptability are adjusted for occupancy.

In addition to quantitative criteria, qualitative guidelines are also given to ensure that off-site risk is prevented and where that is not possible, controlled. For new proposals, in addition to meeting the quantitative criteria, risk minimisation and use of best practice must be demonstrated.

There are no sensitive land uses such as such as schools, nursing homes, hospitals etc. or residential areas in the vicinity of the proposed site. The nearest resident is located at 1.3 kilometres away from the site in a south easterly direction. The area surrounding the site is open space (passive).

E6 Safety Risk Assessment Methodology

The risks associated with an event are commonly defined as a function of the following four elements:

- The likelihood of the event — such as a natural gas or an LNG loss of containment;

- The consequences associated with the event — such as thermal radiation from a fire due to release;
- The effects of the event — such as the thermal damage or level of injury from a fire, and;
- The effectiveness of systems for preventing the event or mitigating hazards and consequences — such as safety and security systems.

The hazard management and risk assessment process is ongoing throughout the duration of a project.

The consequences of the events carried forward from the hazard identification are modelled using the internationally recognised consequence and risk modelling software from the Dutch TNO (the Netherlands Organisation for Applied Scientific Research) entitled *Effects* and *Riskcurves*. The events modelled include jet fires, vapour cloud explosions, pool fires and flash fires.

To characterise the range of leaks that may occur from the different equipment items typically present within this type of facility, representative hole sizes are used. Following assessment of incident consequence, events are carried forward for frequency analysis and assessment of the risk level to the public. Incident frequencies are derived for the various scenarios using historical release frequency and ignition probability data.

The consequences of an incident are combined with its likelihood to calculate the risk of each incident. The risk of each identified scenario is then combined to produce the risk contours for the proposed development, using established Quantitative Risk Assessment techniques.

E7 Quantitative Risk Assessment Results

From an adherence to generally accepted risk criteria point of view the proposed site in Tomago near Newcastle is acceptable for the proposed Gas Storage Facility, the interconnecting pipeline and for the receiving station.

The risk results of the preliminary hazard assessment for the NGSF are presented in the figures below. By comparing the individual risk results with established risk criteria, the following conclusions can be drawn:

- **Criteria for industrial development:** The $50x10^{-6}$ per year individual fatality risk contour (i.e. a 1 in 50 million chance per year of fatality for person spending 24 hours per day and 365 days per year with this contour), corresponding to the maximum tolerable risk for industrial facilities, is contained within the site boundary.

  The risk levels at the NGSF pipeline is below $50x10^{-6}$ individual fatality risk at all points of the pipeline and the receiving station.

  Hence the risk criterion for boundaries of an industrial site would be met for the NGSF, for the NGSF pipeline and for the receiving station. This implies that the proposed NGSF does not preclude further industrial development in the vicinity of the proposed site. It also implies that the risk criteria for industrial development is met at the Tomago aluminium smelter site and at the proposed gas-fired power station approximately 2 km west of the gas plant site.

- **Criteria for active open space:** The $10x10^{-6}$ per year individual fatality risk contour, corresponding to the maximum tolerable risk for active open spaces, is contained within the NGSF site boundary.

  The risk levels at the NGSF pipeline is below $10x10^{-6}$ individual fatality risk at all points of the pipeline and for the receiving station.

  Hence the risk criterion for active open spaces would be met. This implies that the proposed NGSF and associated infrastructure (receiving station and pipeline) does not preclude further development of open space in the vicinity of the proposed site. It also implies that the risk criteria for active open space is met at the Hunter Region Botanical Gardens.

- **Criteria for residential development:** The $1x10^{-6}$ per year risk contour, which is applicable for residential areas, extends up to about 310 meters beyond the NGSF site boundary in the southerly and northerly directions, about 120 meters in the westerly and 80 meters in the easterly direction.

  This risk contour does not encroach into any residential areas - there are no residential areas within 1.6 kilometres of the site and hence the risk criterion for residential areas would be met.

  The risk level at the NGSF pipeline is below the $1x10^{-6}$ per year individual fatality risk at all points of the pipeline. Hence the risk criterion for residential areas is met.

  The 1 x 10^{-6} per year risk contour for the NGSF receiving station reaches about 15 meter from the centre of the station. This will most likely coincide with the hazardous area classification of this station.

- **Criteria for sensitive development:** The $0.1x10^{-6}$ per year risk contour, corresponding to the maximum tolerable risk for sensitive development, extends up to 600 meters beyond the NGSF site boundary.

  This risk contour extends 110 meters from the centre line of the pipeline and about 70 meters from the centre of the receiving station.

  This contour does not encroach into any sensitive developments (nor does it encroach into any residential areas). Hence the risk criterion for sensitive development is met.

- **Criteria for propagation and injury risks:** The $50x10^{-6}$ per year propagation risk and injury risk contour is contained within the boundary of the NGSF site and is never reached at the NGSF pipeline or the receiving station. Hence the criteria for acceptable risk of injury and propagation are met.

- **Criteria for societal risk:** The societal risk falls below the *acceptable* limit for most of the range and within the ALARP (as low as reasonably possible) region for the high consequence scenarios. At no place does the societal risk fall within unacceptable region.

Figure E1 - Individual Fatality Risk Contours, NGSF

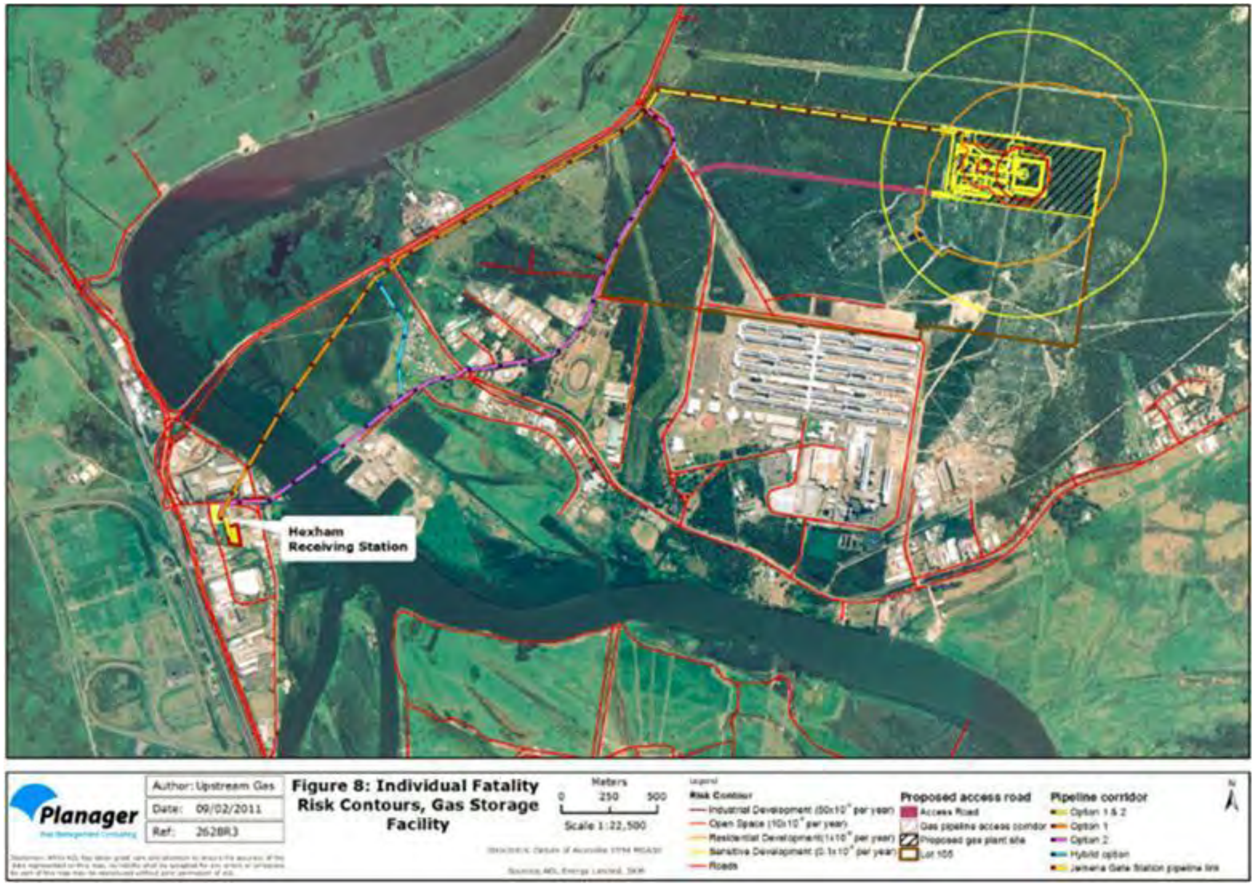


Figure E2 - Societal Risk, Gas Storage Facility

Figure E3 – Injury Risk

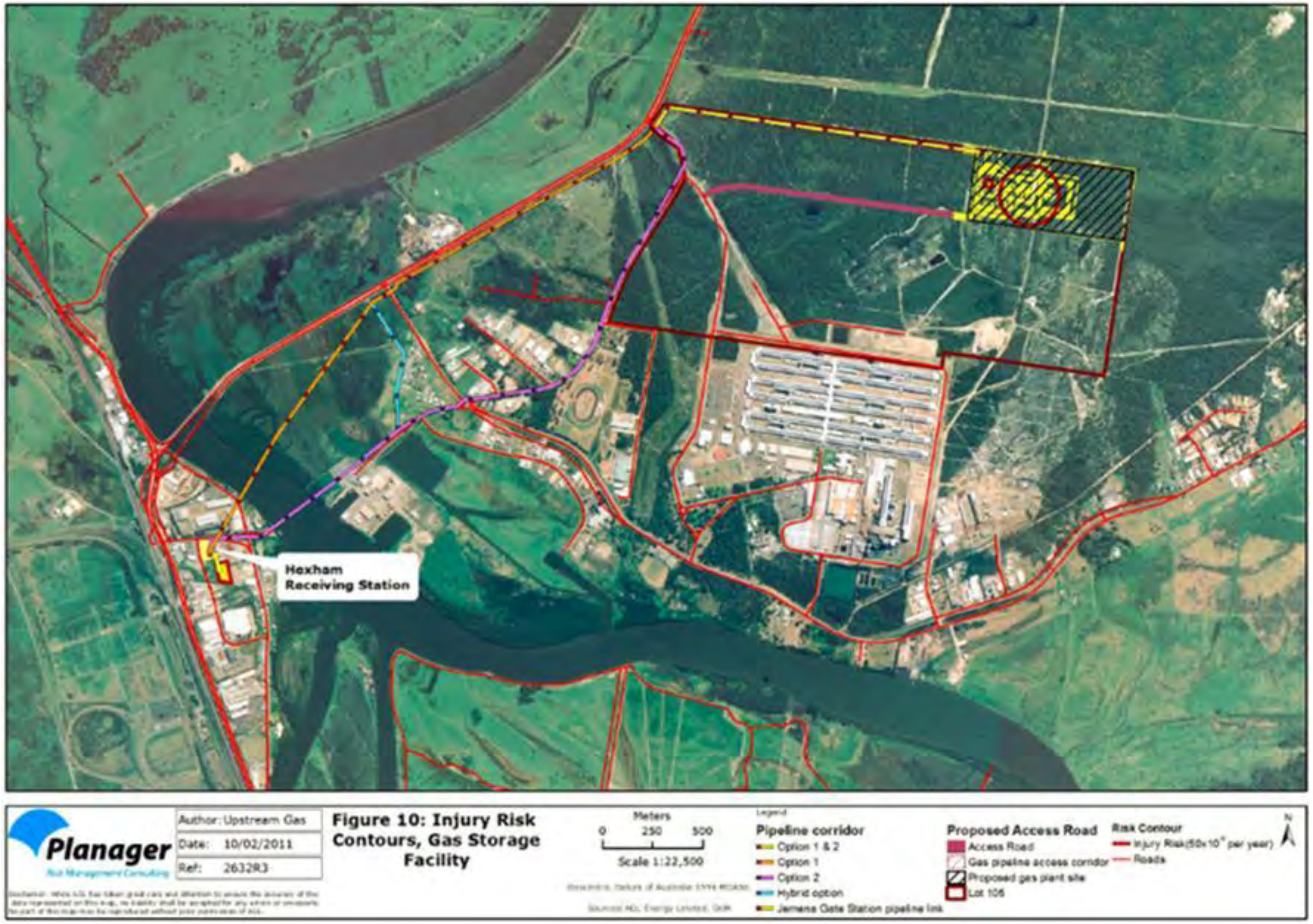


Figure E4 – Propagation Risk

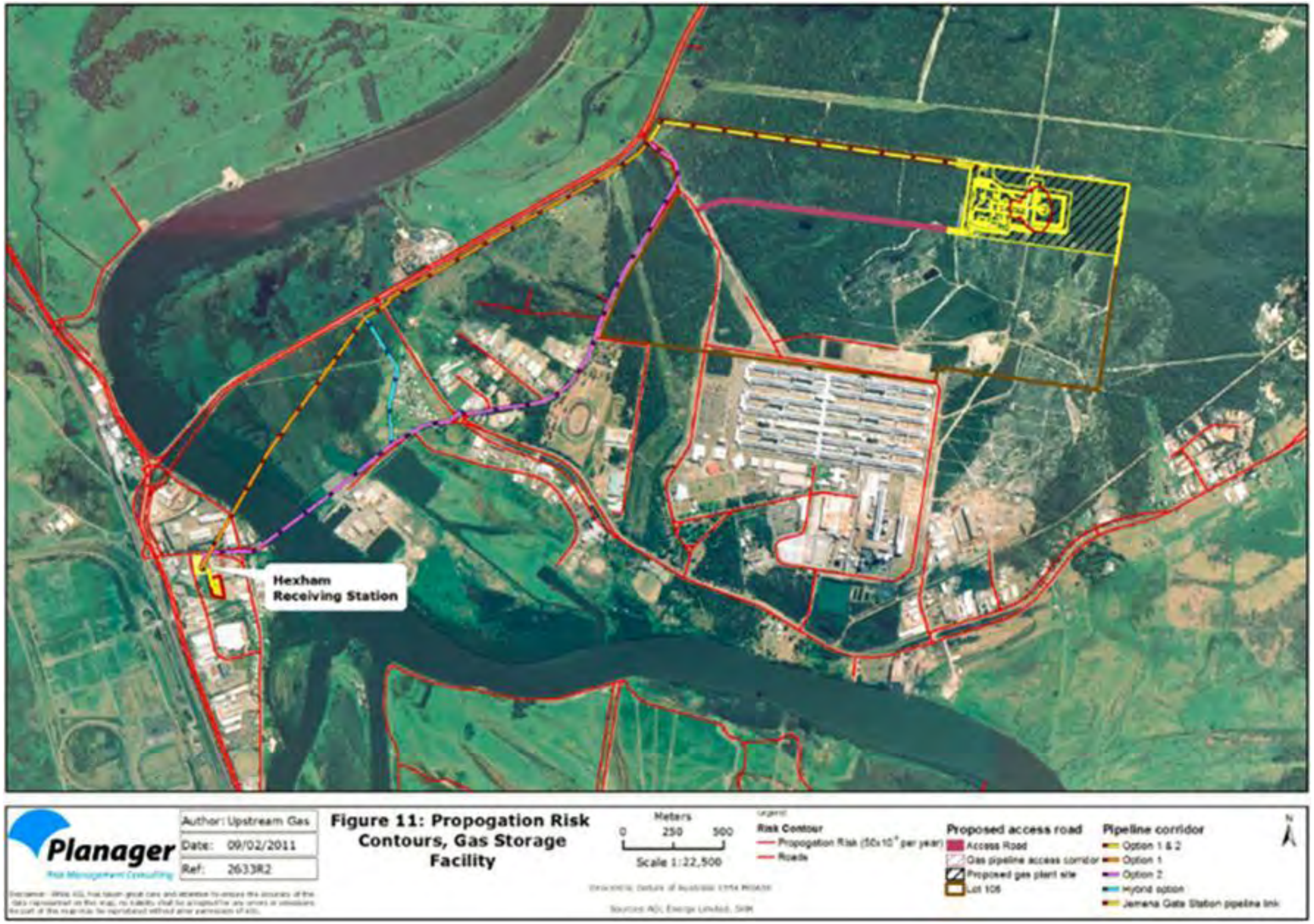


Figure E5 - Individual Risk Transect, NGSF Pipeline

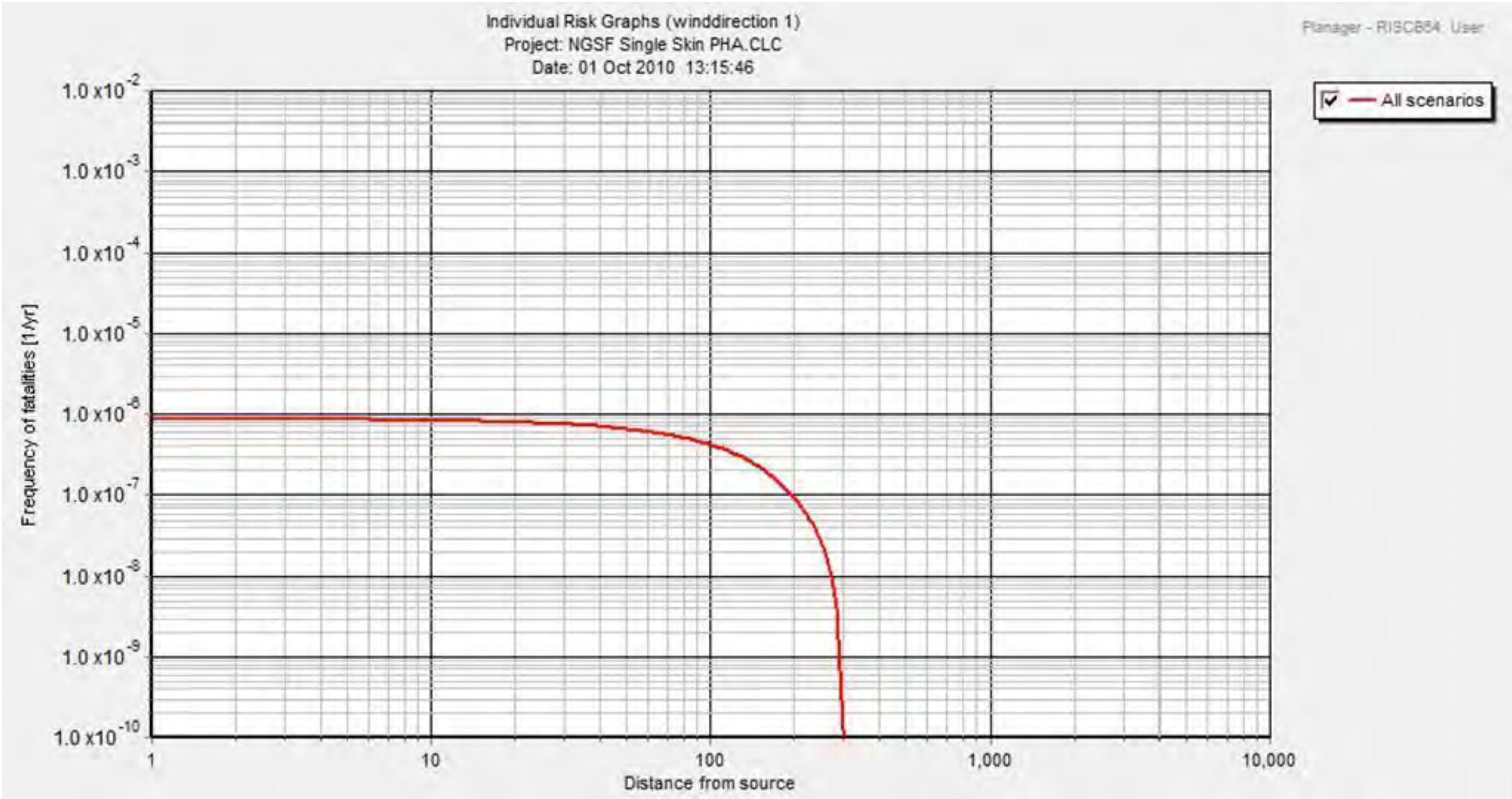
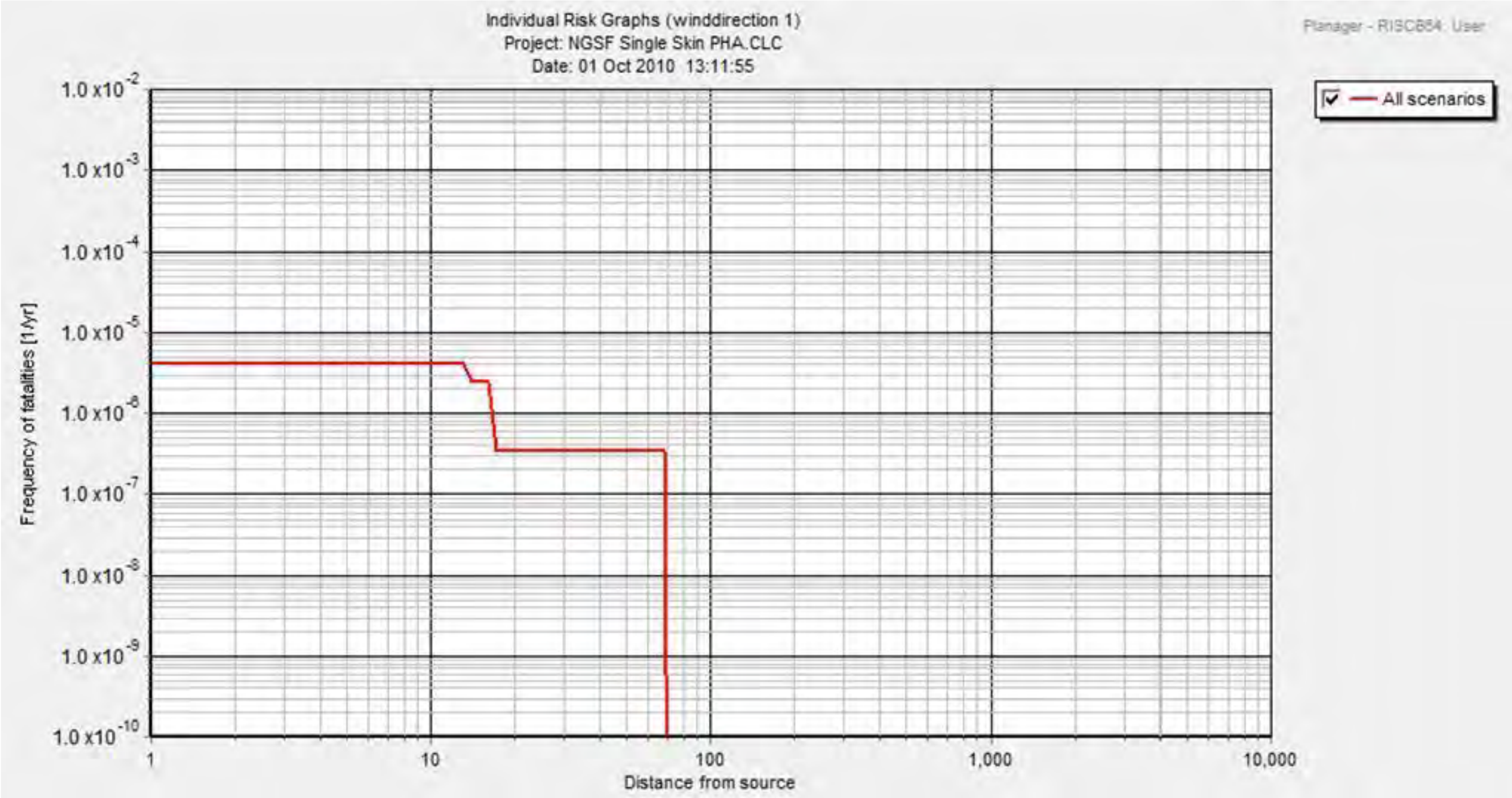


Figure E6 – Individual Fatality Risk Transect, NGSF Receiving Station



E8 Acceptability of Other Risks and Hazards

E8.1 Risk to the Biophysical Environment

Risk to the biophysical environment from accidental releases of hazardous material will be minimised throughout the design, operation and maintenance process of plant and equipment. Bushfire breaks around the facility will be required to prevent fires from the facility impacting bush and vice versa – the bush fire breaks will be minimised while ensuring sufficient protection to and from the surrounding bushland. Further, spills outside of bunded areas will drain to the site drainage systems.

E8.2 Natural Hazards

Seismic Hazard

The risk from seismic effects will be minimised through the use relevant Australian or International standards. To this regard, a seismic hazard review will be conducted for the site during the detailed design stage and for example the tank will be designed to meet the required earthquake characteristics of the site.

Land Subsidence

The risk of land subsidence is minimal and there are no known areas of mine subsidence in the area.

Lightning

The risk from lightning strike will be minimised through the use relevant Australian or International standards.

Bushfire

A bushfire risk assessment (Ref 29) determined a buffer zone between the bush and the NGSF to minimise the risk of a bushfire impacting on the site. This buffer zone will be maintained throughout the operation of the NGSF.

Further, while it is possible that a massive (barely conceivable) incident at the NGSF, such as a massive release from the LNG storage tank, could initiate a bushfire the incremental risk is minimal compared with the inherent risk of bushfires in this area.

Storm Surges and Flooding

The NGSF, located well above sea level and at 10 km from the coast, are protected against any risk from storm surges, waves and other causes of flooding.

Tsunamis

The likelihood of tsunamis is very low in this area. The effect of a tsunami on the NGSF is considered negligible.

Summary – Natural Hazards

The risk of impact from natural hazards, including seismic effects, bushfires and floods, has been shown to be minimised through use of relevant Australian or International standards.

E8.3 External Hazards

Aircraft Crash

The risk associated with an aircraft crash is minimal and has been calculated to be similar to the risk of a meteorite strike.

Incident at the NGSF Causes Knock-on Effect at Neighbouring Facility

Consequence calculations show that heat radiation or overpressure from credible scenarios at the NGSF are highly unlikely to cause major structural damage at any neighbouring facility, including the TAC, the NGSF pipeline and the receiving station.

Propagation risk calculations show that the current criteria for maximum acceptable risk at neighbouring industrial facilities is met at the boundary of the NGSF. On this basis there are no limitations from a land use risk criteria point of view to limit industrial development around the NGSF site.

The risk of propagation at LNG storage tank due to the NGSF Pipeline is below the criteria for maximum acceptable risk at neighbouring industrial facilities.

Incident at Neighbouring Industrial Facility Causes Knock-on Effect at the NGSF

The risk of an incident at TAC causing domino effects at the NGSF is negligible.

Cumulative Risk

The assessment shows no or minimal risk of propagation from the NGSF onto any future industrial use neighbouring the proposed facility. It also shows minimal impact to the risk contours of other facilities from the NGSF, assuming other facilities also meet the applicable risk criteria.

E8.4 Intentional Acts

A comparison on the risk of terrorist threats of the NGSF compared with other industrial facilities indicate that the Tomago site is lower in exposure compared to the other site LNG (and other industrial) locations. The (current) overall low threat environment in Australia is also a factor.

E8.5 Road Transport Risk

The overall risk associated with the transport of dangerous goods associated with the proposed development is low and the proposed LNG tankers do not introduce an excessive additional risk to the risk associated with dangerous goods traffic at the Pacific Highway at Hexham.

E9 Recommendations

Where possible, risk reduction measures have been identified throughout the course of the study in the form of recommendations, as follows:

Recommendation 1: The hazard and risk assessment to be reviewed once detailed design and HAZOPs have been completed for the proposed development to ensure that the assumptions made in this hazard and risk assessment remain valid though conservative.

Recommendation 2: An audit of AGL's Health, Safety and Environment Management System is conducted within 12 months after commissioning of the proposed NGSF. This audit should focus on the management of potential major hazards associated with the development. The DoP Hazard Audit Guidelines can be used as a basis for this audit.

Recommendation 3: AGL should develop an Emergency Response Plan and coordinate procedures with the adjacent industrial facilities and with local emergency planning groups; fire brigades; state and local Police; and appropriate governmental agencies. This plan should include, at a minimum:

- designated contacts with state and local emergency response agencies;
- scalable procedures for the prompt notification of appropriate local officials and emergency response agencies based on the level and severity of potential incidents;
- procedures for notifying adjacent industrial facilities, residents and recreational users within areas of potential hazard;
- evacuation routes/methods for residents, business users and other public use areas in the vicinity (including if the access road becomes unavailable);
- locations of permanent sirens and other warning devices;
- an —emergency coordinator” to be available on site at all times;
- plans for initial and continuing training of plant operators and local responders, along with provisions for periodic emergency response drills by terminal emergency personnel; first responders; emergency response agencies; and appropriate federal, state, and local officials.

Further, reference to the MHF requirements for emergency planning should be made.

The appropriate governmental agencies (including the NSW WorkCover MHF Team and the NSW Fire Brigades) should review and approve the Emergency Response Plan.

Recommendation 4: A security assessment should be carried out to ensure security arrangements are acceptable for the NGSF as per the requirements for Major Hazard Facilities.

Recommendation 5: Investigate placing the compressor in a shelter rather than fully enclosed (subject to noise criteria) to minimise risk of accumulation of flammable vapours.

Recommendation 6: The risk of cold metal brittle fracture should be considered in the design of the proposed plant and be verified during the HAZOP and Safety Integrity Level (SIL) Studies. This initiating cause is not considered further in the present risk assessment and is effectively assumed to be negligible compared with other, more generic, failure events.

Recommendation 7: Review risk reduction from the use of insulating concrete inside the LNG impoundment trenches and sump.

Recommendation 8: Review risk reduction from additional mitigation of vapour generation in impoundment system.

Recommendation 9: During detailed design, determine need for automatic shutdown (trip) requirements.

Recommendation 10: Overfill protection system for tanker loading to be developed during detailed design.

Recommendation 11: Overpressure protection system for tanker loading to be developed during detailed design.

Recommendation 12: It is recommended that the detailed design of the flare system be HAZOPed, particularly for abnormal operations including flare operations.

Recommendation 13: Investigate lightning protection for the top of the tank.

Recommendation 14: Request restricted airspace.

Recommendation 15: Review need for aircraft warning light or other device on high point of facility.

Recommendation 16: Pipelines located in the same easement to be separated so as to protect the adjacent pipeline from radiative heating from a neighbouring pipeline.

E10.2 Recommendations for Safe Engineering Design

In general, risk can be managed by prevention or mitigation. Prevention seeks to avoid an incident or attack; mitigation reduces the effects of an incident or attack. Combinations of these types of strategies can improve both safety and security involving either accidental or intentional incidents.

Risk management should be based on developing or combining approaches that can be effectively and efficiently implemented to reduce hazards to acceptable levels in a cost-effective manner. These efforts include a number of design, construction, safety equipment, and operational efforts to reduce the potential for a flammable release.

One of the key safety drivers is the layout of the plant in order to minimise the risk of escalation of fires and explosions in order to protect people and assets. This is optimised most cost-effectively during the early, design stage of a project by implementing inherent safety principles.

It is recommended that the following inherent safety principles be adhered to during the detailed design of the proposed facilities:

- Maximise as far as reasonably practicable the separation of credible (though rare) leaks from possible ignition sources and isolate physically any fire to prevent its spread in order to minimise the risk to people and property;
- Minimise where possible inventory of LNG and of pressurised natural gas in process equipment and maximise the integrity of containment of flammable material;
- Minimise pumping rates and pressures used within the facility;
- Minimise vulnerability of equipment and processes through selection of equipment type and through careful design, including through reduced process complexity and maintenance requirements;

The designers should demonstrate how these safe design principles are dealt with for the proposed facilities.

E10 Conclusion

The construction, commissioning and operation of the proposed development will be subject to a rigorous governmental scrutiny and to the safety case process, safeguarding delivery and operation of the development in a manner that minimises the risk to workers, contractors and the community.

The safety, efficiency and stability of the proposed NGSF will be achieved through the use of high level safety systems, regular preventative maintenance programs, detection and protective measures. Security measures will include security patrols, protective enclosures, lighting and monitoring equipment.

The preliminary hazard and risk assessment of the proposed NGSF and it's associated NGSF Pipeline and receiving station has found that the levels of risks to public safety from the site are within generally accepted safety and risk guidelines.

From the point of view of adherence to land use risk criteria the proposed Tomago site would be acceptable for the proposed development. The potential for accidents is understood and the design of the facilities will emphasise minimisation of the probability of an incident happening and mitigating an incident if it did occur.

The present risk assessment has shown that the overall risk associated with the proposed development is low and does not introduce an excessive additional risk to the surrounding area.

GLOSSARY

ADG	Australian Dangerous Goods
AS	Australian Standard
BCA	Building Code of Australia
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOG	Boil Off Gas
CCTV	Closed Circuit Television
CP	Cathodic Protection
DCGV	Direct Current Voltage Gradient
DG	Dangerous Goods
DoP	Department of Planning
ERP	Emergency Response Procedure
ESD	Emergency Shut Down
HIPAP	Hazardous Industry Planning Advisory Paper
HAZOP	Hazard and Operability Study
HSE	Health and Safety Executive (UK)
HWC	Hunter Water Corporation
ILI	Inline Inspection
JSA	Job Safety Analysis
kPa	kilo Pascal (unit for pressure)
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
MAOP	Maximum Allowable Operating Pressure
MHF	Major Hazard Facility
MPa	Mega Pascal (unit for pressure)
MSDS	Material Safety Data Sheet
MW	Mega Watt (unit for energy output)
NDT	Non Destructive Testing
NFPA	National Fire Protection Association (US)
NG	Natural gas
NGSF	Newcastle Gas Storage Facility
NO_x	Nitrogen oxides

OH&S	Occupational Health and Safety
pa	Per Annum
PJ	Peta Joules
PM	Preventative Maintenance
QRA	Quantitative Risk Assessment
RPT	Rapid Phase Transitions
SCADA	Supervisory Control and Data Acquisition
SEPP	State Environment Planning Policy
SHEMS	Safety Health and Environment Management System
SIL	Safety Integrity Level
SOP	Standard Operating Procedure
TAC	Tomago Aluminium Corporation
UFL	Upper Flammable Limit
VCE	Vapour Cloud Explosion

REPORT

1 INTRODUCTION

1.1 BACKGROUND

To meet the peak gas market requirements over winter and to provide additional security of supply during supply disruption events, AGL Energy Limited (AGL) proposes to develop the Newcastle Gas Storage Facility (NGSF) at Tomago, New South Wales.

Due to the potentially hazardous nature of the natural gas used and stored, there is a requirement to review the hazards and risks associated with the proposed facility, as per the Director's Requirements by the NSW Department of Planning.

Risk has been evaluated in terms of individual fatality and injury risk (which is the risk to a person at a given location exposed to the hazard 24-hours of the day and 365 days in the year), societal fatality risk and incident propagation to nearby facilities.

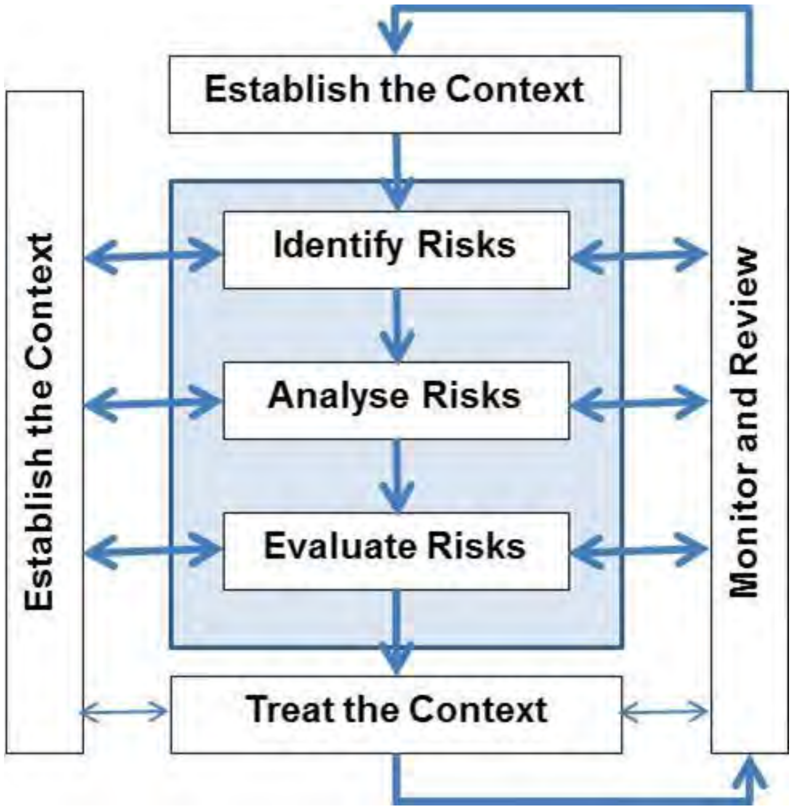
This hazard and risk assessment has been prepared in accordance with the requirements of the NSW Department of Planning Hazardous Industry Planning Advisory Paper (HIPAP) No. 4: *Risk criteria* (Ref 1) and No 6: *Guidelines for Hazard analysis* (Ref 2).

1.2 OVERVIEW OF THE METHODOLOGY

An overview of the methodology employed in the risk assessment is provided in this section. Further details are provided in Section 3.

This hazard and risk assessment forms part of the risk management framework for any new development. An outline of the risk management framework undertaken for AGL's proposed development is conceptually depicted in Figure 1 below.

Figure 1 – General Risk Management Framework



The methodology for the hazard and risk study presented in this document is well established in Australia and follows internationally recognised methodologies for risk assessment, and is outlined in the guidelines for risk assessments, as presented in the NSW Department's HIPAP No. 4: *Risk criteria*, HIPAP 6: *Guidelines for Hazard Analysis* and in the Australian Standard for *Risk Management* AS4360 (Ref 3). The risks associated with an event are commonly defined as a function of the following four elements:

- The likelihood of the event — such as a natural gas loss of containment;
- The consequences associated with the event — such as thermal radiation from a fire due to a natural gas release;
- The effects of the event — such as the thermal damage or level of injury from a fire, and;
- The effectiveness of systems for preventing the event or mitigating hazards and consequences — such as safety and security systems.

Details of the models used and input data and assumptions are provided in Sections 5 (Consequence Assessment) and Section 6 (Likelihood Evaluation) and in Table 4 below.

1.3 Scope and Purpose of the Development

The proposed development will comprise of the following components:

- Gas Storage Facility site;

- Bi-directional interconnecting pipeline between the Jemena Trunk receiving Station at Hexham and the NGSF (referred to as the *NGSF pipeline* in this report);
- Receiving / receiving station;
- Access road and utility corridor;
- Gas pipeline access corridor.

The three first components form part of the scope of the present PHA. The last two do not present hazards as defined in NSW Department of Planning Guidelines (Ref 2) and are discussed in the Environment Assessment (Ref 4).

The purpose of the NGSF, the NGSF pipeline and associated receiving station is to transport natural gas from the Wilton to Newcastle pipeline (*the Jemena* pipeline) to the NGSF site and to liquefy the gas by cooling it down, thus forming *Liquefied Natural Gas* (LNG), in a form that can be stored in a large storage tank[2].

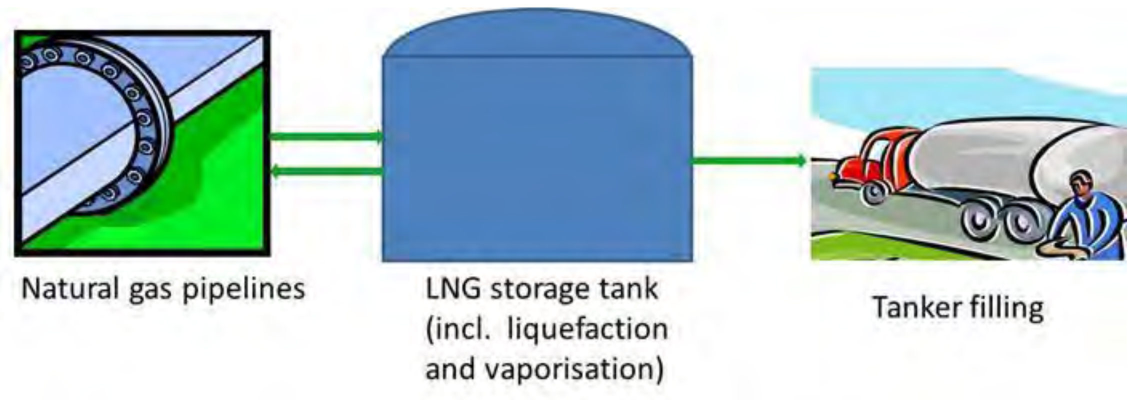
When required, the LNG can then be re-vaporised and delivered back into the Jemena pipeline as natural gas to the Newcastle and Sydney gas network for use during peak demand, typically during winter months, or during supply interruptions.

The capability to transfer the liquefied gas into road tankers is proposed as an option. This would service the emerging alternative fuel market where LNG is used as a substitute for diesel in heavy duty vehicles or for remote power generation.

The ultimate aim of this project is to secure supply during peak demands and to increase reliability of supply of natural gas to customers by increasing the flexibility of the supply source.

The general concept of the proposed development is presented in Figure 2 below and, in more details in Table 1, also below.

Figure 2 - Overview of the Development



[2] By cooling natural gas and transforming it into LNG the volume is reduced by 600 times its initial volume.

Table 1 - Major Project Parameters

Area	Proposed Development
Gas Storage Facility	Location: approximately 13 km northwest of the Newcastle central business district (CBD), 8 km south of Raymond Terrace and 4 km northeast of the Hexham industrial area. • The Project's footprint: 49 hectares (Ha) • Total NGSF site area: 30 Ha • Access road and utility corridor: The access road will join Airstrip Road, a Tomago Aluminium Company private road, between 200 and 300 m south of the intersection of Airstrip Road and Old Punt Road. Utilities (electricity, water, sewer and low pressure gas pipeline).
Supply of natural gas	Using a new underground pipeline, 6 km long within an easement, connecting the existing Jemena pipeline to the NGSF via a new receiving/receiving station. The maximum design pressure of the NGSF pipeline will meet Jemena's MAOP of 6.9 MPa(g).
LNG storage tank	Liquefied natural gas kept at -162°C at atmospheric pressure. Low temperature is maintained by insulation and continuous removal of boil-off (not refrigeration). The LNG will be stored in one tank of gross volume 63,000 m^3 / 30,000 tonnes capacity net (or 1.5 PJ). The storage tank will be surrounded by a bund designed to NFPA 59A (Ref 5), AS3961-2005 (Ref 6) and EN1473 (Ref 7). The tank has no penetrations below the maximum liquid levels such that the only way LNG can leave the tank is to be pumped out or to have a failure of the tank integrity. Diameter up to 60m; height up to 56m. Properties of LNG, see Appendix 1.
Processing equipment	Process equipment include vaporizing and liquefaction equipment and well as gas treatment and flaring / venting.
Gas conditioning and refrigeration	Gas refrigeration circuit will use mixed refrigerants such as methane, propane, ethylene, butane, i-pentane and nitrogen. Gas conditioning will use amines.
Risk mitigation	There will be an extensive hazard detection system and continuous monitoring from the control room. There will be an emergency shutdown system which will secure the facility in case a hazardous event occurs.
Use of LNG	• Improve gas supply security to NSW by providing an alternative gas source independent of gas field production facilities in South Australia, Victoria and Queensland. • This is of particular benefit to industrial and commercial gas users in the greater Hunter and Newcastle area who are furthest from these gas fields. • Allow the efficient use of the NSW coal seam gas resources that have recently been or will be developed. Unlike, conventional gas reserves where the rate of gas recovery can quickly be adjusted to meet peak demands, coal seam gas is most efficiently recovered if the flow of gas from the well is steady. The Project will store coal seam gas recovered over summer to feed back into the gas network over winter. • Provide a reserve of gas to ensure continuity of supply to customers (primarily commercial and industrial) during periods of maximum hourly and daily demand, which are generally expected to occur on cold winter days or when gas-fired electricity demand peak. • Provide security of supply to peak gas-fired power stations. This will enhance the ability of these power stations to provide back-up power to electricity generated by renewable energy sources (e.g., wind or solar). • Supply the emerging market for LNG as an alternative to diesel for heavy duty trucks or for remote power generation. This LNG will be distributed by road tanker.

This PHA has been conducted based on a mid-design hazard study review (summarised in the Hazard Identification Word Diagram in Table 8 below) and on current knowledge of hazards and risks associated with similar developments elsewhere. In situations where the lack of detailed design knowledge could impact on the hazard and risk assessment, assumptions have been made. These assumptions are intentionally conservative and have been stated in the report.

Recommendation 1: The hazard and risk assessment to be reviewed once detailed design and HAZOPs have been completed for the proposed development to ensure that the assumptions made in this hazard and risk assessment remain valid though conservative.

1.4 PROJECT TIMING AND PHASING

The complete NGSF will be constructed once the required legislative requirements have been met. It is expected that construction will begin in 2011 and the facility will be operational by 2014.

1.5 LEGISLATIVE CONTEXT

The proposed development may pose a risk to the surrounding area and as such requires a hazard and risk assessment to be conducted, as per the requirements of the NSW Department of Planning (DoP) in State Environmental Planning Policy 33 (SEPP 33) (Ref 8).

In this policy, the DoP sets the integrated assessment process for safety assurance of development proposals that are potentially hazardous. The integrated hazards-related assessment process includes the (present) preliminary hazard analysis which is undertaken to support the project application by demonstrating that risk levels do not preclude approval.

Other safety related studies, reviews and programs which will be undertaken at a later stage include:

- A hazard and operability study (HAZOP), fire safety study, emergency plan and an updated hazard analysis undertaken during the design phase of the project.
- A construction safety study carried out to ensure facility safety during construction and commissioning, particularly when there is interaction with existing operations.
- Implementation of a safety management system to give safety assurance during ongoing operation.
- Regular independent hazard audits to verify the integrity of the safety systems and that the facility is being operated in accordance with its hazards-related conditions of consent.

Further, the present report provides inputs to allow AGL to comply with the requirements for the NGSF as a Major Hazard Facility (MHF), as set out in the following National Occupational Health and Safety Commission documents, and as translated in the NSW regulations:

- *Control Of Major Hazard Facilities - National Standard* (Ref 9);
- *National Code of Practice* for the control of MHFs (Ref 10).

The Australian Standard AS 4360 - *Standard for Risk Management* (Ref 3) apply for the general methodology of this hazard and risk assessment.

A list of industry codes and standards applicable for the development is presented in Appendix 2.

1.6 AIM AND SCOPE OF THIS PRELIMINARY HAZARD ANALYSIS

Operation of the NGSF poses potential hazards that could affect the surrounding areas unless strict design and operational measures are implemented to control potential undesirable incidents. The present study evaluates the risk associated with the proposed NGSF and associated pipeline and compares this risk with relevant risk criteria for land use planning.

As per the requirements by the DoP, the primary concerns in the present risk assessment are those events at the proposed new development that could lead to an *off-site* hazard. Hence the aim is to evaluate the effects of the proposed project on risks to people and property off-site in the vicinity of the facility and to compare those risks to industry standards and *everyday* risks.

In particular, the risk study examines the risk effects, if any, the development would have on the nearest local community with nearby residences and industrial development (TAC and possible future development to the South and West of the NGSF), the Hunter Region Botanical Gardens and the gas-fired power station proposed approximately 2 km West of the gas plant site.

Potential interactions between the NGSF and the Newcastle (Williamtown) Airport are assessed as are the risk aspects associated with dangerous goods transport to and from the site.

The report also looks at any specific consideration of on-going maintenance and safety management of the project, including potential for impacts on and from bushfires and floods.

The identification of any contaminated land affected by the proposal and the potential to contaminate land are not included in the Preliminary Contamination Assessment in Ref 11.

As per DoP guidelines (Ref 2), risk issues during construction and commissioning phases of the NGSF will be evaluated separately and are not reported in this study.

1.7 HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEMS

AGL operates in accordance with its Health, Safety and Environment Management System (HSEMS). The HSEMS provides a framework for AGL to ensure responsible management practices that minimise any adverse health, safety or environmental impacts arising from activities products or services and to continually improve their safety, health and environmental performance.

AGL have numerous policies and procedures to achieve a safe workplace. An active OH&S Committee will be established at the site. Written safety procedures will be established and will be updated for the development. An incident reporting and response mechanism will be established, providing 24 hour coverage.

All personnel required to work with these substances will be trained in their safe use and handling, and are provided with all the relevant safety equipment.

An emergency response plan will be established. All staff will be trained in the emergency procedures and the plan will be incorporated in the plant's quality system. The emergency response plan will include responses to emergency evacuation, injury, major asset damage or failure, spillages, major fire, and threats.

The site will have a manager with overall responsibility and who is supported by experienced personnel trained in the operation and support of the plant.

A permit to work system (including Hot Work Permit) and control of Modification systems will be in use on site to control work on plant and to control plant and structure from substandard and potentially hazardous modifications.

All protective systems will be tested to ensure they function reliably when required to do so. This will include scheduled testing of trips, alarms, gas and fire detectors, relief devices and fire protection systems.

All persons on the premises will be provided with appropriate personal protective equipment suitable for use with the specific corrosive substances.

First aid stations will be located at various points comprising an appropriate first aid kit and first aid instructions, i.e. MSDSs, for all substances kept or handled on the premises.

Specific health, safety and environment management strategies for this development will be delivered through the following measures:

- Project approval conditions;
- Health and Safety and Environmental, Commissioning, Construction and Operations Management Plans developed for the Project; and
- Contractual obligations imposed by AGL on the suppliers of the various elements of the Project.

Recommendation 2: An audit of AGL's Health, Safety and Environment Management System is conducted within 12 months after commissioning of the proposed NGSF. This audit should focus on the management of potential major hazards associated with the development. The DoP Hazard Audit Guidelines (Ref 12) can be used as a basis for this audit.

1.8 LESSONS LEARNT FROM SIMILAR DEVELOPMENT

According to the US Congress Report for LNG Infrastructure Security (Ref 13) land based LNG facilities have had a favourable safety record in recent decades. In 2003 there were more than 150 peak-shaving plants worldwide. Since the 1944 Cleveland fire, which was due to poor materials of construction during World War II, there have been a small number of serious accidents at these facilities directly related to LNG. Two of these accidents caused fatalities of facility workers–one death at Arzew, Algeria in 1977, and another death at Cove Point, Maryland, in 1979. Another three incidents which caused fatalities, were due to construction or maintenance accidents in which LNG was not present.

The US has the largest number of LNG facilities in the world. An analysis by the US Centre for Energy Economics (Ref 14) indicates a very good safety record for the LNG industry due to several factors, including:

- The physical and chemical properties of LNG are such that risks and hazards are easily defined and incorporated into technology and operations; and
- A broad set of standards, codes and regulations applies to the LNG industry, notably the (US) National Fire Protection Association (NFPA) Code 59A (Ref 5), the Australia Standard AS3961 (Ref 6) and the European EN 1473:2007 (Ref 7).

The US Centre for Energy Economics (Ref 14) makes the following observations regarding different types of operations (only those relevant for the NGSF are listed below):

<u>For LNG Storage:</u>

- No off-site public injury or property damage in over 30 years of world-wide LNG storage operations and for LNG terminals world-wide.

<u>For LNG Trucking</u>

- LNG trucks have more robust construction than typical fuel trucks.
- Billions of gallons of LNG have been transported, stored and used in the past 30 years, worldwide, without any serious public exposure.

1.9 REPORT ORGANISATION

The remaining chapters of this report provide the following information:

- Chapter 2 - Description and discussion of the proposed development, the site, as well as the surrounding environment;
- Chapter 3 - Details of the methods employed in performing the risk study;
- Chapter 4 - Details of the qualitative hazard identification carried out for the development and the controls put in place to manage the hazards and risks;
- Chapter 5 - Details of the consequence analysis carried out for hazards which have a potential to reach outside the site boundaries;
- Chapter 6 - Details of the likelihood evaluation;
- Chapter 7 - Presentation of the results of the risk assessment, including discussion of relevant risk criteria for evaluating and providing context for studies of this nature;

- Chapter 8 - Discussion and conclusion as to the results from the study and especially what they mean relative to relevant risk criteria and other benchmarks. Listing of recommendations to further improve risk management at the facility.

2 DESCRIPTION OF SITE AND SURROUNDING ENVIRONMENT

2.1 LOCATION

The NGSF site, the major component of the Project, is located approximately 13 km northwest of the Newcastle central business district (CBD), 8 km south of Raymond Terrace and 4 km northeast of the Hexham industrial area (Figure 3 and Figure 4). Auxiliary infrastructure includes the receiving station in Hexham and a natural gas pipeline to connect the gas plant site to the receiving station.

2.1.1 Gas Storage Facility

The proposed NGSF will be located in the northeast corner of Lot 105 DP 1125747 in the Port Stephens Local Government Area (LGA). This site is north of the TAC smelter on land currently owned by TAC. This lot is also known as 5 Old Punt Road, Tomago. The site is approximately 13 km northwest of the Newcastle central business district, 8 km south of Raymond Terrace and 4 km east of the Hexham industrial area.

The Project includes the subdivision of the NGSF site from Lot 105.

The access road will join Airstrip Road, a Tomago Aluminium Company private road, between 200 and 300 m south of the intersection of Airstrip Road and Old Punt Road.

The gas plant site, access road and utility corridor are zoned 4a (Industrial-General) within Port Stephens LGA. These areas are generally covered with native vegetation, including re-growth.

The gas plant site component of the Project is located within an industrial area (zoned 4a) with lands to the north of the zone zoned for environmental protection (water catchment). The Tomago industrial area is located to the south.

Immediately to the west and south of the NGSF site is vegetated land owned by TAC and to the north and east land owned by Hunter Water Corporation (HWC). The Hunter Region Botanical Gardens are approximately 500 m northwest of the gas plant site. A gas-fired power station is proposed approximately 2 km west of the gas plant site.

The surrounding land use is mixed further afield. The Project is located a considerable distance from broader residential areas. While there are scattered residences (including a caravan park) in the area of Tomago, according to the Socio-economic study (Ref 15) the nearest residential areas are Hexham (whose population centre is approximately 4 km south of the gas plant site) and Heatherbrae (whose population centre is approximately 3 km north of the gas plant site).

The socio-economic study determined that the closest resident to the NGSF is approximately 1.3 km away. A single residence is also located at 1902 Pacific Highway, Tomago, 2 km west of the NGSF site. A caravan park, Tomago Village Van Park, exists approximately 2.8 km southwest of the NGSF site and approximately 400 m southeast of the intersection of the Pacific Highway and

Tomago Road. The caravan park provides short-term accommodation, including cabins, vans and tented sites. A single residence neighbours the southern boundary of the caravan park. Two residences on larger properties are also located on opposite sides of the Pacific Highway, between 2.0 and 2.5 km west of the NGSF site.

Large areas of land to the south, west and east of Tomago are covered with native vegetation or have been cleared for open pastures.

Hexham has a population of 152 persons (ABS, 2007). The area has mixed industrial and residential land uses, with most residential development being located on Old Maitland Road. The closest residence to the receiving station is located approximately 150 m west on the corner of Old Punt Road and Old Maitland. More residences are located approximately 300 m southeast of the receiving station site (Ref 15).

The Hunter River flows in a southwest direction approximately 3 km west of the site. A bend in the river then directs the flow towards the southeast into the Ramser Wetlands at Hunter Estuary, approximately 2.5 km south and east of the gas plant site.

Williamtown Royal Australian Air Force (RAAF) Base and adjoining Newcastle Airport are approximately 10 km from the site to the northeast. The Pacific Highway, is located approximately 2 km to the west side of the gas plant site.

Hexham is located south of the Hunter River. The Hexham receiving station will be located within an existing industrial precinct between the Pacific Highway and the Hunter River.

Gas for the Project will be supplied from the Jemena pipeline via a 6 km long pipeline connecting the trunkline to the NGSF.

The Jemena gas pipeline currently terminates at Hexham.

The proposed location of the NGSF was chosen based on a number of selection criteria, including the following:

- Buffered from residential or sensitive neighbours such as public gathering places (NGSF site is approximately 1.3 km from the nearest residences or any other sensitive place therefore maintaining a safe buffer distance from such uses).
- Size of the site (sufficient to ensure that the NGSF does not pose any unacceptable risks to neighbouring industrial development).
- Proximity to the (Jemena) Wilton-Newcastle trunk line of the NSW gas network.
- Compatibility with existing land uses. The Project will largely be located in existing or future industrial areas. The gas plant site is zoned 4a (Industrial-General) within Port Stephens LGA and the Hexham receiving station is zoned Industrial 4b (Port and Industry) within Newcastle LGA. The two gas pipeline corridor options currently being considered by AGL lie within land zoned 4a (Industrial-General) and 1a (Rural Agriculture) as well as crossing under the Hunter River (which is not zoned).

Other criteria include the proximity to future gas supplies and to gas users and available land, as discussed further in the Environmental Assessment.

2.1.2 NGSF Pipeline

The NGSF pipeline would be a bi-directional pipeline interconnecting the Jemena Trunk Receiving Station at Hexham with the NGSF.

The alignment of the gas pipeline between the Hexham receiving station and the gas plant is yet to be determined. AGL is considering two potential gas pipeline corridor options:

<u>Option 1:</u>

- Northeast from the Hexham receiving station to the southern bank of the Hunter River.
- Horizontal directional drilling will be used to pass the pipeline under the Hunter River and the adjacent coastal wetlands.
- Northeast from the corner of Tomago Road and Old Punt Road, through the industrial area, to near to the northern end of Old Punt Road. The pipeline will run in a trench beneath or adjacent to Old Punt Road.
- Horizontal directional drilling may be used along Old Punt road to minimise the impact on the industrial area.

<u>Option 2:</u>

- Northeast from the Hexham receiving station to the southern bank of the Hunter River.
- Horizontal directional drilling will be used to pass the pipeline under the Hunter River and the adjacent coastal wetlands listed in State Environmental Planning Policy (SEPP) No. 14.
- Northeast from near the corner of Tomago Road and the Pacific Highway, along the south side of the Pacific Highway easement, to near to the northern end of Old Punt Road.

A gas pipeline access corridor on land owned by AGL will connect the gas plant to the gas pipeline options at the north end of Old Punt Road.

Table 2 below discusses the land development along the pipeline corridor. The Kilometre Post (KP) measurement, i.e. the distance along the pipeline measured from the junction at Hexham, is preliminary only and will be detailed once the pipeline route has been finalised, as per the requirements in AS2885. An aerial photo showing the pipeline alignment is given in Figure 4.

Table 2 – Location Analysis for the NGSF Pipeline

Kilometer post (approximate)	Development / Type Land	Main Features
Option 1 – Through Tomago Industrial Area and Along Old Punt Road		
0 – 0.41 km	Industrial	Adjacent to Hexham receiving station, through medium density industrial area. Crossing Old Maitland Road. To the southern border of the Hunter River.
0.41 – 0.70 km	Hunter River	Under boring the Hunter River and coastal wetlands
0.70 – 1.05 km	Industrial area	Along Old Punt Road.
1.05 – 1.48 km	Cleared area	Along Old Punt Road following the road easement.
1.48 – 2.67	Industrial area	Under boring crossing Tomago Road. Through Tomago medium density industrial area.
2.67 – 3.5 km	Vegetated area	Along eastern side of Old Punt Road.
3.5 – 5.7 km	Forested area	Through AGL easement on TAC land, within forested area.
Option 2 – Along Pacific Highway		
0 – 0.33 km	Industrial	Adjacent to Hexham receiving station, through medium density industrial area. Crossing Old Maitland Road. To the southern border of the Hunter River.
0.33 – 0.51 km	Hunter River	Under boring the Hunter River and coastal (Ramsar) wetlands, adjacent to Pacific Highway easement
0.51 – 1.46 km	Wetland and vegetated coastal area	Through easement below costal vegetation area. Some under boring under road crossings.
1.46 – 3.29 km	Easement following Pacific Highway	Under boring crossing Tomago Road. Along south side of Pacific Highway.

Kilometer post (approximate)	Development / Type Land	Main Features
3.29 – 4.87 km	Forested area	Through easement within forested area.

Depending on it's final location, the pipeline could potentially run close to Tomago Village caravan park and to some residents (e.g. at Old Punt Road).

There is a detention centre at Tomago Road which would be considered sensitive location as per NSW DoP's risk criteria (Ref 1).

There are no other sensitive areas such as schools, hospitals etc. near the pipeline.

In each case, the appropriate buffer zones between the pipeline and other land uses (as established in Section in Section 8.2) will need to be established.

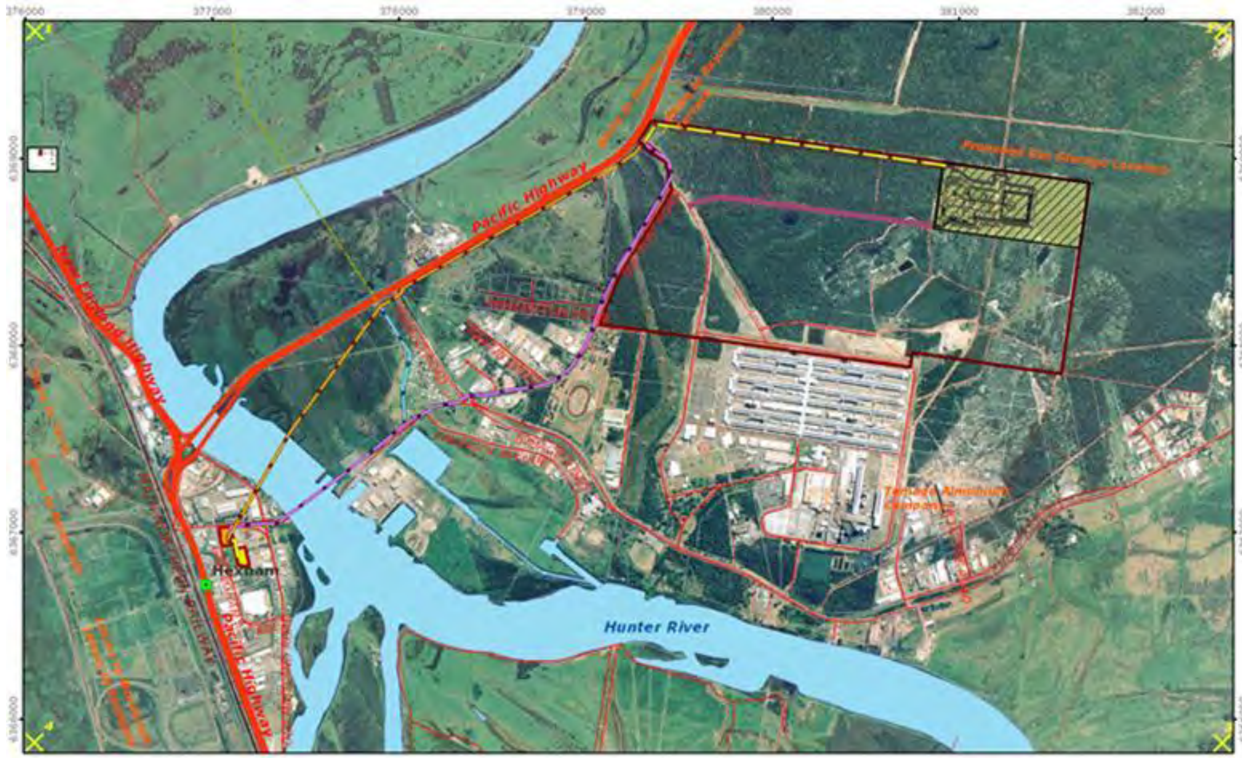
2.1.3 Receiving Station

The receiving station connects the NSW gas network to the NGSF via the existing Sydney to Newcastle pipeline. The receiving station will be within Hexham, an existing industrial precinct between the Pacific Highway and the Hunter River (Figure 3). It is proposed that the receiving station will be built on a site on Old Maitland Road adjacent to the existing Jemena Gate Station facility.

The nearest residence to the receiving station site is approximately 150 m east on the corner of Old Punt Road and Old Maitland Road. More residences are located approximately 300 m southeast of the receiving station site and are older detached dwellings of weatherboard construction.

Figure 3 – Site Location (Large Scale)

Figure 4 – Site Location and NGSF Pipeline Alignment (Options 1 and 2) – Small Scale



2.2 OPERATING HOURS

The NGSF will be operating continuously with on-site personnel during daytime operating hours with 24 hour process monitoring. Tanker filling may occur on a 24 hours per day, 365 days per year (an operator would be present at all times during tanker filling).

2.3 OPERATIONAL WORKFORCE

The operation workforce for the Project is expected to be approximately 15 people with additional contractors for some activities, including maintenance. The gas plant site, pipelines and Hexham receiving station will operate continuously.

2.4 FIRE PROTECTION

Fighting a fire involving natural gas and LNG involves first and foremost an isolation of the source (usually by closing valves on either side of the leak).

The main purpose of fire protection of an LNG spill fire is to cool adjacent structures and plant to prevent propagation of the event to other parts of the facility.

Fire protection at the NGSF will include fire water storage and distribution systems. One electric driven fire water pump and one standby diesel driven pump will be available to distribute the water to fire hydrants and monitors within the facility. Dry chemicals may also be required.

Fire risk and emergency management will be developed for the NGSF and will include:

- Remote isolation of fuel sources.
- Fire water system to cool adjacent structures to prevent escalation of an incident and domino effects, including fire monitors and hydrant system, deluge water systems and extinguishers. The mixed refrigerant tank will be fitted with automatically initiated deluge system. The need for any further automatic fire detection and protection system will be determined during detailed design.
- Water for fire protection will be stored in fire water tanks on site.
- Fire pumps will consist of two types, diesel and electrical. The required design and capacity will be evaluated in detailed design.
- There will be many fire extinguishers of varying sizes and types located throughout the NGSF to address small fires.
- Maintenance of fire protection equipment and detectors is to be in accordance with the relevant Australian Standards.
- Training requirements for people required to respond to a fire incident.
- An Emergency Response Plan will be prepared for the site, including collaboration with adjacent industrial facilities. Evacuation of both the workforce and, if required, of adjacent industrial facilities, will need to be

included in the emergency response procedure. Any need to communicate with other parties, e.g. the residential areas and communities in the vicinity of the site will be determined.

Recommendation 3: AGL should develop an Emergency Response Plan and coordinate procedures with the adjacent industrial facilities and with local emergency planning groups; fire brigades; state and local Police; and appropriate governmental agencies. This plan should include, at a minimum:

- designated contacts with state and local emergency response agencies;
- scalable procedures for the prompt notification of appropriate local officials and emergency response agencies based on the level and severity of potential incidents;
- procedures for notifying adjacent industries, residents and recreational users within areas of potential hazard;
- evacuation routes/methods for residents, business users and other public use areas in the vicinity (including if the access road becomes unavailable);
- locations of permanent sirens and other warning devices;
- an —emergency coordinator" to be available on site at all times;
- plans for initial and continuing training of plant operators and local responders, along with provisions for periodic emergency response drills by terminal emergency personnel; first responders; emergency response agencies; and appropriate federal, state, and local officials.

Further, reference to the MHF requirements for emergency planning should be made.

The appropriate governmental agencies (including the NSW WorkCover MHF Team and the NSW Fire Brigades) should review and approve the Emergency Response Plan.

2.5 SECURITY

Security at the NGSF will be provided with the use of a perimeter fence and the likely use of a fibre optic intrusion detection system. Closed Circuit TV cameras will also be strategically located throughout the facility to monitor activities. The main gate will have a personnel communication link to the Control/Administration Building for management of traffic into and out of the facility. The gates will be powered sliders with activation from the Control/Admin building.

A remote gate with security features will be provided at entrance to the access road. This gate will have a personnel communication link to the Control/Admin building for management of traffic, as well as a CCTV camera. The gate will be a powered slider with activation from the Control/Admin building.

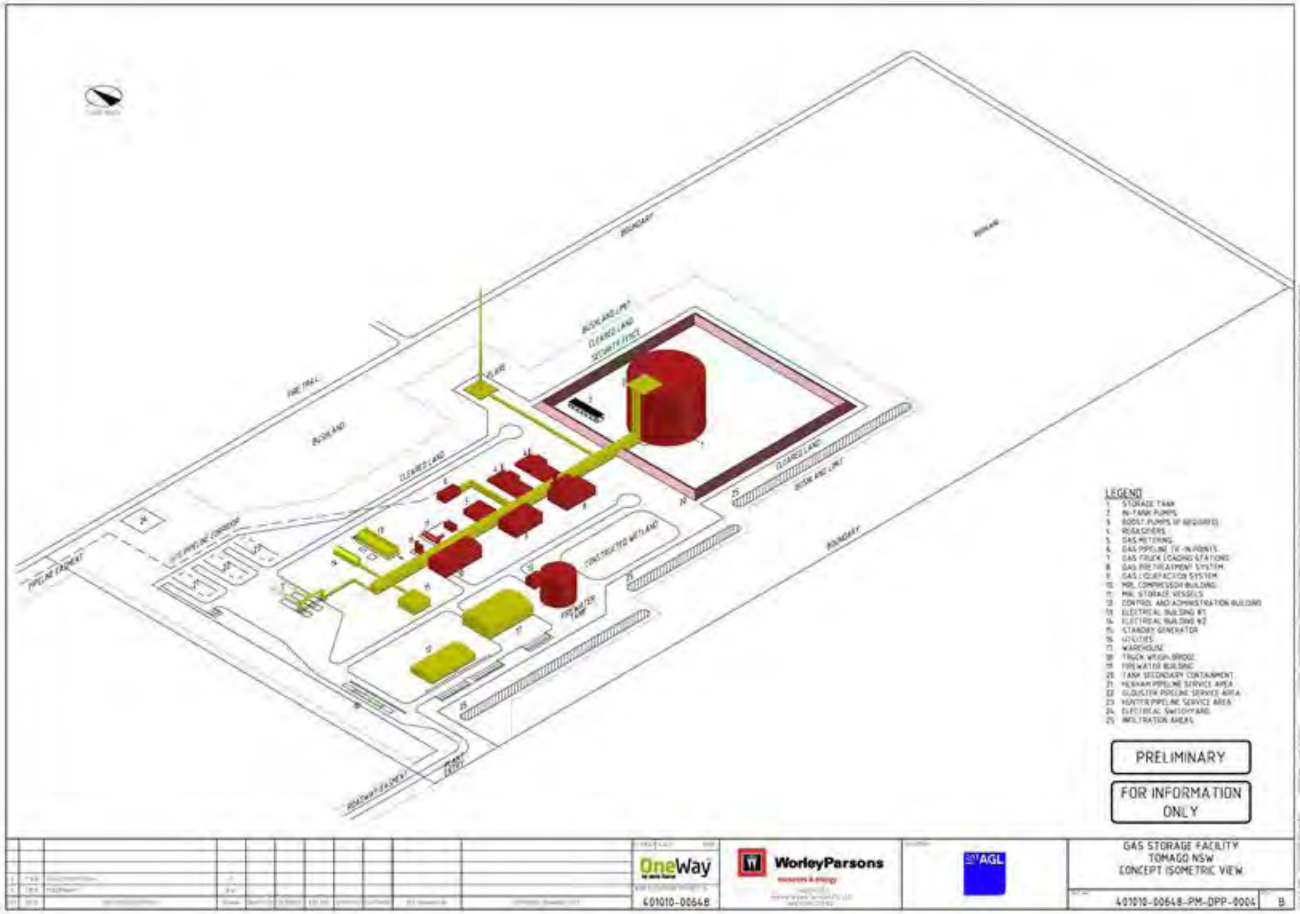
Primary and emergency party to party personnel communications within the facility will be by two-way radios.

The facility will have multiple connections points in the Control Building for telephone and high-speed internet communication systems.

The receipt station at Hexham station will be signposted and located inside fenced area. Any control building doors will be fitted with intruder alarms. There will be no 3rd party assets in fenced area of the receipt station which minimises activities near the station.

Recommendation 4: A security assessment should be carried out to ensure security arrangements are acceptable for the NGSF as per the requirements for Major Hazard Facilities.

Figure 5 – Preliminary Layout of the NGSF



2.6 MAIN CODES AND STANDARDS – NGSF AND INTERCONNECTING PIPELINE

The following table shows some of the main codes and standards which are applicable for the proposed NGSF designs. A more exhaustive listing is provided in Appendix 2.

Table 3 – Codes and Standards for Design of NGSF

Area of Concern	**Standard / Code**
NGSF plant layout	• AS/NZS3961 *Liquefied Natural Gas Storage and Handling* and, when not specified in AS3961 (Ref 5); • NFPA 59A *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)* (Ref 6); • *EN 1473 - The European Norm Standard - Installation and equipment for Liquefied Natural Gas* (Ref 7); • AS/NZ1596 for refrigerant storage (mixed refrigerant) (Ref 16).
Bunding arrangement and design	• AS1940 *The storage and handling of flammable and combustible liquids* (Ref 17); • NFPA 30 *Flammable and Combustible Liquids Code* (Ref 18).
Pipeline (interconnecting NGSF pipeline) design, operation and maintenance	• AS2885 Pipelines - gas and liquid petroleum (Ref 19).
Emergency response and fire safety	• Control Of Major Hazard Facilities - National Standard (Ref 9) • National Code of Practice (Ref 10); • Hazardous Industry Planning Advisory Papers No 1 and No 2: *Emergency Planning Guidelines* and *Fire Safety Study* (Refs 20 and 21); • Building Code of Australia for any buildings and protected works (Ref 22).
Dangerous goods storage and transport	*Australian Code for Transport of Dangerous Goods by Road and Rail* (ADG Code), 7th Ed (Ref 23).
Occupational health and safety	(NSW) Occupational Health and Safety Act 2000. (NSW) Occupational Health and Safety Regulations 2001.

2.7 INFRASTRUCTURE

2.7.1 Gas Storage Facility

The NGSF infrastructure will include foundations, a number of buildings (including workshop, control room and amenities), gas and LNG pipelines and vessels, power distribution, area lighting, fire detection and protection system, security system, communication system, Closed Circuit TV (CCTV), LNG storage tank within a containment bund, tanker loading bay and a flare. The proposed NGSF would consist of the following equipment:

- LNG storage tank storing up to 63,000 m^3 LNG at atmospheric pressure and at -162^{o}C;
- Gas treatment including carbon dioxide removal (using an amine wash unit), dehydration plant;

- Refrigeration unit and liquefaction plant using a mixed refrigerant stream to produce approximately up to approximately 66,500 t/year of stored LNG (approximately 180 tonnes per day in average);
- LNG vaporisation unit;
- Tanker loading station, manually operated;
- Venting or flare facilities to which safety relief valves on piping and process equipment are directed; and
- Utilities including compressed air system, cooling system, nitrogen generation unit, demineralised water unit, hot oil unit, waste water treatment, safety and fire protection system, electrical distribution system and control system.

A block flow diagram presenting the operation of the NGSF is presented in Figure 6 below.

2.7.2 Storage Inventory

The PHA assumes that the NGSF is operating fully pressurised 100% of the time and that the LNG storage tank is at full capacity for 100% of the time. This is a conservative assumption as it is expected that the storage tank will be at full capacity 50% of the time and less than half-full at an expected 50% of the time (see Section 2.7.1 below).

The expected fill levels of the LNG tank are as follows:

- Full (63,000 m^3): 50% of the time
- Half full to quarter full: 25% of the time
- Quarter full to empty: 25% of the time.

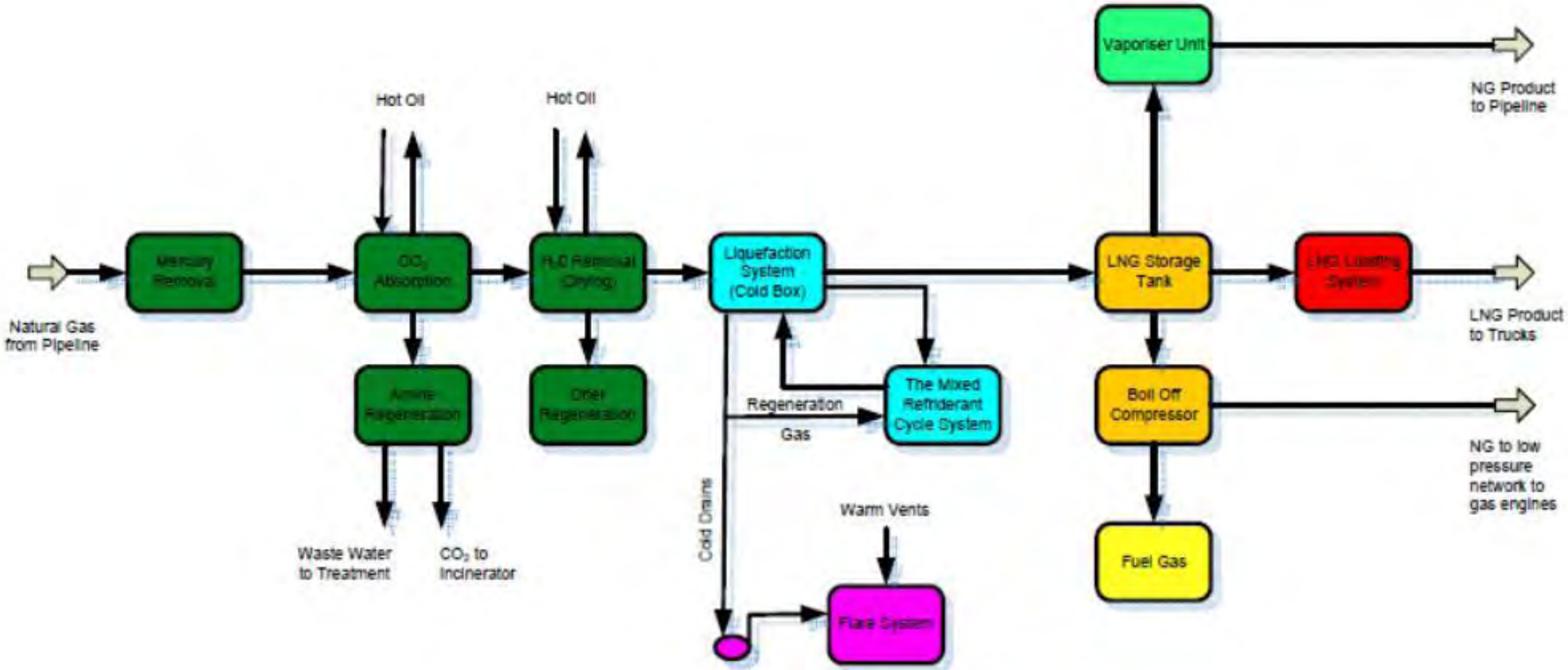
2.7.3 Interconnecting NGSF Pipeline

The pipeline interconnecting the Jemena pipeline with the NGSF will consist of a 400 mm diameter steel pipeline designed to the same maximum allowable operating pressure as the Sydney to Newcastle pipeline, refer Table 1 above.

2.7.4 Receiving Station

Where possible, the equipment at Hexham receiving station will be minimised but will most likely include filters, meters, flow control valves, and water bath heaters. There will also be a pig launcher/receiving trap at the Hexham receiving station and another at the other end of the pipeline at entrance to the NGSF site. The traps will be designed to enable the use of an in-line non destructive testing (NDT) tool (intelligent pig) which is a metal device that is sent through the pipeline at regular intervals to detect any material loss or minor damage to the pipeline which could otherwise, in the long term, affect the integrity of the pipeline.

Figure 6 – Block Flow Diagram of the NGSF Process



PLANAGER
Risk Management Consulting

2.8 MAJOR ENGINEERING ASSUMPTIONS MADE IN THE RISK ASSESSMENT

The engineering assumptions with respect to lengths, diameters and pressures of the various flammable gas and liquid pipelines which form part of the development, as well as those that are already existing on site, are listed in Table 4 below.

Table 4 – Summary of Assumptions Used in the QRA

Feature	**Assumption(s)**
General – Overall NGSF	
Percent operational	All data used in the present risk assessment are for a plant operating 100% of the time and with all vessels and tanks full 100% of the time. The quantitative risk results are valid, though conservative, for the plant under the expected operating conditions.
Gas Pipelines Inside NGSF	
Lengths	Pipeline would enter the site at the north western corner of the site and runs above ground up to the receiving station and pressure reduction valve at the NGSF.
Diameter up to pressure reduction valve	Assumed to be about 400 mm.
Diameter downstream of pressure reduction valve	Assumed to be about 300 mm reduced down to 250 mm up to the plant inlet isolation valve, then 150 mm up to the liquefaction unit.
Pressures	NGSF pipeline: 6,200 kPa operating pressure (MAOP = 6,895 kPag) up to the tie-in point and the pressure regulator. 4,000 kPa downstream of the pressure regulator up to the liquefaction unit and forward to the NGSF tank. Inside the NGSF storage tank: atmospheric pressure. Outlet of the NGSF tank through the vaporisation unit and up to the boil off gas compressors: 100 kPa.
Temperature	Natural gas: 10^{o}C. Liquefied LNG: -162^{o}C. Atmospheric: Extremes between about 0^{o}C to 40^{o}C with normal temperatures ranging between 15^{o}C and 25^{o}C. Cold weather provides the worst case dispersion results – this risk assessment uses 15^{o}C for the area.
Number of tankers to be loaded each year	1000 tankers, 18 tonnes each. The truck filling will have 2 hoses, one to fill LNG and one for gas from the tanker. At the NGSF, this gas will go into the boil-off gas stream.

3 METHODOLOGY

The methodology for hazard and risk assessment is well established in Australia. The assessment has been carried out as per the NSW Department of Planning's HIPAP No 4 - *Risk Criteria for Land Use Planning* (Ref 1) and No 6 - *Guidelines for Hazard Analysis* Ref 2. These documents describe the methodology and the criteria to be used in hazard and risk assessment for major *potentially hazardous* development.

The level of quantification of such a risk assessment depends on the inherent risk associated with the materials used and produced at the proposed facility. The NGSF will handle and store large quantities of natural gas and LNG as well as some mixed refrigerants. Due to the quantities and the flammable nature of the materials stored, the hazard and risk analysis required to accompany the development application contains a thorough *quantitative risk analysis* (or QRA) component.

There are five stages in risk assessment:

Stage 1. Hazard Identification: The hazard identification includes a review of potential hazards associated with all dangerous and hazardous goods processed, used and handled at the site. The hazard identification includes a comprehensive identification of possible causes of potential incidents and their consequences to public safety and the environment, as well as an outline of the proposed operational and organisational safety controls required to mitigate the likelihood of the hazardous events from occurring.

The tasks involved in the hazard identification includes a review of all relevant data and information to highlight specific areas of potential concern and points of discussion, including drafting up of hazard identification (HAZID) word diagram. The review takes into account both random and systematic errors, and gives emphasis not only to technical requirements, but also to the management of the safety activities and the competence of people involved in them. The final HAZID word diagram is presented in Table 8 below.

Stage 2. Consequence and Effect Analysis: The consequences of identified hazards are assessed using current techniques for risk assessment. Well established and recognised correlations between exposure and effect on people are used to calculate impacts. For this risk assessment, the software tools *Riskcurves* and *Effects* (both by Dutch owned TNO (the Netherlands Organisation for Applied Scientific Research) were used, incorporating internationally recognised consequence estimation methods described in TNO's *Yellow Book* (Ref 24).

Stage 3. Frequency Analysis: For incidents with significant effects, whether on people, property or the biophysical environment, the incident frequency is estimated from historical data. A probabilistic approach to the failure of vessels and pipes is used to develop frequency data on potentially hazardous incidents.

Stage 4. Quantitative Risk Analysis: The combination of the probability of an outcome, such as injury or death, combined with the frequency of an event gives the risk from the event. In order to assess the merit of the proposal, it is necessary to calculate the risk at a number of locations so that the overall impact can be assessed. The risk for each incident is calculated according to:

Risk = Consequence x Frequency

Total risk is obtained by adding together the results from the risk calculations for each incident, i.e. the total risk is the sum of the risk calculated for each scenario.

The results of the risk analysis are presented in three forms:

- Individual Fatality Risk, i.e. the likelihood (or frequency) of fatality to notional individuals at locations around the site, as a result of any of the postulated fire and explosion events. The units for individual risk are probability (of fatality) per million per year. Typically, the result of individual risk calculations is shown in the form of risk contours overlaid on a map of the development area. For pipelines (as for other transport activities), the individual risk contours are best represented as risk transects, showing the risk as a function of the distance from the pipeline.
- Injury and irritation risk, i.e. the likelihood of injury to individuals at locations around the site as a result of the same scenarios used to calculate individual fatality risk.
- Societal risk takes into account the number of people exposed to risk. Whereas individual risk is concerned with the risk of fatality to a (notional) person at a particular location, societal risk considers the likelihood of actual fatalities among any of the people exposed to the hazard. Societal risk are presented as so called *f-N curves*, showing the frequency of events (f) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the risk results with the population data, a societal risk curve can be produced

For this risk assessment the internationally recognised software tool *Riskcurves* (by TNO) was used.

The risk results are then assessed against the relevant risk criteria (Section 7 below).

Stage 5. Risk reduction: Where possible, risk reduction measures are identified throughout the course of the study in the form of recommendations.

4 HAZARD IDENTIFICATION

The hazard identification step includes a review of hazards associated with the materials used and handled and with the plants and equipment.

4.1 MATERIALS HAZARDS

4.1.1 Storage Inventory of Potentially Hazardous Materials

The inventories of dangerous goods in storage are presented in Table 5 below.

Table 5 - Hazardous Materials Storage Inventory

Chemical/Product	Plant Area / Use	Anticipated Storage Qty
LNG (liquefied natural gas) (flammable gas, Dangerous Goods (DG) Class 2.1)	Storage tank	30,000 tonnes (63,000 m^3).
Natural gas (flammable gas, DG Class 2.1)	Interconnecting pipeline and on-site pipelines to the liquefaction unit and from the vaporization unit back to the interconnecting pipeline	No storage on site of non-liquefied natural gas. Inventories in process piping and vessels.
Mixed refrigerant (flammable gas, DG Class 2.1)	Refrigeration gas for the liquefaction unit	<12 tonnes of propane or butane. <10 tonnes of ethylene. Other flammable gases in process units including methane, butane, i-pentane and nitrogen.
Odorising Agent (Mercaptan) Flammable liquid, DG Class 3)	Re-odorising at the vaporization area of the NGSF	Typically a couple of cubic meters – to be determined.

Possible mercury traces in the feed gas will be removed in the mercury adsorber, to protect the downstream equipment. The mercury adsorber bed is not regenerated and will periodically be replaced. The mercury absorber vessel will be removed from site by a specialist contractor. The absorber bed will be changed out and then the vessel will be returned to site.

There will also be some diesel stored for use in back-up diesel generator, some oil for heating, some lubricating oils for use in rotating equipment (pumps and compressors) and ethylene glycol mixture for the vaporisation unit. Further, some relatively small quantities of chemicals used for maintenance, cleaning and degreasing (for example acetylene, oxygen and argon) will be stored in a dangerous goods store. Provided standard precautionary methods, codes and standards are used for these relatively minor storages, the risk associated with the storage and handling of these materials is very low.

4.1.2 Properties of Potentially Hazardous Material

A. Natural Gas and LNG

Natural gas (and hence LNG) is composed mainly of methane gas (about 95%) with the remainder a combination of ethane, propane and other heavier gases including some nitrogen.

Natural gas is a buoyant, flammable gas which is held under pressure in pipelines and process plant pipes. It is lighter than air and, on release into the atmosphere, tends to rise rapidly and disperse to below hazardous concentrations unless it encounters an ignition source. Fire and/or vapour cloud explosion is only possible with a concurrent source of ignition.

LNG is a cold (at –162^{o}C) flammable liquid which would boil and rapidly vaporise at atmospheric temperatures. LNG is simply natural gas that has been cooled to its liquid state at atmospheric pressure. Liquefying natural gas vapours reduces the gas into a practical size for storage by reducing the volume that the gas occupies more than 600 times.

A loss of containment of LNG, on account of it being cold, would float at ground level until it heats up and mixes with air to a point where it converts to it's gaseous state and rises above the ground. In *Lessons learned from LNG safety research* (Ref 25), LNG vapour clouds were shown to be low and wide and to tend to follow the downhill slope of terrain due to dampened vertical turbulence and gravity flow within the cloud.

Ignition at the point of release is possible, in which case natural gas would burn as a jet (or torch) flame and the liquid (LNG) form would burn as a pool fire.

Explosion is a hazard unlikely to occur within the NGSF. LNG in liquid form itself will not explode within the storage tank, since it is stored as a cryogenic liquid (Ref 14) - without the pressure or confinement or obstruction of vapour clouds, there can be no explosion.

Recommendation 5: Investigate placing compressor in a shelter rather than fully enclosed (subject to noise criteria) to minimise risk of accumulation of flammable vapours.

An explosion from a release of LNG vapours is possible only if all the following conditions occur at the same time:

- Vapours are in the flammability range (i.e. the ratio of natural gas to oxygen is between approximately 5.5 and 14% flammable gas);
- Vapours are in a confined space and a source of ignition is present.

As the storage tank is constructed in the middle a very large bund, far away from confined or cramped plant areas, an explosion following a release of LNG from the storage tank is highly unlikely. On release of LNG (or natural gas) in plant areas where there is possibility of confinement, (e.g. in confined plant areas such as in the liquefaction area) a vapour cloud deflagration (explosion) may be possible but highly unlikely as the plant area is constructed in the open and confinement would only be provided by piping and vessels within the plant areas. Explosion is also made further unlikely due to methane gas (the main constituent of LNG and natural gas) being of low reactivity (compared with for example LPG and other heavier hydrocarbons).

Natural gas (and hence LNG) is non-toxic, posing only an asphyxiation hazard. Due to its buoyancy, any release of credible proportions from operations of this scale, in the open, would not present an asphyxiation hazard. With standard confined space entry procedures and appropriate security arrangements to prevent unauthorised access to any of the facilities, the risk associated with asphyxiation from natural gas should be minimal and off-site risks negligible.

From an environmental standpoint, there is very little smoke associated with an LNG and natural gas fire. If a loss of containment of natural gas or LNG was to occur, the material would quickly evaporate leaving no residue when it came into contact with soil or water. Hence, there would be no need for environmental clean-up of LNG or natural gas spills. If in contact with LNG, plant matter would be frozen – however, spilled LNG would be contained within the impoundment system and would not come into contact with plant material.

Locally, the pressure of compressed natural gas may be hazardous in case of an uncontrolled release. Pressure hazards, while import to people working at the site, do not have implications beyond the immediate location of the release. Therefore, the risk associated with non-ignited compressed gas does not form part of the scope of the present risk assessment. This potential risk would need to be closely managed through job safety analysis (JSA) and/or other risk assessment practices used by management and operators of the facility (in accordance with NSW Occupational Health and Safety Act and its associated legislation).

B. Mixed Refrigerant

The refrigerant used in the liquefaction part of the NGSF will be composed of a mixture of commercially available hydrocarbons such as methane, propane, ethylene, butane, i-pentane and nitrogen.

The mixed refrigerant cycle includes the vaporization and condensation of the refrigerant under pressure. A leak from this system has the potential to produce a flammable cloud.

In common with natural gas, the primary hazard of these mixed refrigerant gases is fire, either immediate upon vapour release or a delayed ignition of vapours which creates a potential hazard to the extent that the vapours are not dispersed below the lower flammable limit (LFL) concentration. Upon release, the mixed refrigerant vapours are heavier than air (negative buoyancy) because they are cold. As they warm to ambient temperature, there is a decrease in density and the vapours become lighter. While methane and ethylene are lighter than air (positive buoyancy), propane, butane and i-pentane are heavier than air and thus disperse as a —dense gas" even at ambient temperature. The density influences the vapour dispersion and must be considered.

A phenomenon referred to as a BLEVE (Boiling Liquid Expanding Vapour Explosion) may occur with mixed refrigerant gases stored under pressure, in which case a massive rupture of the storage vessel releases the superheated liquid which immediately vaporizes and causes an explosion.

Notwithstanding the different behaviour of the mixed refrigerant storage compared with that of natural gas, the risks are offset by much smaller inventories of mixed refrigerants as well as by the specific equipment design and appropriate fire protection provisions. These materials are handled in current everyday operations that will not change as a result of being part of an LNG facility. Because the mixed refrigerant volumes are lower, the risk associated with these refrigerants is much smaller compared with the overall NGSF risk.

C. Odorant

The odorant (mercaptan) is a flammable liquid. All the requirements for fire risk management of these relatively small quantities of odorant will comply per AS1940 (Ref 17), including:

- Bunding requirements, i.e. 100% of the largest tank, with bunding design and construction as per Section 5.9.3 in AS1940.
- Fire protection, including fire extinguishers, hose reel requirements, separation distances.
- Design of ventilation of enclosure with regards to flammable vapours.
- Valving and piping associated with the storage as per AS1940 Section 7.
- Control of ignition sources is as per AS1940 Section 9.7.6.

Provided the requirements from AS1940 are adhered to, the probability of a fire involving the odorant is negligible and will not be discussed further in this report.

In the event of spillage, unless contained, the odour could extend considerable distances at detectable odour levels, thus creating an unpleasant atmosphere persons in the vicinity. To manage this risk, AGL proposes to locate the odorant facility inside a building which is ventilated to a scrubber or an adsorber in order to remove any unpleasant odours in the event of a loss of containment inside the hut.

Excess dosing of odorant into the natural gas stream is expected to be a gas quality issue only and is likely to be identified by periodic gas checks. The potential for excess dosing will be considered during the design phase, including during the HAZOP study[3].

The possibility of under-dosing of odorant in the natural gas stream is another possibility. Such potential will again be considered during the design phase (including in the HAZOP study). Under-dosing will be prevented through monitoring of levels in the vessel(s). It is further noted that once the line has

[3] This is entirely consistent with the HAZOP study methodology, where the effect of a high and low (or no) flow of any process steam is considered.

been in use for some time, the odorant —contamination” of the piping is such that the gas would continue to be odourised for some time after cessation of dosing.

D. Summary of Main Materials Hazards

Physical properties of the hazardous materials used in the NGSF are listed in Appendix 1. A summary of the main hazards associated with LNG and natural gas is listed in Table 6 below.

Table 6 – Summary of Main Materials Hazards

Topic	Description
Appearance	Natural gas, LNG and mixed refrigerant vapours are colourless, odourless, and non-toxic. If released into the atmosphere, these vapours typically appear as a visible white cloud, because their cold temperature condenses water vapour present in the atmosphere. Natural gas in the interconnecting pipeline has been odorised. The odour is removed in the gas treatment to enable the gas to be liquefied. The odour is re-injected into the gas stream at the vaporisation stage before the natural gas is re-introduced into the interconnecting pipeline. The odorant is a colourless gas with a garlic-like or rotten cabbage-like smell.
Physical properties	Natural gas is lighter than air with a relative density of 0.6 compared with that of air at 25^{o}C. LNG and mixed refrigerant are roughly half the density of water and at its boiling point the vapour is 1.5 times the density of air. Odorant is lighter than water at about 0.8 the density of water. Further details in Appendix 1.
Flammable hazard	Natural gas is a flammable gas held under pressure at atmospheric temperature. LNG is a flammable liquid held refrigerated at close to its atmospheric boiling point. The mixed refrigerant is made up of largely flammable gases held liquefied under pressure. Both natural gas and LNG are composed mainly of methane. The lower and upper flammability limits of methane are 5.5% and 14% in air (by volume) at a temperature of 25°C. The mixed refrigerant is composed of a mixture of methane, propane, ethylene, butane, i-pentane and nitrogen. The lower and upper flammability limits of the mixed refrigerant are approximately 2% to 10% in air at 25°C. Odorant is a flammable liquid. The lower and upper flammability limits of the odorant are 5% and 15% in air (by volume) at a temperature of 25°C. Ignition of a vapour cloud could cause fires and overpressures that could injure people or cause damage to the tank's structure, or nearby structures.
On-site personnel hazard	Natural gas, LNG and mixed refrigerant vapours displace air and could cause asphyxiation if a person is trapped for example inside a process vessel which has not been purged adequately. Due to the buoyancy of natural gas, any release of credible proportions from operations of this scale, in the open, would not present an

Topic	Description
	asphyxiation hazard. Exposure to mixed refrigerant or LNG can cause cryogenic burns to the on-site personnel if they come into contact with the released material, in case of a loss of containment. The high pressure associated with the mixed refrigerants can cause pressure hazards, typically to on-site personnel during maintenance activities.
On-site materials hazards	Extremely cold fluids such as LNG can have a very damaging impact on the integrity of many steels and common plant structural connections, such as welds (Ref 26). This hazard will be taken into account in material selection throughout the facility and in protecting structural supports in high hazard areas. The site will be designed so that a spill would drain away from other plant items and structural supports so as to minimise the risk of further damage in the case of a release of LNG on the ground. **Recommendation 6:** The risk of cold metal brittle fracture should be considered in the design of the proposed plant and be verified during the HAZOP and Safety Integrity Level (SIL) Studies. This initiating cause is not considered further in the present risk assessment and is effectively assumed to be negligible compared with other, more generic, failure events.
Hazard dimensions	**Natural gas:** Ignition at the point of release is possible in which case the gas may burn as a jet (or torch) flame. On release in an enclosed area (for example if released inside a non-ventilated building) it may burn as a flash fire or explode. Design will prevent, as far as possible, the gas from accumulating inside any enclosed areas. **LNG and mixed refrigerant:** The shape and size of a pool and subsequent vapour cloud of LNG and mixed refrigerant is affected by environmental conditions such as wind, atmospheric stability, and ground conditions such as obstruction from structures and terrain. An increase in wind speed tends to increase the evaporation rate. On the other hand, the increase in wind speed and a lowering in the atmospheric stability would increase the dispersion rate of the vapours. Low wind speeds and stable atmospheric conditions (typical night time conditions) result in worst case scenarios with greater distances to the Lower Flammable Limit (LFL) for most of the incident scenarios analysed. Obstruction and rough terrain will increase the dispersion rate and hence decrease the distance to LFL. The fact that the LNG is refrigerated and therefore evaporates relatively slowly makes for much smaller hazard dimensions of an LNG incident than for a same size release involving LPG. Ignition may lead to a pool fire or, as for natural gas, if allowed to accumulate, to a flash fire or an explosion. Design will prevent, as far as possible, the gas from accumulating inside any enclosed areas.
Composition of the vapour cloud	Although LNG and natural gas are comprised of many components, methane will boil off first since it is the lightest component. Thus the vapours formed above spilled LNG will initially be composed of methane (Ref 27).

4.2 DETAILED CONSIDERATION OF ALL HAZARDS

Several variables must be addressed in developing an assessment of a release and its general dispersion, including potential for ignition sources. The factors, as presented in Appendix 3, determine the possible outcomes of an uncontrolled release, i.e. whether it:

- Disperses without a fire,
- Burns as a pool fire,
- Burns as a flash fire or
- Explodes or BLEVEs.

The hazards identified with potential to cause loss of containment can be broadly categorised as:

- Internal and process related hazards;
- Natural hazards;
- External hazards; and
- Intentional acts.

A preliminary hazard identification exercise was undertaken by a multidisciplinary team, addressing the nature of hazards that might occur during operation of the facility. The Hazard Identification Word Diagram, presented in Table 8, summarises the results of this exercise and shows the potential incident scenarios identified for the proposed development, including initiating causes, consequences and proposed and existing safeguards.

Further elaboration of the hazards under each category is included in Sections 4.2.1 to 4.2.8 below.

4.2.1 Interconnecting NGSF and Process Related Hazards

Safety in the LNG industry is ensured by the following four elements that provide multiple layers of protection both for the safety of LNG industry workers and the safety of communities that surround LNG facilities (US Centre for Energy Economics, Ref 14),

- Primary containment;
- Secondary containment;
- Safeguard systems;
- Separation distances.

Generally, these multiple layers of protection create four critical safety conditions, all of which are integrated with a combination of *industry standards and regulatory compliance*.

The following section summarises how the NGSF's design and construction will comply with these essential elements of safety.

This constitutes *Best Engineering Practice* according to current knowledge of LNG facilities design and comply with relevant international and Australian Standards for LNG facilities (Refs 5, 6 and 7).

A. Primary Containment

The first and most important requirement for containing the LNG is based on the integrity of containment, including the use of appropriate materials for the LNG facility, proper engineering design and construction practices and minimising the risk of damage and fatigue of storage tank and processing plant. The measures to be used at the NGSF include:

- The use of recognised and experienced plant designers.
- The use of latest technology construction of storage tanks and processing equipment;
- The design and associated piping in accordance with the most widely recognised and used codes for its type (Refs 5, 6, 7);
- Minimising the risk of mechanical damage caused by malicious damage through security measures (to prevent sabotage);
- Quality control during the construction of the tank and piping, including radiography of welds, testing of weld and heat affected zones, hydrostatic overpressure test and/or vacuum tests as appropriate, production weld testing and other recognised Non Destructive Testing (NDT) requirements;
- Minimising lengths of piping and number of flanges (use welded connections wherever possible), particularly of piping holding LNG;
- Proper securing of piping; and
- Regular and periodic inspection and maintenance.

B. Secondary Containment

The second layer of protection ensures that, if a leak or spill did occur, the LNG can be fully contained and isolated from the public. The NGSF will include a system of containment areas (or an *impounding system*), capable of containing the quantity of LNG that could be released by a credible incident involving the component served by each particular containment system.

Table 7 summarizes the assumptions made as to the design of the sumps and bunds (referred to here as *impoundments*). These assumptions have a bearing in the calculation of pool spreading and evaporation rates.

Table 7 – Impoundment Systems Design

Bund configurations	Impoundment length and width (m)	Impoundment Depth (m)	Impoundment Volume (m^3)	Design Basis
LNG storage tank bund	150 x 100	5.05	89,530	capable of containing the full contents of the tank)
LNG storage tank sump	7.2 x 7.2	2.1	109	capable of containing a 10 minutes release
Processing area / future truck loading large sump	12.6 x 9.6	2.1	254	capable of containing a 10 minutes release

Bund configurations	Impoundment length and width (m)	Impoundment Depth (m)	Impoundment Volume (m^3)	Design Basis
Processing area / future truck loading small sump (within the large sump)	4 x 4	1	16	capable of containing a 10 minutes release

While ensuring full containment of the maximum credible spill event, the containment surface areas will be minimised, thus minimising the area of vaporisation and the size of a pool fire should ignition occur.

Recommendation 7: Review risk reduction from the use of insulating concrete inside the LNG impoundment trenches and sump.

Recommendation 8: Review risk reduction from additional mitigation of vapour generation in impoundment system.

A spill would be drained away from tanks and tankers containing large volumes of LNG (preventing so-called knock-on events). For example, the slope of the floor surface of the storage tank bund will be directed away from the storage tank in order to direct a spill away from the tank as far and as much as possible. Similarly, the slope of the floor surface of the tanker loading bay will be sloped away from the tanker(s). All LNG processing areas, including the liquefaction and vaporisation units and the tanker loading bay, are located well away from the LNG storage tank.

Should a spill occur the chances of ignition will be minimised through the use of a combination of hardware plant design features (such as control of static electricity through earthing and electrical continuity and suitable electrical equipment to comply with hazardous area classification requirements) and procedural requirements (through use of maintenance systems such as permit to work systems and preventative maintenance programs for electrical equipment in hazardous area).

Some ignition sources are located within the NGSF site and are integral to the operation of the station. These sources are located well outside of the hazardous zones which will be defined for the NGSF. However, in case of a massive release of natural gas or LNG it is conceivable that concentrations within the flammable range may reach these ignition sources resulting in a flash back and pool fire or possibly a flash fire or vapour cloud explosion (if the gas was allowed to accumulate). The known sources of ignition on the site are listed below:

- Fired heater;
- Fire pumps;
- Compressors;
- Nearby roads;
- Vehicles on NGSF site;
- Bushfires.

Appendix 3 details how the control of ignition sources is factored into the risk assessment.

C. Safeguard Systems

The goal of the third layer of protection is to minimize the frequency and size of LNG releases and prevent harm from potential associated hazards, such as fire.

For this level of safety protection, the NGSF will be fitted with a number of sensors, detectors and alarms and multiple back-up safety systems, which include emergency shutdown (ESD) systems. The ESD system can identify problems and shut off operations in the event certain specified fault conditions or equipment failures occur, and are designed to prevent or limit significantly the amount of LNG and LNG vapour that could be released. The ESD system will be *fail safe*, i.e. the equipment associated with the ESD system will be capable of compensating automatically and safely for a failure (e.g. failure of a mechanism or power source). The ESD system will include emergency shutdown buttons which will be located in strategic locations throughout the site, at the control room and at the site entrance/exit gate. For potentially catastrophic events, automatic initiation of the ESD system will be investigated.

Recommendation 9: During detailed design, determine need for automatic shutdown (trip) requirements.

Fire and gas detection and fire fighting systems all combine to limit effects if there is a release.

Necessary operating procedures, training, emergency response systems and regular maintenance to protect people, property and the environment from any release will also be established.

The details of this layer of protection will be defined during the detailed design process. Some important safeguards already defined (and built into the present hazard and risk assessment) include:

Overfilling: Overfilling of the inner tank may lead to overflow into the annular space between the inner tank and the outer tank which could lead to damage to the outer tank and loss of containment. Detectors are provided to detect any LNG leak in the annular space bottom so that an overfilling event, if it ever occurs, can be detected and shutdown initiated. Overfilling if prevented through the several factors, including: Continuous level measurement on tank using several (at least four) separate detection systems with at least two different types of level measuring device; Pre-alarm at normal maximum level in tank, corresponding to the usable capacity; Level high and high-high which initiates trip of shutdown valves in liquid inlet stoping further inflow of liquid into the tank. The safety integrity level (SIL) of the high-high level trip of liquid inlet will be determined during detailed design, however, SIL 2 classification is typical for this instrumented protective system which means that the probability of failure on demand will be less than 0.01;

Overpressure: Overpressure in tank may be caused by several factors, including: Normal boil-off due to heat leak from ambient; Vapour displacement during filling operation; Variation in atmospheric pressure (i.e. drop in atmospheric pressure); Flashing of incoming liquid if it is at a higher temperature than the bubble point of liquid at tank pressure. Overpressure can result in failure of the tank. However, there are a number of safeguards provided against overpressure: Normal boil-off vapours from the tank and vapour displaced during tank filling is routed to a boil-off compressor where the vapour is compressed and sent to the low pressure gas network or used as fuel gas in the NGSF; The tank pressure is continuously monitored by two sets of pressure measurements; A pressure control valve is provided on the tank to route all the excess tank vapours to a flare stack (the vent stack height and tip will be determined such that vapours discharged will disperse safely or if ignited, the radiation on the equipment and buildings adjoining the stack are within permissible limits as per Codes and Standards); The pressure control valve relieving to stack is typically designed for all overpressure cases under normal operations; An independent high-high pressure trip is provided which will initiate shutdown of tanker filling operations (to stop liquid inflow); As a last resort, pressure relief valves are provided on the tank which are sized for all the cases of overpressure. The governing case for relief valve is however, the rollover case, which is an emergency case.

Underpressure: Underpressure may be caused by several factors, including: Pump-out of liquid; Increased compressor suction due to control malfunction; Variation in atmospheric pressure (i.e. rise in atmospheric pressure). Under normal operating conditions, the boil-off generated due to heat leak is sufficient to prevent under pressure condition. Underpressure or vacuum conditions due to control malfunction can cause failure of the tank containment. There are a number of safeguards in place: Continuous monitoring of tank pressure by two sets of pressure measurement; Low pressure alarm; Low-low pressure will trip the boil-off gas compressors and in-tank pumps and thus prevent further fall in tank pressure; Pressure control valve provided to inject external gas into the tank; Vacuum relief valves are provided which are typically sized for maximum vapour flow arising from compressors and pumps in operation. The operation of vacuum relief will lead to air-ingress into the tank and thereby avoid collapse of the tank. The operation of vacuum relief is envisaged as a measure of last resort.

Roll over: Prevention of roll over risk, through the use of down pipe for tank filling (promoting tank mixing by the incoming liquid), monitoring of incoming LNG stream temperature), means to detect stratification with density gauge (automatic travelling probe), and procedures and training, as well as operational practices to be put in place in case of extended down-time of the NGSF. Adequately sized relief valves and load-bearing bottom insulation to be designed such that it will withstand considerable thermal and mechanical stresses without jeopardising the integrity of the container.

BLEVE in Mixed Refrigerant: A BLEVE in the mixed refrigerant can occur when the vessel is subjected to destructive radiative heat from a fire. The vessels which store these gases are equipped with safety pressure relief valves set at about twice the normal operating pressure. When these relief valves open, the pressure is maintained at the relief valve setting and the tank vents. In these circumstances, the liquid evaporation keeps the tank surface in contact with the tank liquid at the boiling temperature. However, the vapour above the liquid may be unable to keep the steel at the top of the tank from getting very hot. This will weaken the steel which may rupture and release the contents. Safeguards include the pressure relief and also active and passive fire protection (in the form of automatic deluge system or insulating material which protects the vessel from the heat radiation).

D. Separation Distances

The fourth layer of protection employed for LNG facility design is required by regulation to maintain separation distances from communities and other public areas for land-based facilities.

The separation distances are based on requirements code and on the maximum tolerable risk principles (as per the present hazard and risk assessment).

With respect to the code-based requirements, the NFPA Code, the Australian and the European Standards (Ref 5, 6 and 7) specify thermal radiation exclusion zones which must be large enough so the heat from an LNG fire does not exceed a specified limit for people and property.

Similarly the vapour dispersion exclusion zone must be large enough to encompass that part of the vapour cloud which could be flammable.

Throughout the design process, designers are required to demonstrate how these safe design principles are dealt with for the proposed NGSF. As this hazard and risk analysis is prepared in the early stage of the design, a number of assumptions have been necessary to proceed with the risk estimations, as listed below.

While these assumptions are believed to be conservative Recommendation 2 is to verify that the assumptions made remain valid in detailed design.

4.2.2 Tanker Loading Operation

Uncontrolled release during filling operation: Uncontrolled release of LNG during tanker filling may be caused by several factors including drive-away, failure of hose preventative maintenance program, mechanical impact, and leak in supply pipe, valves, and equipment.

There are a number of safeguards in place, including:

- Material selection, robust and secured pipework to code requirements, welds radiographed, hydrostatic testing, design pressure and relief valves, and thermal reliefs.
- Protection against mechanical damage include vehicular assess to the tanker loading area, including protection of plant and equipment and speed restrictions.
- Hoses are approved and checked using regular non destructive testing regime as per Code requirements.
- Drive off protection will be provided to ensure shut off valves are closed if truck moves.

- Gas and fire detectors and detection of upset operating conditions with subsequent plant ESD will also be provided, including quick response shutoff valves at tanker loading and low temperature detection in the sump with alarm and manual shutdown.
- In case of a spill at the tanker loading bay, the LNG drains to sump and bund, minimising the surface area for evaporation and removes cold liquid and possible heat radiation from neighbouring structures, vessels etc.

Overfilling: Overfilling of a tanker results in liquid being transferred into the vapour return. Further, excessive filling of a tanker may compromise tank design during transport. Safeguards include:

- Tanker driver will be required to be present during tanker filling, allowing for detection of upset conditions;
- Filling using a slow fill rate will allow for timely detection of an overfill scenario;
- Overfill goes into the vapour return and not to ground. A level switch in the vapour return sump vessel will shut down LNG flow;
- The tanker will be fitted with level gauge. Further, a weigh bridge will detect an overfilled tanker prior to it leaving the site, allowing for removal of excess material from tanker.

Recommendation 10: Overfill protection system for tanker loading to be developed during detailed design.

Overpressure: Blocking of the vapour return line could lead to damage to the tanker resulting in vapour release, possibly during transport. Safeguards include:

- Tanker driver will be required to be present during tanker filling, allowing for detection of upset conditions;
- Filling using a slow fill rate will allow for timely detection of an overpressure scenario;
- Tanker will be fitted with a pressure gauge and with pressure relief valves.

Recommendation 11: Overpressure protection system for tanker loading to be developed during detailed design.

The failure frequency data in Appendix 3 includes all the causes discussed above, namely overfilling, overpressure, ruptures, defects and maintenance hazards.

4.2.3 Odorant Piping and Equipment

Typically a couple of cubic meters will be stored at the site. Even though the odorant is a liquid at atmospheric conditions, it will most likely be stored in transportable pressure vessel(s) because of its very unpleasant odour. The pressure vessels will be constructed to Australian Standards for pressure vessels and Certified.

The vessels will be delivered to site, moved off the truck and transported into place (no liquid unloading operation will take place). The vessels will be located in a bunded area provided with a sump (a low point) to allow pump out in case of a spill and covered by a shade roof. The odorant will be pushed out of the storage vessel using a slight overpressure of natural gas and injected into the natural gas stream via a fixed (about 10 mm diameter) stainless steel line.

All the requirements for fire risk management of these relatively small quantities of flammable liquid will be as per AS1940 (*Storage and handling of flammable and combustible liquids*), including:

- Bunding requirements will be per AS1940, i.e. 100% of the largest tank, with bunding design and construction as per Section 5.9.3 in AS1940.
- Fire protection (fire extinguishers, hose reel requirements, separation distances etc.) will be as per AS1940.
- If installed within a building, design of ventilation of building will be as per AS1940 Section 4.4 with regards to flammable vapours.
- Valving and piping associated with the storage will be as per AS1940 Section 7.
- Control of ignition sources is as per AS1940 Section 9.7.6.

Excess dosing of odorant into the natural gas stream is expected to be a gas quality issue only and is likely to be identified by periodic gas checks. The potential for excess dosing will be considered during the design phase, including during the HAZOP study[4].

The possibility of under-dosing of odorant in the natural gas stream is another possibility. Such potential will be considered during the design phase (including in the HAZOP study). Under-dosing will be prevented through monitoring of levels in the vessels by the control room as well as at manual check during periodic inspections. It is further noted that once the line has been in use for some time, the odorant ―contamination" of the piping is such that the gas would continue to be odourised for some time after cessation of dosing.

Provided the requirements from AS1940 are adhered to, the probability of a fire involving the relatively small quantities of odorant is negligible. A pool fire involving the odorant materials is possible (just as for any storage of a flammable liquid). With the AS1940-requirements, the risk of a fire and a potential propagation to other areas is minimal and will not be assessed further.

With respect to the very unpleasant odour, in the event of spillage, the odour would be expected to extend considerable distances at detectable odour levels, thus creating an unpleasant atmosphere for any person in the vicinity. While the material has relatively low toxicity, the odour is so unpleasant that exposed

[4] This is entirely consistent with the HAZOP study methodology, where the effect of a high and low (or no) flow of any process steam is considered.

people may report distress or nausea at levels which are well below those which would be of concern in terms of toxic impact.

4.2.4 Flaring Operation

Flaring will be undertaken under the following circumstances:

- Emergency blowdown following ESD;
- Gas venting from storage tank in case of failure of liquefaction unit;
- Compressor unit blowdown (via blowdown valves on individual compressor units);
- During plant start-ups and shut-downs.

Potential hazards with the flare operation include:

- Dispersion of unignited natural gas – Designers will carry out dispersion calculations to confirm no flammable gas at ground level. Further, to provide a reliable flare should it be needed, a spare pilot flame will be running all of the time and automatic relight on loss of pilot and alarm on pilot failure will be incorporated into the design.
- Heat radiation from flare operations – Designers will carry out heat radiation calculations to confirm no excessive heat at ground level.
- Noise generation – the flare will be designed to minimise noise generation in non-emergency situations. High rate of flare gas (and high noise levels) occurs only in rare (and short duration) emergency conditions

Recommendation 12: It is recommended that the detailed design of the flare system be reviewed using Hazard and Operability (HAZOP) technique, particularly for abnormal operations including flare operations.

4.2.5 Interconnecting NGSF Pipeline and Receiving Station Hazards

Australian Standard AS2885 (Ref 19) sets the minimum standard for high-pressure pipelines in Australia. This code gives detailed requirements for the design, construction and operation of gas and liquid petroleum pipelines. It has gained wide acceptance in the Australian pipeline industry. AS2885 also sets the classification of locations which guide the designer in the assessment of potential risks to the integrity of the pipeline, the public, operating and maintenance personnel as well as property and the environment.

AS2885 accommodates changes in population density by its location classification scheme concept. The classification scheme allows broad division of the pipeline design requirements according to whether the pipeline is to be installed in rural, semi-rural, suburban or urban areas. For each of these classifications the minimum design requirements in terms of wall thickness and depth of cover are specified.

Allowance is made in AS2885 for the improvement in safety performance possible through the use of thick walled pipe with a low design factor. AS2885 also mandates that the integrity of the pipeline be maintained throughout the pipeline operating life.

The safeguards have been grouped together under the potential hazardous events associated with the pipeline, and listed in the Hazard Identification Word Diagram in Table 8 below.

4.2.6 Natural Hazards

A. Seismic Hazard

Structures and plant are designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or International standards.

A seismic hazard review will be conducted for the site during the detailed design stage. The tank will be designed to meet the required earthquake characteristics of the site. Seismic loads shall be calculated in accordance with AS1170.4. API 620 also has specific requirements for LNG tank design/earthquake loads

Further, foundations and subsurface integrity will be reviewed prior to constructing the storage tank. Initial review of the geotechnical requirements for the site indicates there may be a need for piling.

B. Land Subsidence

The pipeline route and the NGSF are not built on any known areas of mine subsidence.

C. Lightning and Earthing

The site will be protected against lightning strike in accordance with Australian Standard AS 1768 Lightning Protection (Ref 28) requirements. This will include a combination of earthing grids, electrodes, down conductors and air terminals..

Lightning strike can ignite flammable vapour discharges from vents and stacks. Lightning strike has been the one of the causes of petroleum tank fires. However, this is applicable to cone roof tanks and floating roof tanks. In the case of cone roof tanks, the tank vent is in direct communication with the atmosphere. Breath-in and breath-out occurs during withdrawal of liquid from tank and during filling respectively. Vapours in flammable concentration may be generated which upon ignition at the vent tip due to lightning strike can flashback to the liquid inside (flame arrestor provided at the vent prevents such flame flashback). In the case of floating roof tanks, vapours generated due to seal leaks may get ignited.

The above scenarios are not applicable to an LNG tank, which is a dome roof tank and is maintained under pressure of about 50 to 250mbarg. A lightning strike is not expected to impact on an LNG tank.

Recommendation 13: Investigate lightning protection for the top of the tank.

D. Bushfires

The risk associated with an incident at the site initiating a bushfire is minimised through passive protection in the form of plant layout, equipment spacing and drainage of possible liquid spillages away from critical equipment to containment sumps. Further, active measures such as fire and gas detection, a firewater system and overpressure protection will also be included in the detailed design, minimising the effect of an incident.

The active measure of hydrants / monitors located at the LNG storage tank is available to cool this tank in case of an adjacent (e.g. bush) fire.

The fire protection and safety systems will include:

- fire water – underground distribution loop and aboveground system;
- detection systems – response to release of combustible, hazardous and/or low temperature gases and fires;
- fire proofing and proofing for cold liquids exposure (subject to fire studies to be conducted during detailed engineering);
- fire water tank; and
- fire water pumps.

Further, emergency response plans and procedures will be developed for the facility in conjunction with NSW Fire Brigades. These plans and procedures will detail the steps to be taken in case of a bushfire in the vicinity of the NGSF.

The consequence assessment Section 5 determined the heat radiation from an incident at the NGSF and its potential to initiate a bushfire. The result showed that the hazardous levels of heat radiation resulting from an incident at the NGSF remain well within the site boundaries for most of the incidents identified. The exceptions are the massive (barely credible) scenarios where the LNG storage tank ruptures and fills the bund and then catches fire. While in such case an ignition of the surrounding bush is possible and even credible it should be noted that the likelihood of the event is very low (in the order of 1×10^{-6} per year). The incremental risk of a bushfire initiated from the NGSF is minimal compared with the inherent risk of bushfires in this area.

In order to assess the risk from a bushfire to the NGSF, a bushfire threat assessment was conducted in January 2011 (Ref 29), in accordance with the Rural Fires and Environmental Assessment Legislation Amendment Act 2002 (Ref 30) which requires all developments in bushfire prone lands to conform to documented bushfire protection specifications.

The bushfire assessment determined the need for a 25m Asset Protection Zone between the surrounding bush and the gas plant site, which would provide a defendable space around the structures, and avoid flame contact and radiant heat exceeding 40kW/m^2. Further, the bushfire assessment recommended a 31m Asset Protection Zone to the process plant and LNG storage tank to ensure radiant heat does not exceed 23kW/m^2.

The NSW DoP in their HIPAP 4 (Ref 1) state that: *Heat radiation levels of 23 kW/m^2 as the result of fire incidents at a hazardous plant may affect a neighbouring installation to the extent that unprotected steel can suffer thermal stress that may cause structural failure... This may trigger a hazardous event unless protection measures are adopted*.

The 23 kW/m^2 is commonly used in Australia as a measure of the maximum heat radiation from a neighbouring fire above which a propagation incident is possible. Based on the proposed layout, the separation distance between the bush and processing plant area, the maximum heat radiation at the processing plant area will not exceed 23kW/m^2, thus adhering to the NSW DoP requirements.

The European LNG Code, EN 1473 (Ref 31), further recommends an upper limit of 15kW/m^2 radiant heat flux on the metal outer surface of an LNG tank.

Based on the proposed layout, the separation distance between the bush and the storage tank (about 75m) is such that the heat radiation resulting from a bush fire will not exceed the 15kW/m^2 and will in fact be about 6.2kW/m^2 (Ref 29), which is less than the maximum heat radiation allowed as per both the NSW DoP and the European LNG Code requirements.

The LNG storage tank will further be protected through thermal insulation and fire water monitors, and the mixed refrigerant tanks will be protected through either passive protection or through deluge, reducing the heat load at these structures.

E. Storm Surges and Flooding

If the LNG storage tanks or piping become submerged under water, it is possible for buoyancy forces to lift the pipes/tanks, causing damage and possible loss of containment.

Flooding risks and hydraulic calculations have been conducted for the NGSF (as reported in the Flooding Assessment in Ref 32).

The study showed that the peak flood levels are expected to be constant across the site, which is reflective of the nature of flooding in the vicinity of the site, as an area of flood storage to the east of the main Hunter River floodplain. The study estimated that flow velocities across the site and adjacent areas will be minimal (i.e., typically less than 0.1 m/s). Notwithstanding, the study determined the following peak flood levels at the NGSF site:

- 4.6 mAHD during the 100 year ARI flood;
- 4.9 mAHD during the 200 year ARI flood; and,
- 5.4 mAHD during the 500 year ARI flood.

The site will be levelled to a finished surface of 6.35 mAHD, which is well above the peak flood levels.

Further, the tank will be located in a bund surrounded by at least three (3) meter high earth mound which is expected to provide ample protection against flood levels and against debris.

Winds, and to a lesser extent pressure, cause a rise in sea level in coastal areas. In general, storm surges are limited to several metres unless channelling effects from the coastline exasperate the surge. The NGSF location will not create such channelling.

The NGSF, located well above sea level and at 10 km from the coast are therefore protected against any risk from storm surges, waves and other causes of flooding.

Floods may cause erosion of the ground cover of the NGSF pipeline or floatation of the pipeline. This is prevented through horizontal directional drill below Hunter River; entry and exit points are set back from the river at least 50 m. Where it is determined that flooding or inundation of the pipeline easement is a risk, concrete weight coating or other means of ensuring negative buoyancy will be employed in the design of the pipeline. The pipeline trench and easement will be compacted and restored to minimise the impact of flooding. Depth of cover and extra wall thickness will be provided at waterways/drain/swamp crossings. Regular inspections and patrols of the pipeline will identify any erosion problems and initiate repair of the ground cover.

F. Tsunami

While Tsunamis are unlikely events, similar to storm surges, the main hazard from tsunamis is the rise in sea level and possible floatation of piping and tanks. A review of the effects of tsunamis (Ref 33) show that, with tanks and equipment positioned well above sea level and at a distance of 10 km from the coast, the risk of a tsunami affecting the NGSF is considered negligible.

G. Summary of Natural Hazards

The NGSF site and design of the facility are such that there will be no special risks from natural hazards. Natural hazards are therefore not treated separately in the analysis but are included in the generic failure frequencies (Section 6.1).

4.2.7 External Hazards

A. Aircraft Crash

The risk of an aircraft crashing into any given facility is based upon the following:

- The location of the airways relative to the facility;
- The location of the airport relative to the facility;
- The relative consequences should an aircraft crash into the facility.

The proposed NGSF site is about 10 km from the Newcastle (Williamtown) airport runways and hence 10 km from the arrival and departure flight paths. While airplane crashes are highly unlikely in Australia due to the stringent Civil Aviation Safety Authority requirements, they are possible and an aircraft crash onto the LNG tank would be catastrophic as the tank is not designed to withstand such mechanical load. The natural gas pipeline, being buried, is on the other hand unlikely to be damaged even in the event of an aircraft crash.

The Australian Transport Safety Board (ATSB) published in 2006 a study comparing the aircraft safety in Australia with that of United States, Canada, the United Kingdom, and New Zealand in the period between 1995 and 2004 (Ref

34). One of the key findings indicated that the fatal accident rate for Australian air carrier operations, which includes all regular public transport and commercial charter operations, was slightly higher than the rate for the United States for all years (up to twice as high for some years), except for 2002 when it was marginally lower, and for 2004, when the rate was zero. These results show that the US data can be used for the Australian situation provided they are slightly increased to account for the slightly higher rates (i.e. doubled).

US aircraft crash data for recent years shows a rate of about 2 x 10^{-7} per flight. However, only 13.5% of accidents were associated with the approach to landing, 15.8% were associated with take-off and 4.2% were related to the climb phase of the flight (Ref 35). The accident frequency for the approach to landings was calculated as 2.7 x 10^{-8} per flight and for take-off/climb 4.0x10^{-8} per flight. The frequency of aircraft crash was estimated using the methodology of the HSE (Ref 36) calculating the crash frequency per unit ground area (per km^2). The crash frequencies for take-offs were calculated to be well below 10^{-10} per year and impacts from aircraft landing accidents to have a frequency close to the 10^{-10} per year threshold for a conservative estimated of about 20,000 take-offs and landings at the Newcastle (Williamstown) airport (Ref 37. This is a very low number and similar to the risk of a meteorite crash. The risk of an aircraft crash causing damage to the LNG storage tank can therefore neglected from the analysis.

In order to minimize the impact of the NGSF to the airport the following is recommended:

Recommendation 14: Request restricted airspace.

Recommendation 15: Review need for aircraft warning light or other device on high point of facility.

B. Incident at the NGSF Causes Knock-on Effect at Neighbouring Facility

Consequence calculations (in Section 5) shows that separation distances from the NGSF tank and the processing plant to neighbouring locations (TAC, NGSF pipeline, receiving station, etc.) ensures that the heat radiation or overpressure from credible scenarios at the NGSF are highly unlikely to cause major structural damage.

Further, the propagation risk calculations (in Section 7.3.4) shows that the risk of domino effects generated from the NGSF site complies with current criteria for maximum acceptable risk at neighbouring industrial facilities, even if the land around the proposed NGSF site sees further industrial development.

The NGSF and low pressure pipelines are buried at a depth of a minimum of 750 mm – thermal radiation or overpressure effect from even a massive incident at the NGSF is not believed to constitute a threat for an operational buried pipeline. Further, a mounded earth wall separates the pipeline from the storage tank and bund, making propagation even less likely.

C. Incident at NGSF Causes Knock-on Effect at NGSF Pipeline

An incident at a nearby facility is highly unlikely to expose the pipeline and, provided that the pipeline is not exposed.

Research has shown that a pipeline cannot be damaged by the radiative heating or explosion overpressure from a nearby incident (as discussed in the recent risk assessment of the Young to Bomen pipeline which will be installed alongside an existing high pressure pipeline (Ref 38)).

Recommendation 16: Pipelines located in the same easement to be separated so as to protect the adjacent pipeline from radiative heating from a neighbouring pipeline.

D. Incident at Neighbouring Industrial Facility Causes Knock-on Effect at the NGSF

Hazard assessments were conducted for the TAC aluminium smelter in 1995 and 2000, as outlined in the Statement of Environmental Effects – Modification of Development Consent – Proposed Production Capacity Increase (Ref 39). The assessments found that the existing facility was not considered to be potentially hazardous based on the dangerous goods on site.

The risk of an incident at TAC causing domino effects at the NGSF is considered negligible and will not be considered further in this PHA.

Future development in the close vicinity of the NGSF will need to consider any potential risks to the NGSF, following Council and possibly NSW Department of Planning requirements.

4.2.8 Intentional Acts

Intentional acts include terrorism and vandalism.

Security at the NGSF and at Hexham receipt station is discussed in Section 2.5 above.

The consequences that would result from a terrorist attack are included in the scenarios evaluated, which include a total failure and massive leak of the LNG storage tank.

A comparison on the risk of terrorist threats of the NGSF compared with other major industrial facilities in Australia (such as refineries or major processing facilities in more publically visible, accessible and prominent locations) indicate that the Tomago site is equal to (or possibly even lower) in exposure compared to the other industrial locations. The (current) overall low threat environment in Australia is also a factor.

The threat of intentional acts such as sabotage or terrorist activities are therefore not treated separately in the analysis but are included in the generic failure frequencies (Appendix 3). It will however form part of the requirements for management of Major Hazard Facilities.

4.2.9 Road Transportation Risks

Up to 1000 tankers per year will enter the site empty for loading of LNG and then leave the site again when filled up with LNG. When full, each tanker will contain approximately 18 tonnes of LNG. The tankers will enter the site using the current network of roads.

The risk associated with LNG transport is similar to that of other flammable materials and is heavily regulated through the ADG Code (Ref 23). This includes requirements for training of tanker drivers, construction and design of road tankers, and maintenance requirements for equipment associated with the loading (and unloading) of the material.

The transport routes in and out of the site go through industrial areas suitable for this type of transport before reaching the Pacific Hwy. The destination of the LNG tankers is not known at this stage but would most likely go north or south on the Pacific Highway and west on Maitland Highway to reach the F3 Freeway.

The Annual Average Daily Traffic (AADT) of Heavy Vehicles will be about 16,000 in 2013 at the Pacific Highway at Hexham (Ref 40 and 41 taking into account a 3.4% annual growth in traffic). With about 1.15% of heavy vehicles carrying dangerous goods (WorkCover Authority as reported in Ref 42), approximately 180 dangerous goods trucks use the Pacific Highway at Hexham on a daily basis, or about 66,000 per year. The 1,000 extra LNG tankers do not introduce an excessive additional risk to dangerous goods traffic at this location.

With the exception of the LNG tankers, once the development has been built and put into operation, the frequency of road transportation to the site of dangerous goods and potentially hazardous material will be minimal and in any case will be negligibly incremental to the delivery frequency for the existing site.

It is expected that a few deliveries per year will be sufficient for the operation of the site, consisting of the occasional resupply of lube oil, mercaptan and mixed refrigerant and the occasional transport of material used for maintenance or cleaning. The removal of the closed mercury vessel will occur about 5-yearly. General transport risks of these materials are handled by transport companies' internal safety requirements. Clean up and incident management will be as per the transport company's procedures.

On this basis, the overall risk associated with the transport of dangerous goods associated with the proposed development is low and in particular the 1,000 extra LNG tankers do not introduce an excessive additional risk to the risk associated with dangerous goods traffic at the Pacific Highway at Hexham.

4.2.10 Other

A. Environmental Pollution and Risk to the Biophysical Environment

A failure to contain a spill of potentially environmentally pollutant materials (such as heating fluid, amine, mercury, lubrication oil from rotating machinery, diesel, or fire water) could cause environmental pollution to surface and groundwater. Prevention will include:

- Adequately designed piping, vessels, and storage tanks used for liquids;

- Storage tanks located inside bunded/contained areas;
- Welded pipes outside of contained area;
- Any vessels containing mercury will not be opened on site;
- Spills outside of bunded areas will drain to the site drainage systems which will be segregated so that any potentially contaminated surface water runoff will be kept separate from clean rainwater runoff;
- Potential surface water contaminants will include wash-water, runoff from the bunded plant areas and water accumulated in the bunds. Water from these areas will be directed through a treatment system designed to remove oil and grease, and minimise suspended soils to an acceptable level prior to discharge;
- Only suitably treated water will flow in the stormwater system. The discharge location for the treated stormwater will be subject to further detailed design of the gas plant.

B. Exposure of personnel to hazardous materials

A failure of control systems may cause exposure to cryogenic temperatures and asphyxiant properties from mixed refrigerant, LNG, and nitrogen.

Further exposure to materials used in gas treatment and odorising (amine, odorant, activated carbon, catalyst, molecular sieve, mercury removal media) due to failure of maintenance procedure, failure to train personnel, inadequate design of sample point is also possible. Prevention measures include:

- Plant design limits confined areas where cryogenic / asphyxiant gas may accumulate after a loss of containment (mainly limited to compressor buildings and sumps/trenches).
- Safe operating procedures (SOPs) will be established for routine tasks.
- Permit to work including job safety analysis will be conducted on all work which are not covered by SOPs, including confined space procedures for work within drains and sumps.
- Personal protective equipment (PPE) will be supplied to all personnel.
- Detailed design will evaluate need for placing odorant system inside ventilated building. Equipment design to enable adequate access and venting facilities.
- Emergency response procedure including access to medical treatment, ambulance etc. as required. Eyewash and shower stations for small exposures. Emergency response plan.

Table 8 – Hazard Identification Word Diagram

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
Natural Gas Pipeline (NGSF Interconnecting Pipeline)					
1	Uncontrolled release from the natural gas pipeline due to generic faults in the pipeline.	Construction damage, weld fault, coating flaw or faulty materials. Aging of pipeline. Stress corrosion cracking.	Damage to the pipeline and release of natural gas. If ignition then possibility of flash or jet fire. Physical explosion from the pressure of the released gas creates projectiles (earth, sand, stones). Injury and property damage. If confinement then possibility of a vapour cloud explosion.	**Prevention:** Coating on external surfaces of pipelines; Cathodic Protection (CP); inductive current and fault levels; internal corrosion virtually absent with clean hydrocarbon; design to include control devices, e.g, Transformer Rectifier Assisted Drainage (TRAD) unit to divert stray currents. Hydrotesting; Radiography &/or ultrasonic testing of welds; design to limit crack propagation; pipeline Integrity Management Plan. Stress corrosion cracking not expected as limited pressure and temperature cycling. A *No Rupture* design limits stress in wall thickness and reduces the risk of stress corrosion cracking; further prevented through use of pipeline coating. Stress in wall expected to be well below the threshold. Welding procedures and welds radiographed; material certificates; hydrostatic testing and QA/QC. Natural gas disperses readily upwards, minimising chances of ignition. **Detection:** Routine inspection (incl. patrol, pigging, CP monitoring, Inline Inspection (ILI) and Direct Current Voltage Gradient (DCVG). Odourised gas for hazard warning. **Protection:** Pipe thickness and design factor to AS2885 requirements. Pipeline runs within a cleared easement - explosion is not credible in unconfined situation. **Emergency response:** Emergency response plan to be developed, including emergency isolation of pipeline and links to external authorities.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
2	Uncontrolled release of natural gas due to impact or damage to the pipeline.	3rd party involvement e.g. digging or trenching, or other earth work. 1st party involvement (exca-vation inspection damages coating and corrosion). Destructive vibration near the pipeline. Aircraft or heavy vehicle crash. Terrorism. Vandalism. Fire or explosion in the vicinity of the pipeline (bush / brush fire; incident at the neighbouring. Operational error upstream or downstream facility. Natural event (flooding, land subsidence).	Release of natural gas. Physical explosion from the pressure of the pipeline creates projectiles (earth, sand, stones). If ignition then possibility of flash or jet fire. Injury and property damage. If confinement then possibility of a vapour cloud explosion.	**Prevention:** Buried pipeline within an easement (except for in the roadways where extra burial depth and/or slabbing will provide additional protection from third parties); No 3rd party assets in easement minimises activities near the pipeline; Signage, incl. Dial-Before-You-Dig; Pipeline designed to ~~-~~No Rupture" and maximum discharge rate requirements; Use of mechanical over pressure and temperature protection at upstream and downstream facility. An incident at a nearby facility is highly unlikely to expose the pipeline and, provided that the pipeline is not exposed. No known areas of land subsidence under the site or the pipeline. Flooding hazards prevented through horizontal directional drill below Hunter River; entry and exit points set back from the river at least 50 m. Possible weighing of pipeline. **Detection:** Pressure sensors and alarm transmitted to the control room (24hr/7d monitoring). Routine inspection and patrol. Gas is odourised, allowing for hazard warning. **Protection:** Resistance of pipelines to penetration through use of pipe thickness and adequate design factor. Repair to soil cover if erosion is detected. Repair of any coating damage as required. All pipes and valves will be of robust design and construction. Depth of cover / extra wall thickness provided at waterways/drain/swamp crossings. **Emergency response:** Manual shut down at detection of pressure drop. Emergency response plan.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
Receipt Station					
3	Uncontrolled release from the natural gas due to generic faults.	Construction damage, weld fault, coating flaw or faulty materials. Corrosion (internal or external) Gasket leak. Weld failure Vibration. Valve leak	Damage to the pipes and equipment and subsequent release of natural gas. If ignition then possibility of flash or jet fire. Injury and property damage. If confinement then possibility of a vapour cloud explosion.	**Prevention:** Use of cathodic protection (CP) and painting of aboveground pipework in station; internal corrosion virtually absent with clean hydrocarbon. Hydrotesting; radiography and or ultrasonic testing of welds; welding procedure. Natural gas disperses readily upwards, minimising chances of ignition. **Detection:** Routine inspection (including regular patrol, testing, pigging, CP monitoring, inline inspection (ILI) and direct current voltage gradient (DCVG)). Gas is odourised, allowing for detection and subsequent response in case of a small leak before it can develop into a larger leak. **Protection:** Resistance of pipelines to metal loss through use of pipe thickness and adequate design factor as per AS2885 requirements. **Emergency response:** Emergency response plan to be developed, including emergency isolation of pipeline and links to external authorities.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
4	Uncontrolled release of natural gas due to mechanical impact or damage to the station.	Mechanical impact e.g. motor vehicle impact. Damage station through terrorism or vandalism. Aircraft or heavy vehicle crash result in damage to the station resulting in hazardous releases. Fire and explosion in the vicinity (bush / brush fire; incident at the neighbouring facility (i.e. at NGSF); explosion at neighbouring pipeline; lightning). Flooding.	Release of natural gas. If ignition then possibility of flash or jet fire. Injury and property damage. If confinement then possibility of a vapour cloud explosion.	**Prevention:** Thickness and grade of equipment and pipes. Spiral wound gaskets on flanged equipment. Receipt station is located inside a fenced area; any control building doors will be fitted with intruder alarms; signage provided; no 3rd party assets in fenced area of the station minimises activities near the station. Any major work within the station requires permit to work, including job safety analysis; remote operated isolation valve; robust nature of valve body; regular inspection of station; routine maintenance. Station will be located safely away from potential road crash locations. Security fencing which will assist in slowing down a vehicle. Refer recommendations relating to minimising the impact from the NGSF site the airport. Control of vegetation around station. Electrical design for equipment in hazardous areas. Security fencing around station in line with hazardous area classification (AS2430). Lightning protection system Natural gas disperses readily upwards, minimising chances of ignition. **Detection:** Pressure sensors and alarm transmitted to the pipeline controller (24hr/7d monitoring). Periodic leak surveys. Personal monitors for hot work. **Protection:** Resistance of pipes and equipment to damage from mechanical impact through use of pipe thickness and adequate design factor. Above ground valves are fire safe Metering station is within a cleared, non-confined area - explosion is not credible in unconfined situation. Valve station is protected against floating debris equipment above design flood level where required. **Emergency response:** Shut down at detection of pressure drop.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
NGSF Processing Facility					
5	Leak in pipe or equipment handing natural gas.	Mechanical impact e.g. impact from mobile equipment. Drain/bleed valve open by error. Gasket failure. Valve leak. Erosion, vibration, corrosion. Operator error, over pressure. Small bore fitting failure.	Loss of containment of flammable gas. If ignited at source, the gas will burn as a jet fire. If impingement occurs then possible further plant damage. If the gas is allowed to accumulate, for example inside a building, it may ignite and burn as a short but intense flash fire or explode as a Vapour Cloud Explosion (VCE).	**Prevention:** Material selection. Design pressure and relief valves. Robust and secured pipework to code requirements. Welds radiographed. Hydrostatic testing. Preventative maintenance (PM) and inspections, including Non Destructive Testing (NDT) regime. Site layout prevents containment and explosion. Control of ignition sources. Vehicular assess controlled to prevent mechanical damage. **Detection:** Gas and fire detectors with alarm and remote activation of emergency shutdown system (activated from control room, field, area, and front gate). Closed Conduit Television (CCTV) system. **Protection:** Overpressure and vacuum protection. Natural gas is lighter than air – tends to disperse at altitude without ignition. Plant layout outdoors, spacious and free of areas for accumulation and to prevent flame impingement. **Emergency response:** Isolation at source. Firewater system, firewater storage on site to cool adjacent equipment. Emergency response procedure with call out of Emergency Services.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
6	Leak in pipe or equipment handing LNG or mixed refrigerants.	Mechanical impact, drain/bleed valve open by error. Gasket failure. Valve leak. Erosion, vibration, external/internal corrosion. Operator error. Small bore fitting failure. Cold metal embrittlement. Heat exchanger failure. Thermal expansion of LNG between blocked in sections.	Leak of LNG. The extremely cold liquid may cause localised cold metal brittle failure of structural elements and supports leading to further plant damage and releases. Asphyxiation hazard and cold burn hazard for people in the vicinity of the release. If the flammable vapours are ignited at source, the LNG may burn as a pool fire. If impingement occurs then possible further plant damage. If impingement on mixed refrigerant storage vessel then BLEVE is possible. If the evolved gas is allowed to accumulate it may ignite and burn as a short but intense flash fire or explode as a Vapour Cloud Explosion.	**Prevention:** Material selection; robust and secured pipework to code requirements; welds radiographed; hydrostatic testing; design pressure and relief valves; thermal reliefs. Vehicular assess controlled. Preventative maintenance and NDT regime. Adequately sized cryogenic reheat facilities with control of process upset conditions; process separation between cryogenic and non-cold process streams. Site layout prevents accumulation and subsequent explosion. Control of ignition sources. **Detection:** Gas and fire detectors with alarm and remote activation of emergency shutdown system. Closed Conduit Television (CCTV) system. Low temperature detection in sumps with alarm and manual shutdown. Gas and fire detectors in compressor building and inside of air intake ducting with alarm and automatic shutdown of compressors. **Protection:** LNG drains to sump and bund (minimising the surface area for evaporation and removes cold liquid and possible heat radiation from neighbouring structures, vessels etc). Layout is outdoors, spacious and free of places where gas can accumulate. Compressor building ventilation reduces build-up of gas. **Emergency response:** Isolation at source; firewater system dry chemical fire extinguisher skid in the liquefaction area for use on pool fire. Mixed refrigerant vessels fitted with automatic deluges or passive fire protection.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
7	Explosion within piping or inside a vessel.	Failure of maintenance activities creates ingress of air into natural gas piping and vessels and subsequent start-up without adequate purging.	Possible explosion due to air remaining in the pipes and vessels once natural gas is re-introduced. Due to the limited quantities of gas involved the effects of the explosion is expected to be localised to on-site damage and possible injury.	**Prevention:** Purging procedures, procedures for preparation of start-up and shut-down, maintenance procedures including permit to work regime and job safety analysis. **Detection:** Flame detection with alarm and remote activation. **Protection / Limitation:** Limited amount of gas present in process piping isolated for maintenance is expected to minimise the damaging effects of the incident. Design pressure of most vessels and piping will contain a deflagration (explosion at low pressure). **Emergency response:** Firewater system with electric and diesel driven pumps (firewater storage on site).	**NO** (not expected to lead to off-site effects and will not be analysed further)
8	Exposure of personnel to hazardous materials.	Exposure to cryogenic temperatures and asphyxiant properties from mixed refrigerant, LNG, and nitrogen. Exposure to materials used in gas treatment and odorising (amine, odorant, activated carbon, catalyst, molecular sieve, mercury removal media) due to failure of maintenance procedure, failure to train personnel, inadequate design of sample point.	Tissue damage, injury, death if exposed to asphyxiant materials. Health hazard and injury for exposure to materials used in gas treatment. For amine, possible irritation to skin and respiratory tract. For odorant, potentially serious injury from inhalation or skin contact. For odorant, possible community complaints.	**Preventions:** Plant design limits confined areas where cryogenic / asphyxiant gas may accumulate after a loss of containment (mainly limited to compressor buildings and sumps/trenches). Permit to work including job safety analysis. Confined space procedures for work within drains and sumps. Training. Safe operating procedures (SOPs). **Detection:** Gas detection and forced ventilation inside compressor building. Visual and audible alarm (on flammable gas detection). Visual indication of high concentration of LNG and mixed refrigerant (white). **Protection:** PPE. Detailed design will evaluate need for placing odorant system inside ventilated building. Equipment design to enable adequate access and venting facilities. **Emergency response:** Emergency response procedure including access to medical treatment, ambulance etc. as required. Eyewash and shower stations for small exposures. Emergency response plan.	**NO** (not expected to lead to off-site effects and will not be analysed further)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
9	Loss of containment of environmentally polluting liquids.	Mechanical impact, drain/bleed valve open by error, gasket failure, valve leak, erosion, vibration, corrosion, operator error, over pressure, small bore fitting failure. Impact from mobile equipment/vehicles.	Environmental pollution to surface and groundwater from environmentally pollutant material, e.g. heating fluid, amine, mercury, lubrication oil from rotating machinery such as compressors and pumps, diesel, fire water.	**Prevention:** Adequately designed piping, vessels, and storage tanks for liquids used in process located inside of contained areas. Welded pipes outside of contained area. Vehicle controls. Any vessels containing mercury will not be opened on site. **Protection:** Spills will drain to the site drainage systems which will be segregated so that any potentially contaminated surface water runoff will be kept separate from clean rainwater runoff. Potential surface water contaminants will include wash-water, runoff from the bunded plant areas and water accumulated in the bunds. Water from these areas will be directed through a treatment system designed to remove oil and grease, and minimise suspended soils to an acceptable level prior to discharge. Only suitably treated water will flow in the stormwater system. The discharge location for the treated stormwater will be subject to further detailed design of the gas plant.	**NO** (assessed as part of the EA and will not be analysed further in this PHA)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
LNG Storage Tank					
10	Uncontrolled release from the LNG storage tank.	Mechanical impact, erosion, vibration, corrosion, operator error, fabrication error. Fire at top of tank (relief valve fire caused by static or lightning) stresses the tank and leads to loss of containment. Natural event causes threat to storage tank (seismic event, storm, flood, bushfire) is discussed in scenario 19 below.	Leak at the inner tank may cause damage to the outer tank leading to a loss of containment of LNG. Localised cold metal brittle failure of structural elements and supports leading to further plant damage and releases. Asphyxiation hazard and cold burn hazard for people in the vicinity of the release. If ignited at source, the LNG may burn as a pool fire. If impingement then possible further tank damage leading to larger and larger release. If the evolved gas is allowed to accumulate it may ignite and burn as a short but intense flash fire or explode as a Vapour Cloud Explosion.	**Prevention:** Design and material, fabrication, assembly and test of the storage tank in accordance with the Codes and Standard. Corrosion and cryogenic failure of equipment prevented by material selection and treatment of supports and structural elements. Welds tested, PM and NDT. Foundation design. Foundation heating. Hydrotest of inner tank. No shell penetration of inner tank. Control of ignition sources. Lightning protection. **Detection:** Low temperature detector in sump with alarm. Gas detectors with alarm (in processing plant and top of tank). CCTV. Pressure sensors on outer tank provide early warning. **Protection:** Spills are directed away from the tank to the trench and sump. The bund is designed to the full contents of the tank. Spacious site layout limiting places where gas can accumulate. Separation distances for thermal radiation and vapour dispersion. Non-combustible insulation at tank walls and roof offers some protection in case of flame impingement. Dry chemical snuffing system (remotely manually activated) on top of tank; isolation valve under each relief valve (normally locked open) used to snuff a small relief valve fire. **Emergency response:** Isolation at source. Firewater system and firewater storage on site to cool adjacent equipment. Dry chemical fire extinguisher skid located in the liquefaction area for use on pool fire. ERP.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
11	Overfilling of the LNG tank resulting in uncontrolled vapour release.	Failure of tank level measurement, operator error, automatic filling valve stuck open.	Liquid into the outer tank with potential for damage to the outer tank (not designed to withstand cold temperatures) and vapour generation/ release from the space between the inner and the other tanks. Loss of production during repair of outer tank.	**Prevention, detection and protection:** Overflow prevention as per Code requirements (includes at least four level gauges, with process alarms and shutdown, and with safety system shutdown (different technologies will be used)). Level gauges read to full height of tank. Control of ignition sources. **Detection:** 24hr/7d monitoring of levels by operators. **Protection:** Slow fill rate allows for reaction time. Freeboard distance to top of inner tank allows for additional response time before over-filling. Sump and bund catches spill and drains away from tank. **Emergency response:** Emergency Response Procedure including call out of Emergency Services.	**YES**
12	Overpressuring of the LNG tank resulting in uncontrolled vapour release.	Failure of upstream protection at the liquefaction allowing high pressure gas to enter the tank, or failure to cool the liquid adequately.	Excessive pressure in the inner tank causes damage to the outer tank (weakest point at the roof to shell joint) and uncontrolled vapour release.	**Prevention:** Preventative maintenance. Pressure reliefs and automatic emergency shut-down and trips of plant initiated from sensors in the inlet plant which would be triggered in case of an overpressure situation. **Detection:** Pressure sensor/gauge (including testing facility) with 24hr/7d monitoring of pressures by operators. Gas detection on part of the plant linked to alarm and remote emergency shut down. **Protection:** Automatic increase of Boil Off Compressor capacity to reduce overpressure (multiple (2) compressors). Overpressure trip interlock (pressure transmitter). Vent to flare to control pressure. As a last resort, pressure reliefs, designed to relieve the largest credible flow. **Emergency response:** Emergency Response Procedure including call out of Emergency Services.	**YES** (as incorporated in the generic likelihood data for the storage tank)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
13	Creation of a partial vacuum in the LNG tank resulting in air ingress and tank top fire.	Pumping out of a closed-in vessel or atmospheric pressure changes.	Excessive vacuum in the storage tank. If design of tank is incapable of holding the under-pressure then possible damage to the outer tank (weakest point at the roof to shell joint), with possibility of air ingress and, if ignition source present, of tank top fire.	**Prevention:** Fuel gas make-up (automatic from the safety system). Pump Trip, Pressure/Vacuum vents. Control of ignition sources. **Detection:** Low pressure trip interlock (pressure transmitter). **Protection:** Vacuum safety devices. **Emergency response:** Emergency Response Procedure including call out of Emergency Services.	**YES** (as incorporated in the generic likelihood data for the storage tank)
14	Stratification (roll over) leads to major vapour release from atmospheric relief valves and severe tank vibration resulting in a tank collapse.	Material allowed to sit for a long period of time resulting in stratification	Eventually, the warm (low density) bottom layer will rise to above the cold (high density) upper layer. When the warmer layer rises to the top it is no longer subject to the hydraulic pressures from the cold layer which may result in extensive major vapour releases from atmospheric relief valves and severe tank vibration. The tank vibration may in turn cause tank collapse.	**Prevention:** Operational practices to not allow material to sit for extended period of time; procedures and training. Monitoring of incoming stream temperature and stream composition information. Option for top and bottom fill and recycle pumps (allows for mixing in tank). The load-bearing bottom insulation to be designed such that it will withstand considerable thermal and mechanical stresses without jeopardising the integrity of the container. Tank bottom temperatures will be monitored continuously and a periodic survey of temperatures will be conducted. **Detection:** Means to detect stratification with density gauge (automatic travelling probe). **Protection:** Relief valves oversized**.** The load-bearing bottom insulation to be designed such that it will withstand considerable thermal and mechanical stresses without jeopardising the integrity of the container. **Emergency response:** Emergency Response Procedure.	**YES** (as incorporated in the generic likelihood data for the storage tank)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
Tanker Loading of LNG					
15	Uncontrolled release of LNG during tanker filling.	Drive-away, failure of hose PM program, mechanical impact, leak in supply pipe, valves, and equipment.	Loss of containment of LNG. Cold metal brittle failure potential. Asphyxiation and injury from exposure to cold material. If ignited at source, the gas may burn as a jet fire. If impingement then possible further plant damage. If the evolved gas is allowed to accumulate it may ignite and burn as a short but intense flash fire or explode as a Vapour Cloud Explosion. Possible impact on the tanker.	**Prevention**: Material selection; robust and secured pipework to code requirements; welds radiographed; hydrostatic testing; design pressure and relief valves; thermal reliefs. Vehicular assess controlled. Approved hoses and regular NDT regime as per Code. Protection against mechanical damage. Drive off protection to ensure shut off valves are closed if truck moves. Tanker filling procedures and checks. **Detection:** Gas and fire detectors and detection of upset operating conditions with subsequent plant trip. Quick / automatic response shutoff valves at tanker loading. Low temperature detection in the sump with alarm and manual shutdown. **Protection:** LNG drains to sump and bund (minimising the surface area for evaporation and removes cold liquid and possible heat radiation from neighbouring structures, vessels etc). Layout to be built outdoors, spacious and free of places where gas can accumulate. **Emergency response:** Isolation at source; firewater system; emergency response procedure.	**YES**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
16	Over-filling the tanker leads to uncontrolled vapour release.	Failure of level gauge on tanker, operator error.	Liquid into vapour return. Excessive filling of tanker may compromise tank design during transport.	**Prevention:** Manned operation. Slow fill rate. Overfill into vapour return and not ground. **Detection:** Level gauge on truck. Weigh bridge will detect an overfilled tanker prior to it leaving the site, allowing for removal of excess material from tanker. **Protection:** Level switch in vapour return sump vessel will shut down LNG flow. **Emergency response:** Emergency response procedures.	**NO** (The risk associa-ted with this scenario will need to be rendered negligible through design and hence this scenario will not be evaluated further)
17	Over-pressuring the tanker leading to uncontrolled vapour release.	Blocking of the vapour return line.	Damage to the tanker leading to vapour release, possibly during transport.	**Prevention:** Manned operation. Slow fill rate. Procedures. **Detection:** Local pressure gauge on truck. **Protection:** Relief valves on tanker truck.	**NO** (As above)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
Whole NGSF Site					
18	Natural event causes failure of LNG tank, structural collapse or other damage to plant and subsequent loss of containment of flammable gas.	Earthquake or land subsidence. Severe storms and cyclones, local flooding, sea level rise or tsunamis Lightning	Damage to plant. Release of LNG, mixed refrigerant or natural gas. If ignition then possibility of flash or jet fire. If massive release and accumulation then possibility of explosion.	**Prevention:** Seismic effect : A site-specific seismic study will be conducted for the site during the detailed design stage; the tank will be designed to meet the required earthquake characteristics of the site (seismic loads shall be calculated in accordance with AS1170.4; API 620 also has specific requirements for LNG tank design/earthquake loads); foundations and subsurface integrity to be reviewed prior to building the storage tank. Land subsidence: The pipeline route and the NGSF are not built on any known areas of mine subsidence. Flood, storm, tsunami: The tank will be built above the flood zone, including allowance for global warming and sea level change. The tank will be located in a bund surrounded by approximately three (3) meter high earth mound which is expected to provide protection against flood levels and against debris. The site is located in excess of 10 km from the coast. Lightning: The site will be protected against lightning strike in accordance with Australian Standard requirements. This will include a combination of an earthing grid under the NGSF for instrument earthing and static earths and lightning rod for the storage tank. **Emergency response:** Passive and active fire protection systems.	**YES** (as incorpora-ted in the generic likelihood data used in the QRA)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
19	Security threat / Terrorism or external mechanical damage causes external mechanical or thermal damage failure of LNG storage tank or other flammable gas handling / process equipment.	Terrorism, vandalism.	Leak of LNG, mixed refrigerant or natural gas. If ignited at source, the LNG may burn as a pool fire and the natural gas will burn as a jet fire. If impingement then possible further tank and plant damage. If the evolved gas is allowed to accumulate it may ignite and burn as a short but intense flash fire or explode as a Vapour Cloud Explosion.	**Prevention:** Security measure on sites. Plant design is robust. Security access to the site will be well controlled. Buffer zone to populated areas limit line of sight to the facility. **Detection:** Intruder detection. Gas and fire detectors on site. **Protection:** Security guards.	**YES** (as incorpora-ted in the generic likelihood data used in the QRA)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
20	Incident at the NGSF causes knock-on effect at neighbouring facility (TAC, at the neighbouring NGSF pipeline or the station).	Thermal radiation from a fire (jet of flash) at the NGSF e.g. at the tank bund or due to a tank top fire. Overpressure from a VCE from LNG or natural gas.	Possible threat to: - adjacent TAC. - NGSF interconnecting pipeline. - Metering station. - other equipment and pipes within the NGSF processing plant.	Separation distances from the NGSF tank and the processing plant to neighbouring locations (TAC, pipelines, station etc.) ensures that the heat radiation from a fire or the overpressure from a VCE are highly unlikely to cause major structural damage (refer to the consequence calculations in Section 5 of this report). Further, the QRA shows (in Section 7.3.4) that the risk of domino effects generated from the NGSF site complies with current criteria for maximum acceptable risk at neighbouring industrial facilities, even if the land around the proposed NGSF site sees further industrial development. The NGSF and low pressure pipelines are buried at a depth of a minimum of 750 mm – thermal radiation or overpressure effect from even a massive incident at the NGSF is not believed to constitute a threat for an operational buried pipeline. Further, a mounded earth wall separates the pipeline from the storage tank and bund, making propagation even less likely. Passive and active fire protection systems and emergency response system.	**NO**

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
21	Incident at neighbouring industrial facility causes knock-on effect at the NGSF.	Fire or explosion at the nearby TAC (e.g. at the potline) or at the natural gas pipelines causes major knock-on effect at the NGSF.	Knock-on effect may cause loss of containment of flammable liquids or gases.	Hazard assessments were conducted for the TAC aluminium smelter in 1995 and 2000, as outlined in the Statement of *Environmental Effects – Modification of Development Consent – Proposed Production Capacity Increase (Ref 39*). The assessments found that the existing facility was not considered to be potentially hazardous based on the dangerous goods on site. Layout of plant and separation distances between neighbouring facilities and NGSF to code requirements. Shutdown and depressurisation of the site. Fireproofing of mixed refrigerant and LNG storages as per code requirements. Fixed monitors and deluge for cooling of affected areas. The risk of an incident at TAC causing domino effects at the NGSF is considered negligible and will not be considered further in this PHA. Future development in the close vicinity of the NGSF will need to consider any potential risks to the NGSF, following Council and possibly NSW Department of Planning requirements.	**NO**
38	Aircraft crash results in process upsets, potential damage to process / storage facilities resulting in hazardous releases	Aircraft crash on the NGSF site.	Potential damage to process / storage facilities resulting in hazardous releases, fire / explosion.	**Prevention:** Relatively low number of take-offs and landings at Newcastle (Williamstown) airport. Air safety requirements. Occupied site relatively small – aircraft crash unlikely.	**YES** (as incorpora-ted in the generic likelihood data used in the QRA)

No	Leak scenario	Possible Causes and Threats	Possible Consequences	Preventative and Protective Safeguards	Carried forward to QRA
39	Transport of potentially hazardous material (e.g. LNG, mixed refrigerants, nitrogen, fuel oil, nitrogen, amin, glycol).	Transport accident leads to damage to tanker. Overfilled LNG tanker causes relief valve to lift.	Release of hazardous material onto the roadways and into the environment causing pollution or, in the case of LNG and mixed refrigerant, causes a threat of release of flammable gas. If release of mixed refrigerant or LNG then asphyxiation risks, risks of cold burns and risk of fire / explosion.	**Prevention:** Australian Dangerous Goods (ADG) Code requirements for LNG tanker transport, including driver training and tanker design and maintenance. Overfill prevention and protection system for LNG tankers. Fuel oil, nitrogen, amine and glycol are very seldom transported and in relatively small quantities. It is expected that a maximum of 60 deliveries per year are sufficient for the operation of the site. The (up to) 1000 forecasted LNG tankers per year (3 or 4 per day) is a relatively low number of dangerous goods tankers leaving an industrial site. It only constitutes a small increase (1.5%) in the already existing dangerous goods traffic on the Pacific Highway at Hexham. Access road to site and access at local intersection are of adequate construction for the use and are maintained / repaired. **Protection:** General transport risks are handled by transport company's safety requirements. Clean up and incident management as per transport company procedure.	**NO** (The assess-ment of risks associa-ted with LNG or mixed refrigerant transport outside of the NGSF site boundary is not included in the scope of this PHA as per HIPAP 6.)

5 CONSEQUENCE ANALYSIS

This section summarizes the modelling and analyses conducted to assess the consequences of the incident scenarios detailed in Table 8. The detailed results of these analyses are presented in Appendix 3.

A set of representative incident scenarios was determined, based on the current design of the Facility and knowledge of similar LNG facilities, applicable codes and standards, and good engineering practice. These scenarios include a range of the hazardous events that have some potential to occur in each area of the facility. In general, these events can be divided into the following categories:

- Moderate releases (punctures), characterised by a hole equivalent to 10% of the cross sectional surface area of the pipe diameter;
- Large releases (ruptures), characterised by a hole with a diameter equal to the pipe diameter or, for vessels and certain process equipment, a hole with a diameter equal to the diameter of the largest attached pipe;
- Massive failure of a vessel, characterised by a release over 10 minutes of the full contents of the vessel;
- Catastrophic failure of a vessel, characterised by an instantaneous release of its contents.

5.1 MODELLING SOFTWARE

Consequence analysis was undertaken using the TNO (the Netherlands Organisation for Applied Scientific Research) Quantitative Risk Assessment program *Riskcurves* (version 7.6) and consequence modelling software program *Effects* (version 8.0). The TNO tools are internationally recognised by industry and government authorities.

The consequence models used within Riskcurves are well known and are fully documented in the TNO Yellow Book (Ref 24).

Essentially, an appropriate release rate equation is selected based on the release situation and initial state of the material. The atmospheric dispersion model for denser-than-air releases - SLAB - is used to model dispersion behaviour for heavier than air vapours such as LNG and mixed refrigerant. The software tool is able to predict when the dispersed gas becomes neutral through incorporation of air and switches model automatically.

5.2 EVALUATION TECHNIQUES

5.2.1 Leak Rates

Riskcurves and Effects model release behaviour for compressed gas, liquid or 2-phase releases from vessels, pipelines or total vessel rupture. Input data includes the type of release, location of release with respect to vessel geometry, pipe lengths etc. and initial conditions of the fluid (i.e. before release).

The release rate is assumed to remain constant until isolation can be achieved - this is a conservative approach as in reality there will be pressure reduction and hence reduction in leak rate.

5.2.2 Duration

The duration of a leak will depend on the hardware systems available to isolate the source of the leak, the nature of the leak itself and the training, procedures and management of the facility. While in some cases it may be argued that a leak will be isolated within one minute, the same leak under different circumstances may take 10 minutes to isolate. Under worst case conditions, such as where there are large quantities of materials between two isolating valves, the release may last even longer. In such cases, the release pressure and hence the release rate will decrease.

The approach used in this study for the failure scenarios identified is to assume the release continues until the inventory has been released, up to a maximum duration of one hour. This is a conservative assumption as the operators have the ability to isolate the leak using remote operated valves.

Where automatic response has been designed into the plant (e.g. in the form of process trips), such response has been taken into account, with the relevant probability of failure of the trip. At this early design, the only process trips included in the PHA aim to prevent overfilling, overpressure and vacuum events in the storage tank which are as per Code requirements.

Leak from vessels are assumed to last until the inventory of the vessel and tanks has been released, up to a maximum duration of one hour.

5.2.3 Pool Dimensions

Once the very cold LNG liquid is released from its normal containment it will begin to boil and evaporate as it is exposed to the relatively hot substrate (land) and air. The Riskcurves model calculates the rate of evaporation and spreading of a pool of liquid. There are three release options which have the following implications on the spreading of a pool of liquid:

1. Instantaneous release: the inventory is released instantaneously, with the associated speed of the pool being very rapid;
2. Continuous release: the inventory is released at a constant rate for a given time period; and,
3. Transient release: the inventory is released at a variable rate for a given time period.

The rate of evaporation will depend on many factors, including climatic and weather, as well as the surface area over which evaporation takes place. A large surface area means a higher degree of evaporation if all other variables remain constant.

Table 9 summarizes the main assumptions made in the calculation of pool spreading and evaporation rates.

Table 9 - Input factors used to model LNG Spreading and Evaporation Rate

Substrate:	Land, average soil
Roughness Parameter:	Majority of incidents: Parkland, bushes, numerous obstacles, equivalent to a roughness factor of 0.5 m[5]. For massive release scenarios (storage tank rupture): Regular large obstacle coverage (forest) , equivalent to a roughness factor of 1 m.
Wind weather data:	6 wind weather categories in 12 different directions, refer Appendix 5.
Release Duration	Duration derived from release rate calculation.

For LNG sumps, bunds (impoundment system) dimensions, refer to Table 7 above.

5.2.4 Dispersion Distances

A gas released will disperse in the atmosphere. At concentrations between 14% (upper flammable limit, UFL) and 5.5% (lower flammable limit, LFL) methane (the main constituent of natural gas and LNG) is flammable. The Riskcurves model is used to estimate the distance to which a release of methane will disperse to half the LFL for momentum driven (high pressure, high velocity releases) and dense gas scenarios respectively. Feed rates for gas dispersion models are taken from gas release rates calculated by Effects.

The Effects consequence model is used to model the release of gas from a pressurized vessel or pipeline where the gas is emitted at high velocity.

Weather Data

Weather conditions are described as a combination stability category and wind speed. This is usually denoted as a combination of a letter with a number, such as *D4* or *F2*. The letter denotes the Pasquil stability class and the number gives the wind speed in metres per second.

Wind speeds range from light (1-2 m/s) through moderate (around 5 m/s) to strong (10 m/s or more). The probability of the wind blowing from a particular direction is displayed graphically as a *wind rose*.

The Pasquil stability classes describe the amount of turbulence present in the atmosphere ranging from *unstable* weather (class *A*), with a high degree of atmospheric turbulence to *stable* conditions (class *F*). Class A would normally be found on a bright sunny day; class D (*neutral* conditions), corresponding to an overcast sky with moderate wind; and class F corresponds to a clear night with little wind.

Weather data for the area has been determined through the meteorological pre-processor CALMET, as sourced from the Air Quality Impact Assessment in the Environmental Assessment (EA) for the development (Ref 43). The data was split up over 12 directions and over 6 wind weather categories and included in

[5] This is conservative as in effect the area around the NGSF is forested with regular large obstacle coverage. By choosing the low roughness parameter the dispersion and incorporation of air into released gas cloud tends to be slower and explosive mass contained in the flammable cloud tends to be higher.

the QRA software modelling program Riskcurves. Further details as to the data used is included in Appendix 3

The probability of each combination of wind/weather category and wind direction (data is split into 12 directions) is used in the calculation of flammable impact, as presented in the table below.

Table 10 – Wind Weather Data Used in the Assessment

WIND WEA-THER	DAY	NI-GHT	SSW	SWW	W	NWW	NNW	N	NNE	NEE	E	SEE	SSE	S
A	6.6	0.0	5.34	2.67	2.84	14.2	12.65	28.56	6.01	5.68	5.01	3.67	5.68	7.69
B	22	0.0	5.29	2.14	4.53	27.16	14.39	14.85	3.71	3.46	4.53	6.26	4.93	8.75
C	13	1.2	7.75	1.6	3.57	28.72	14.39	11.17	3.0	2.3	7.27	9.3	3.2	7.73
D	5.7	0.7	10.07	1.94	1.24	13.43	1.41	12.7	0.53	3.89	11.66	11.48	14.13	17.49
E	0.9	1.5	15.02	6.57	0.94	8.92	0.47	11.75	0.47	5.16	10.33	8.92	6.57	24.88
F	8.9	38	6.94	2.71	3.43	23.15	10.49	12.7	7.01	7.42	7.35	5.99	5.97	6.84

Terrain Effects

Ground roughness effects the turbulent flow properties of wind, hence dispersion of a released material. Terrain effects are taken into account to some degree in dispersion modelling by use of a surface roughness length.

The roughness factor used for all plant scenarios with the exception of the very large LNG storage tank ones is described as *High crops, scattered large objects* in the modelling software. This corresponds to a surface roughness factor of 0.5 m, appropriate to a plant located in a rural area, with some buildings, trees and fences in the vicinity, as well as some undulation of the surrounding land. It is conservative for a release within the NGSF where the actual roughness factor would be close to 3, making for a more turbulent release, faster incorporation of air into the released vapour cloud and quicker dispersion. In the case of the very large scenarios associated with massive leak or rupture of the LNG storage tank, the more correct description of *Regular large obstacle coverage (forest)* (equivalent to a surface roughness of 1m) was used to categorise the terrain.

Time Periods

The time periods *Day* and *Night* are used and assumed to represent the periods 6 am-5.59 pm and 6 pm-5.59 am, respectively (used for societal risk calculations).

Distance to the Lower Flammable Limit

The (US) Federal Energy Regulatory Commission showed (in the *Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*) that typically, LNG released into the atmosphere will remain negatively buoyant (i.e. heavier than air) until after it disperses below its Lower Flammable Level (LFL) (Ref 44).

The length of the dispersing vapour cloud was calculated using Effects (by TNO). The results are listed in Appendix 3.

5.3 HEAT RADIATION AND EXPLOSION OVERPRESSURES

5.3.1 Modelling Techniques - Theory

Heat Radiation

The effect or impact of heat radiation on people is shown in Table 11 below.

Table 11 - Effects of Heat Radiation

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure High chance of injury
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure
35	Significant chance of fatality for people exposed instantaneously

In Riskcurves, heat radiation effects are calculated based on flame surface emissive power (which is dependent on the quantity of material, its heat of combustion, flame dimensions and the fraction of heat radiated), as per the Yellow Book by TNO (in Ref 24). The heat flux at a particular distance from a fire is calculated using the view factor method. The view factor takes into account the distance from the flame to the target, the flame dimensions and the orientation angle between the flame and the target.

The effect of heat radiation on a person is calculated from the probit equation which relates to the probability of fatality to the thermal *dose* received (i.e. the combined heat and exposure time) though the following equations.

$$\text{Probit } Pr = -36.38 + 2.56 \ln(tQ^{1.33})$$

With t = exposure time (sec) and Q = heat flux (W/m^2).

And with the relationship between the probit value and the probability of fatality is calculated as follows:

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

Overpressure

The effect or impact of overpressure is shown in Table 12 below.

Table 12 – Effect of Explosion Overpressure

Overpressure (kPa)	Physical Effect
3.5	90% glass breakage. No fatality, very low probability of injury
7	Damage to internal partitions & joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

In Riskcurves, the Multi Energy method is used to predict the overpressures from flammable gas explosions, as per the Yellow Book in Ref 24. The key feature of the Multi-Energy method is that the explosion is not primarily defined by the fuel air mixture but by the environment in which the vapour disperses.

Partial confinement is regarded as a major cause of blast in vapour cloud deflagrations. Blast of substantial strength is not expected to occur in open areas. Strong blast is generated only in places characterized by partial confinement while other large parts of the cloud burn out without contributing to the blast effects. The vapour cloud explosion is not regarded as an entity but is defined as a number of sub-explosions corresponding to various sources of blast in the vapour cloud, i.e. each confined part of the cloud is calculated as a separate vapour cloud explosion.

The initial strength of the blast is variable, depending on the degree of confinement and on the reactivity of the gas. The initial strength is represented as a scale of 1 to 10 where 1 means slow deflagration and 10 means detonation. For explosions in process plant environments the initial strength is thought to lie between 4 to 7 on the scale.

5.3.2 Calculated Fire Dimensions

Flame dimensions will vary depending on the wind weather conditions. Riskcurves calculates the flame dimensions for each wind weather category and incorporates these into the risk assessment together with their respective probability of occurrence.

Pool fire evaporation and burning rates will also vary depending on the wind weather conditions. Riskcurves calculates the heat radiation from a fire for each wind weather category and incorporates these into the risk assessment together with their respective probability of occurrence.

5.3.3 Calculated Blast Overpressure Dimensions

For a release of pressurised natural gas into an unconfined environment the chances of an explosion is extremely small (or of negligible risk).

A vapour cloud explosion is possible however if some degree of confinement is present, for example in a cramped plant area such as the liquefaction area. Hence, in the unconfined environment of the NGSF pipeline which runs in a wide easement, the risk of a vapour cloud explosion is taken as negligible.

In the case of LNG release and due to the negative buoyancy of this cloud, vapour cloud explosions are taken into account for each release. This is believed to be conservative for releases away from process areas around the storage tank and bund and hence, as these releases are associated with the worst-case incident scenarios for the NGSF, the present hazard and risk assessment is inherently conservative. The risk of a vapour cloud explosion in the NGSF is calculated based on the assumptions in Section 6.2.

5.4 Population Density

Societal risk assesses the risk of a hazardous event occurring in time and space with a human population. The population density of the surrounding area is entered into Riskcurves. As per the convention the population at the NGSF itself is set at zero.

The data used to establish this demographic profile is from the information obtained from the Environment Assessment and from TAC, as referenced in the socio-economic assessment for the development (Ref 15).

6 LIKELIHOOD ANALYSIS

6.1 FAILURE RATES

A summary of all incident scenarios that are incorporated into the hazard and risk assessment are listed in Appendix 3. The frequency of each postulated equipment failure was determined using the data in the table below.

The frequencies used for fixed plant are those in the database documented in the *Purple Book* by the Dutch TNO (Ref 45) and which is a worldwide recognised source of reference for QRAs of potentially hazardous industry.

The frequencies used for below ground gas piping installed as per AS2885 requirements (Ref 19) up to the receiving station are based on the data gathered by the European Gas pipeline Incident data Group (EGIG), (Ref 46) between 1970 and 2007. This data source has been chosen based on the extensive statistical significance of the data available (1,470,000 kilometre-years)[6] and because of the similarities between the Australian Standard requirements and the requirements used in the European countries included in the incident statistics (including Britain, Belgium, France, Netherlands, Ireland, Portugal, Finland, Sweden, Switzerland, Germany).

The pipeline will be designed to meet the *No Rupture* requirement for its entire length, to ensure that there is an upper bound to the consequences of a pipeline failure in High Consequence Areas (HCAs), which are defined as any area of location class T1, T2, S or I and some instances of HI (as per the definitions in AS2885.1. Through this design requirement, the pipeline would be designed not to rupture in case of the highly severe attack by the largest excavator (including one using tiger tooth). An analysis of the EGIG report in Ref 46 shows that the likelihood of a rupture involving the NGSF pipeline would be reduced compared with the statistical data available (by a factor of about 2).

The pipeline will be installed offset from the centreline of the roadway, hence there will only be a small number of locations where it would be possible that an auger could contact the pipe.

Similarly, due to the location and development around the area, the use of a ripper would be extremely rare.

However, as rippers and augers may cause a rupture and as other causes rather than external interference (including ground movement and, highly unlikely corrosion) may result in rupture, this risk assessment has conservatively retained the base statistics for the rupture scenario at the NGSF pipeline. The resulting risk associated with the NGSF pipeline is therefore highly conservative.

[6] As a comparison, the available statistics in Australia are based on (only) 160,000 km-yrs. The available statistics from the US Dept of Transportation Office of Pipeline Safety is based on 970,000 km-yrs but the standards used in the US are believed to be further from the Australian standards than those in use in Europe (as included in the EGPIDG).

Table 13 - Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy[7])
NGSF GAS SUPPLY PIPELINE (400 mm NB) up to the Metering Station	
<20 mm hole – steel pipeline	0.040 per meter
Large hole – steel pipeline[8]	0.075 per meter
Guillotine fracture (full bore) – steel pipeline	0.02 per meter
PIPELINES WITHIN FIXED PLANT	
Leak (outflow is from a leak with an effective diameter of 10% of the nominal diameter, a maximum of 50 mm):	
< 75 mm	5 / m
> 75 mm but < 150 mm	2 / m
> 150 mm	0.5 / m
Guillotine fracture (full bore):	
< 75 mm	1 / m
> 75 mm but < 150 mm	0.3 / m
> 150 mm	0.1 / m
LNG TANK (AS FOR SINGLE CONTAINMENT CRYOGENIC VESSEL)	
Instantaneous release of the complete inventory	5
Continuous release of the complete inventory in 10 min at a constant rate of release	5
Continuous release from a hole with an effective diameter of 10 mm	100
PRESSURE VESSELS (INCLUDING THOSE FOR THE MIXED REFRIGERANTS)	
Instantaneous release of the complete inventory	0.5
Continuous release of the complete inventory in 10 min at a constant rate of release	0.5
Continuous release from a hole with an effective diameter of 10 mm	10

[7] per million per year

[8] EGIG does not define the size of the hole other than that it is more than 20mm and less than the full bore rupture diameter. In this risk assessment, a *large hole* is interpreted as one occupying 10% of the surface area of the pipeline.

Type of Failure	Failure Rate (pmpy[7])
PRESSURISED PROCESS[9] VESSEL	
Instantaneous release of the complete inventory	5
Continuous release of the complete inventory in 10 min at a constant rate of release	5
Continuous release from a hole with an effective diameter of 10 mm	100

In the TNO methodology, failures of flanges are assumed to be included in the failure frequency of the pipeline; for that reason, the minimum length of a pipe is set at 10 metres.

6.2 IGNITION PROBABILITY

TNO's *The Purple Book* (Ref 45) gives the probabilities for ignition, as presented in Table 14 below. The probability increases as a function of the size of the release. For the smallest releases the ignition probability may be as low as 1-2%. Methane is considered to be of *low* reactivity, with correspondingly lower ignition probability. The gases which form part of the mixed refrigerant are mainly of *medium* reactivity.

Table 14 – Probability of Ignition

Release Rate for Continuous Source	Mass released for Instantaneous Source	Pipeline Incidents (total ignition)	On-plant Low Reactivity (Natural gas) Immediate ignition	On-plant Average / High Reactivity (Mixed refrigerant) Immediate ignition
<10 kg/s	<1000 kg	0.04	0.02	0.2
10-100 kg/s	1000-10,000 kg	0.02	0.04	0.5
>100 kg/s	>10,000 kg	0.13	0.09	0.7

The probability of delayed ignition of a formed flammable gas cloud, for on-plant incidents, is taken as per the methodology in the TNO Purple Book (Ref 45), by defining the potential ignition sources on the site and the environment and then applying a factor to account for the effectiveness (and strength) of the ignition source. Each vapour cloud is then assessed in turn to determine the expected foot print and the ignition sources that could be present, and their respective probability of presence. The probability of a certain wind direction occurring is finally also applied to calculate the overall probability of delayed ignition. To simplify, the vapour clouds have been classified as “small”, “medium” and

---

[9] In a process vessel a change in the physical properties of the substance occurs, e.g. temperature or phase. Examples of process vessels are distillation columns, condensers and filters. Vessels where only the level of liquid changes can be considered as pressure vessels.

"large" depending on their maximum surface area. Further details are presented in Appendix 3. The probability of delayed ignition for pipeline incidents are takes as per the Orica Hazard Analysis (HAZAN) Course (Ref 47).

Table 15 – Probability of Delayed Ignition

Size Release (kg/s)	Probability of Delayed Ignition On-plant incidents	Probability of Delayed Ignition Pipeline incidents
Small vapour cloud[10]	0.02	0.1
Medium vapour cloud	0.14	0.22
Massive vapour cloud[11]	0.33	0.43

The probability of an explosion is virtually zero for a natural gas leak out in the open, such as for the gas supply pipeline up to and including the receiving station. In this case, all delayed ignition cases are assumed to result in a flash fire.

The probability of an explosion for the fixed plant (where there may be some confinement) is taken as 40% of the total delayed ignition case, with flash fires accounting for the other 60% of cases. This is as per the methodology in the TNO Purple Book and more conservative than observations of actual incidents in process industry.

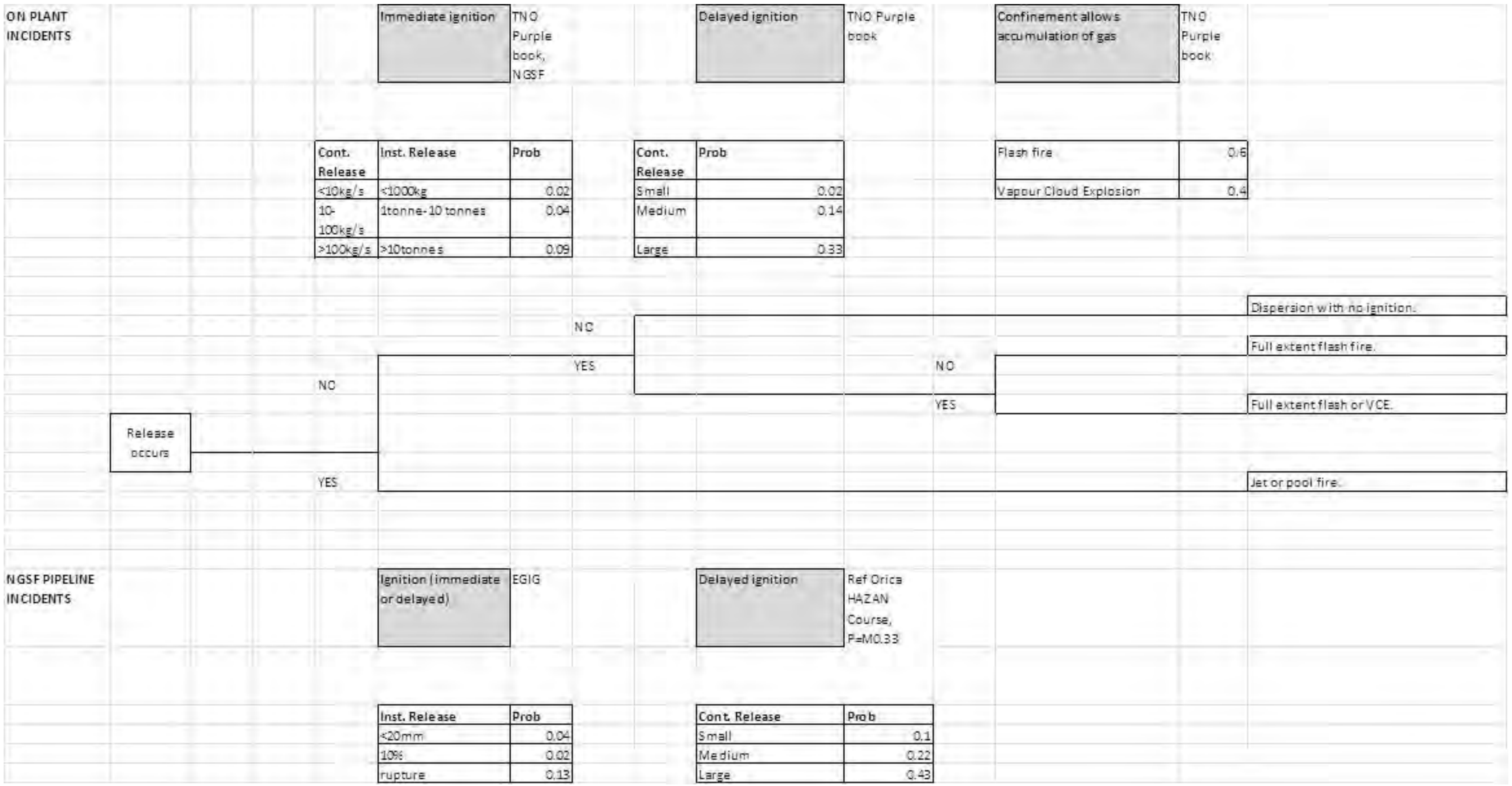
The frequency of outcome of each individual incident scenario is listed in the spread sheet in Appendix 3.

The Event Tree in Figure 7 below shows the flammable even logic used in this assessment for LNG, natural gas and mixed refrigerant releases.

[10] Small release from high pressure pipeline or major release from low pressure pipeline.

[11] Rupture releases or major release from high pressure pipeline.

Figure 7 – Event Tree for Ignition of LNG, Natural Gas or Mixed Refrigerant Releases



Cont. Release	Inst. Release	Prob
<10kg/s	<1000kg	0.02
10-100kg/s	1tonne-10 tonnes	0.04
>100kg/s	>10tonnes	0.09

Cont. Release	Prob
Small	0.02
Medium	0.14
Large	0.33

Flash fire	0.6
Vapour Cloud Explosion	0.4

Inst. Release	Prob
<20mm	0.04
10%	0.02
rupture	0.13

Cont. Release	Prob
Small	0.1
Medium	0.22
Large	0.43

7 RISK ANALYSIS

7.1 RISK CALCULATION – THEORY

The event frequency and hazard consequence data has been combined to produce estimates of risk using Riskcurves, TNO's risk calculation and contour plotting program. Risk levels are calculated by considering each modelled scenario, and combining its frequency with the extent of its *harm footprints*.

Riskcurves considers all scenarios, for each wind-weather combination, and sums their risk contributions across all points. It is then used to plot so-called *iso-risk contours* (i.e. lines of constant risk) to represent *individual risk*. Note that individual risk calculations conservatively assumes that a person is present at a given location, outdoors, all of the time (24 hours per day, 365 days per year), and takes no account of the individual occupancy of the area or the chance that people could escape or seek shelter indoors. In practice the actual risks to persons in these areas would be much lower, since people would only be present outdoors for a fraction of the time.

Riskcurves is also used to plot so called *societal risk* profiles. Societal risk shows the frequency with which it is estimated that **N or more** fatalities will occur as a result of the facilities considered in so called *FN curves*. Societal risk essentially assesses the risk that a scenario will occur in time and in space with a human population.

7.2 RISK CRITERIA

In Australia, tolerable risk is expressed in terms of *individual* and *societal* risk.

Individual risk in the context of a major industrial facility is the risk that a hypothetical individual continuously present at a given location in the vicinity of the facility will be seriously injured as a result of incidents occurring on that facility. It does not take into account whether an individual will actually be present or not at that particular given location.

Individual risk is very useful as it shows the geographical extent and scale of risk presented by a facility, regardless of how many people are exposed to that risk, and can be used relatively easily as a basis for comparing different risks.

Individual risk at a given location is generally defined as the peak individual risk (or the risk of to the hypothetical individual located at the position for 24-hours of the day and 365 days in the year). Since residential areas tend to be occupied by at least one individual all the time, the above definition would easily apply to residential areas. A person indoors would receive natural protection from fire radiation and hence the risk to a person indoors is likely to be lower than to one in open air[12].

For land uses other than residential areas (that is, *industrial*, *active open space* or *commercial*) where occupancy is not 100% of the time, individual risk is still

[12] In this study, the individual risk levels have been calculated for a person in open air.

calculated on the same basis. However, the criteria for acceptability are adjusted for occupancy. The land use criteria used by the NSW DoP criteria are listed below (Ref 1).

Table 16 - Risk Criteria

Land Use	Individual Risk Criteria (per million per year)
Sensitive development (hospitals, schools, child-care facilities, old age housing)	0.5
Residential (and hotels, motels, tourist resorts)	1
Business (commercial developments including retail centres, offices and entertainment areas).	5
Active open space (including sporting complexes)	10
Boundary of an industrial site (facility generating risk) (max risk at boundary of the site which generates the risk)	50
Injury risk criteria (4.7 kW/m^2 and for 7 kPa)	50
Propagation risk criteria (kW/m^2 and for 14 kPa)	50

Societal risk estimates of overall risk to the population. Societal risk takes into account whether an incident occurs in time and space with a population by taking into account the size of the population that would be affected by each incident. By integrating the risk by the local population density over spatial coordinates, the global risk for a given accident scenario is obtained. By adding up the several risk functions (one for each scenario), a global risk function is obtained. In order to estimate the number of people affected, the population density outside of the industrial site under review is determined. Therefore, two components are relevant, namely:

- The number of people exposed in an incident, and
- The frequency of exposing a particular number of people.

In the absence of published criteria in HIPAP 4 (Ref 1), the criteria in the 1996 regional study of Port Botany by the NSW Department of Planning[13] have been used for indicative purposes, as presented in Table 17 below.

[13] then the Department of Urban Affairs and Planning.

Table 17 – Interim Criteria for Tolerable Societal Risk, NSW

Number of fatalities (N) [-]	Acceptable limit of N or more fatalities per year	Unacceptable limit of N or more fatalities per year
1	3×10^{-5}	3×10^{-3}
10	1×10^{-6}	1×10^{-4}
100	3×10^{-8}	3×10^{-6}
1000	1×10^{-9}	1×10^{-7}

The societal risk criteria specify levels of societal risk which must not be exceeded by a particular activity. The same criteria are currently used for existing and new developments in NSW. Two societal risk criteria are used, defining acceptable and unacceptable levels of risk due to a particular activity. The criteria in Table 17 above are represented on the societal risk (f-N) curve as two parallel lines. Three zones are thus defined:

- Above the unacceptable/intolerable limit the societal risk is not acceptable whatever the perceived benefits of the development.
- The area between the unacceptable and the acceptable limits is known as the ALARP (as low as reasonably possible) region. Risk reduction may be required for potential incidents in this area.

Below the acceptable limit, the societal risk level is negligible regardless of the perceived value of the activity.

In addition to quantitative criteria, qualitative guidelines are also given to ensure that off-site risk is prevented and where that is not possible, controlled. For new proposals, in addition to meeting the quantitative criteria, risk minimisation and use of best practice must be demonstrated. These terms imply:

- **Risk Minimisation:** Risks should be reduced to As Low As Reasonably Practicable (ALARP), regardless of calculated risk levels and criteria.
- **Best Practice:** Industry best practicable should be used in the engineering design, and industry best practice management systems should be used for the operation of new plant.

7.3 Quantified Risk Results

7.3.1 Individual Risk of Fatality

Individual risk contours are shown in Figure 8. The results show the following:

A. Natural Gas Storage Facility

The maximum risk level at the site boundary is 7.5×10^{-6} per year.

Risk criterion for residential areas: The 1×10^{-6} per year risk contour, which is applicable for residential areas, extends up to about 310 meters beyond the

NGSF site boundary in the southerly and northerly directions, about 120 meters in the westerly and 80 meters in the easterly direction.

The risk of fatality at the nearest residential area 1.6 kilometres from the NGSF is about 3 x 10^{-12} per year. This is less than the risk of dying from a meteorite (Refer 2). It is well below the maximum tolerable limit of one chance in a million per year (1 x 10^{-6} per year).

Risk criterion for active open space: The 10 x 10^{-6} per year risk contour for active open space is contained within the NGSF site boundary. The risk of fatality at the nearest active open space, e.g. the Hunter Region Botanical Gardens or the nearby public roads, is well below the criterion of ten chances per million years (10 x 10^{-6} per year).

Risk criterion for industrial areas: The 50 x 10^{-6} per year risk contour for industrial buffer is contained within the NGSF site boundary. On this basis there are no limitations from a land use risk criteria point of view to limit industrial development around the NGSF site.

The risk of fatality at the nearest industrial area, i.e. the TAC is less than 1x10^{-9} per year which is well below the criterion of fifty chances per million years respectively (50 x 10^{-6} per year) and it is even less than the criteria for acceptable risks for sensitive developments such as schools and hospitals.

Risk criterion for sensitive development: The risk criterion for any sensitive development (0.1 x 10^{-6} per year) extends well beyond the NGSF site boundary in all directions (about 580 meters to the south and north, 360 meters to the west and 340 meters to the east). It does not however extend anywhere near any neighbouring sensitive developments such as nursing homes or schools etc.

Note that all data used in this risk assessment are for the NGSF operating 100% of the time and at full capacity with the LNG storage tank being filled to capacity 100% of the time. The results are valid though conservative for a NGSF which operates at full capacity only for 50% of the time and for the rest of the time either half full to quarter full (25% of the time) or quarter full to empty (25% of the time).

Major Risk Contributors: The major risk contributors to the 1x10^{-6} per year and the 0.1x10^{-6} per year risk contours are listed in Table 18 below.

Table 18 – Major Risk Contributors

Scenario	Percent contribution to the 1x10^{-6} per year contour	Percent contribution to the 0.1x10^{-6} per year contour
LNG storage tank catastrophic rupture	50%	50%
LNG storage tank complete release over 10 minutes	50%	50%

B. Natural Gas Storage Facility Pipeline and Receipt Station

Risk criterion for residential areas:

- The 1 x 10^{-6} per year risk contour (applicable for residential areas) for the NGSF pipeline is never met, i.e. the risk is below 1 x 10^{-6} per year at all points away from the pipeline.
- The 1 x 10^{-6} per year risk contour for the NGSF receiving station reaches about 15 meter from the centre of the station. This will most likely coincide with the hazardous area classification of this station.

Risk criterion for active open space: The 10 x 10^{-6} per year risk contour for active open space is never reached for the NGSF pipeline or the receiving station. The risk of fatality at the nearest active open space is well below the criterion of ten chances per million years (10 x 10^{-6} per year).

Risk criterion for industrial areas: The 50 x 10^{-6} per year risk contour applicable for industrial development is never reached for the NGSF pipeline or the receiving station.

Risk criterion for sensitive development: The risk criterion for any sensitive development (0.1 x 10^{-6} per year) extends 110 meters from the NGSF pipeline and about 70 meters from the centre of the receiving station.

7.3.2 Societal Risk of Fatality

Societal risk is presented in Figure 9. The societal risk of fatality falls within the acceptable risk zone. It never enters the unacceptable region. Note that societal risk only looks at risk to neighbouring landuse and not at risk to staff and people present on the NGSF site. This will be considered during the detailed design process and through the MHF Safety Case process.

7.3.3 Injury Risk

The injury risk from the NGSF is presented in Figure 10 below. This contour shows the 50 x 10^{-6} risk of injury from 4.7 kW/m^2 heat radiation and 7 kPa overpressure as per the NSW Department of Planning risk criteria (Ref 1).

The 50 x 10^{-6} per year risk contour for injurious levels to heat radiation and overpressures is contained within the site boundary. The risk of injury at the nearest residential area is well below the criterion for new installations of fifty chances per million years (50 x 10^{-6} per year).

7.3.4 Propagation Risk

The risk contour for levels of heat radiation and overpressures which may be damaging to process equipment (23 kW/m^2 and 14 kPa as per the NSW DoP risk criteria - Ref 1) is presented in Figure 11 below. The 50 x 10^{-6} per year risk contour, representing the maximum risk of propagation to neighbouring industrial facilities as per the DoP risk criteria, is contained within the site boundary. The risk of propagation at the neighbouring TAC and other industries in the vicinity from the site is negligible.

Figure 8 - Individual Fatality Risk Contours, Gas Storage Facility

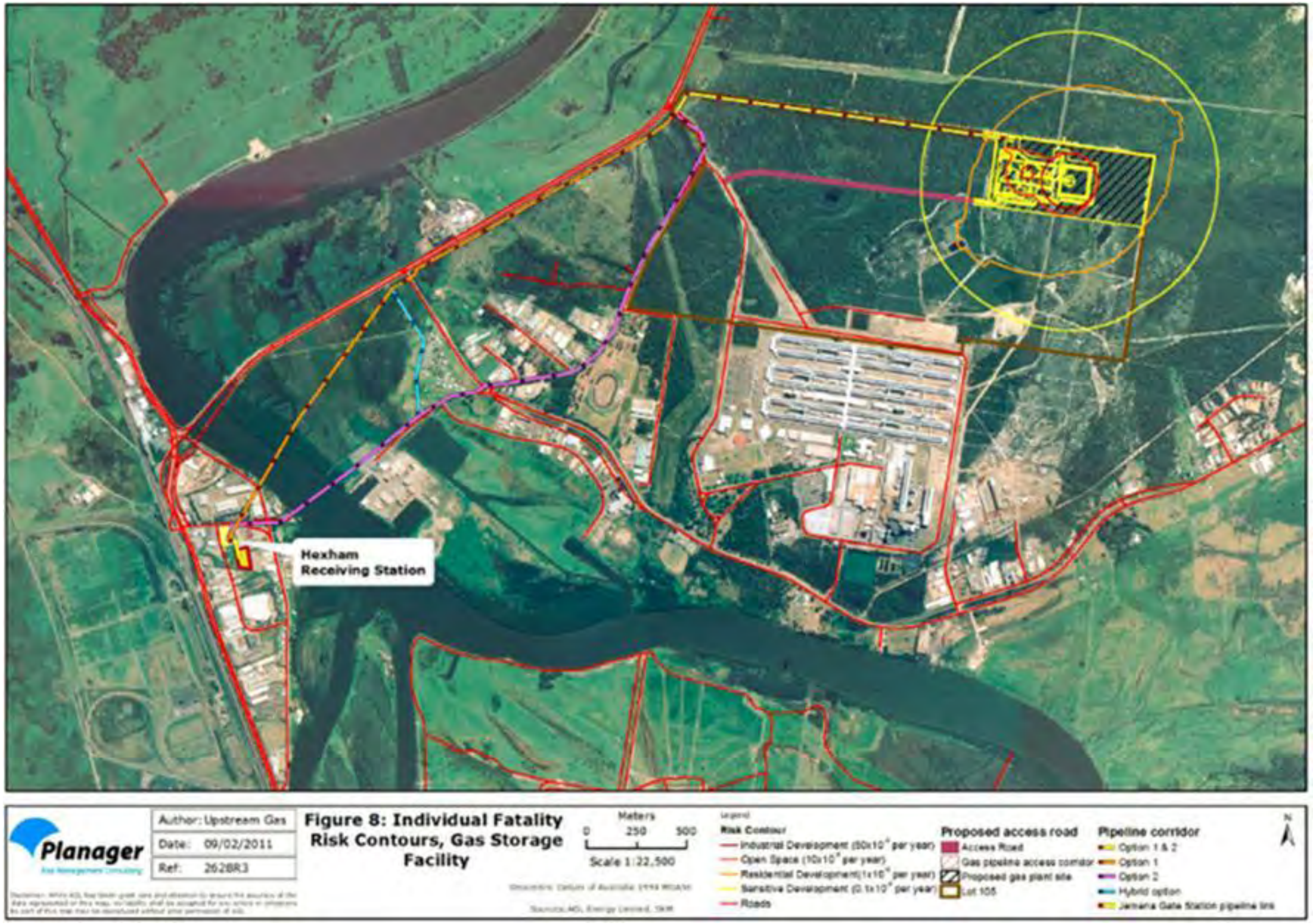


Figure 9 - Societal Risk, Gas Storage Facility

Figure 10 – Injury Risk, Gas Storage Facility

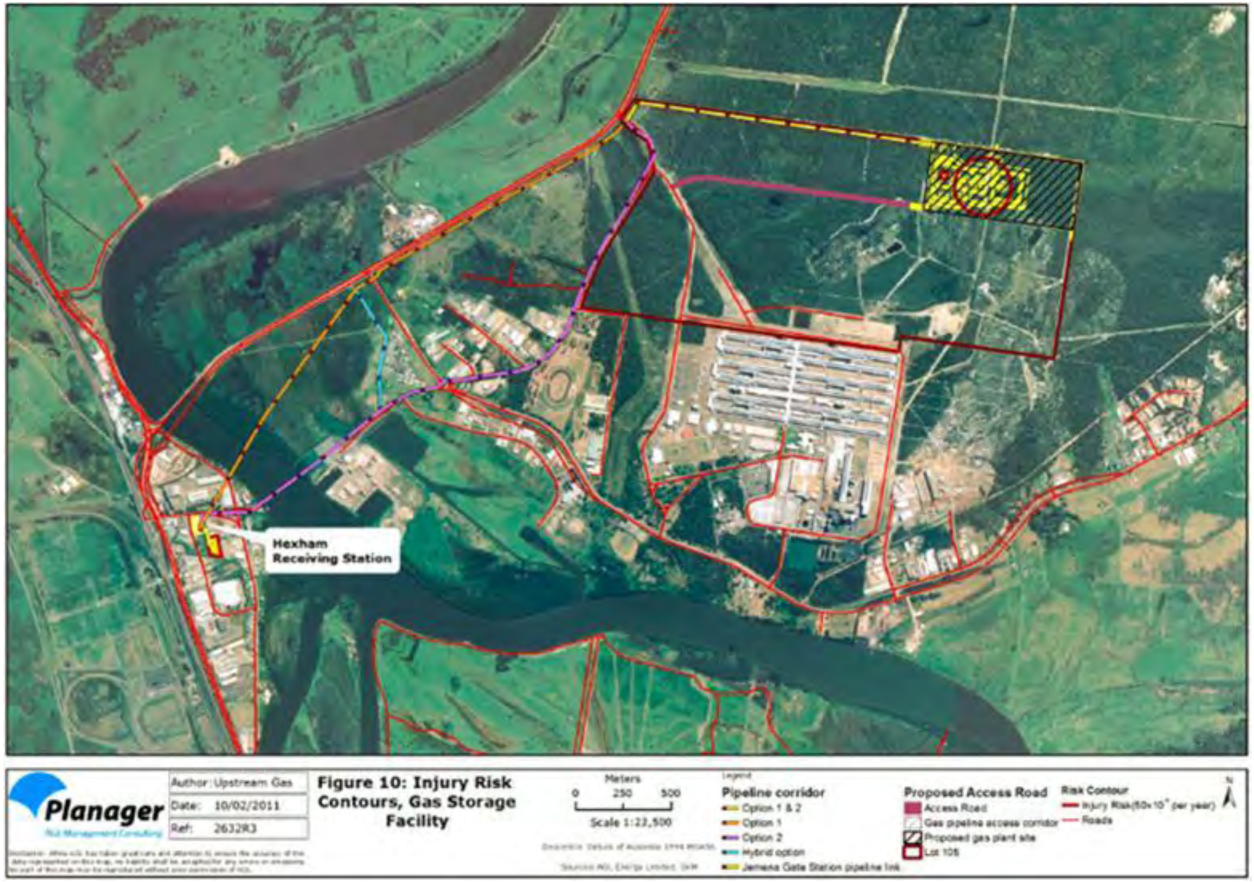


Figure 11 – Propagation Risk, Gas Storage Facility

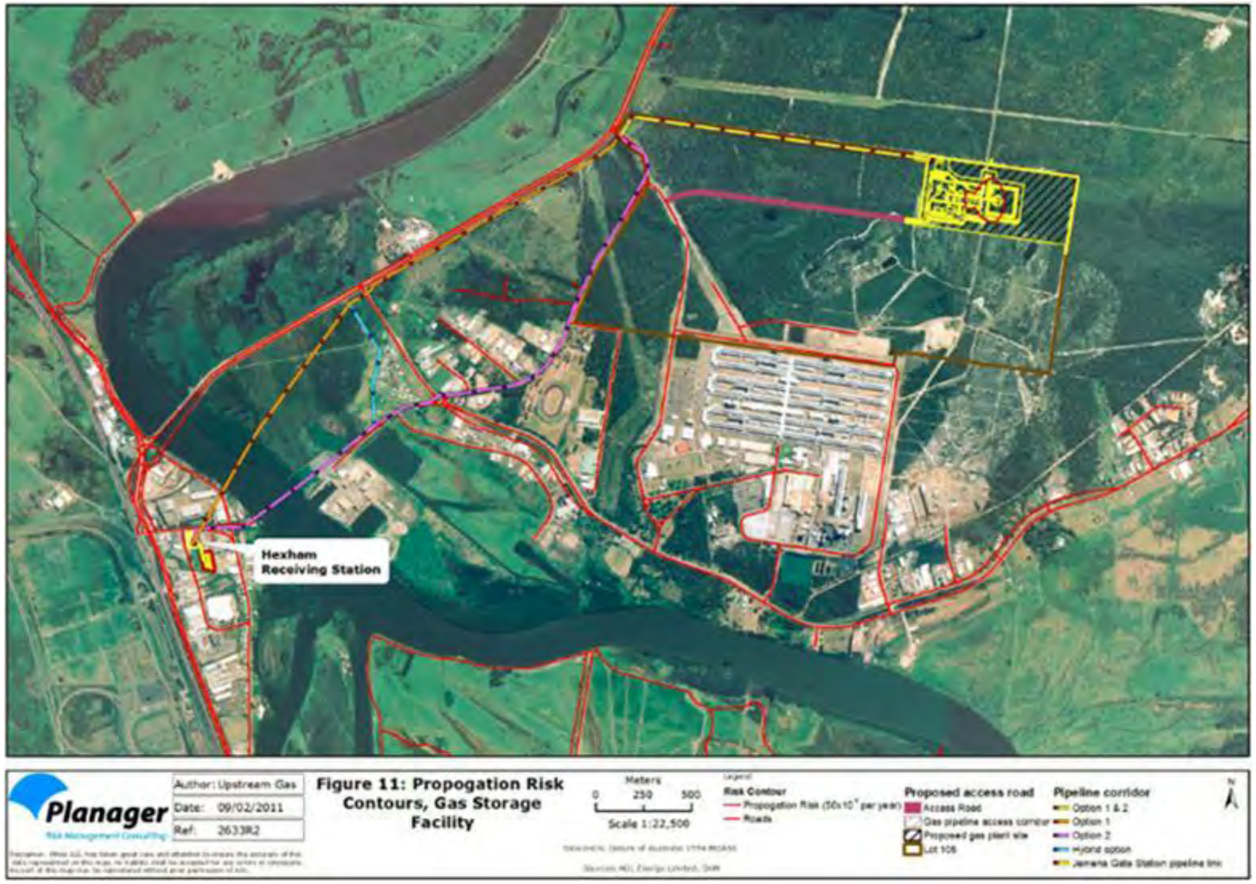


Figure 12 – Individual Fatality Risk Transect, NGSF Pipeline

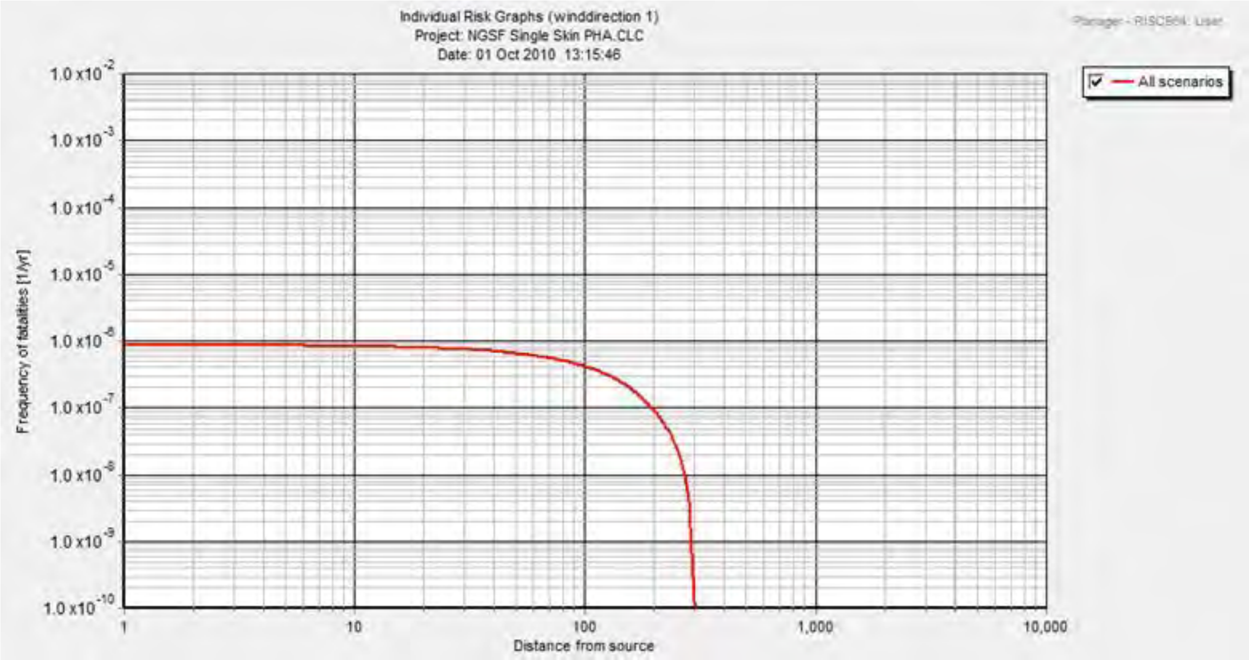
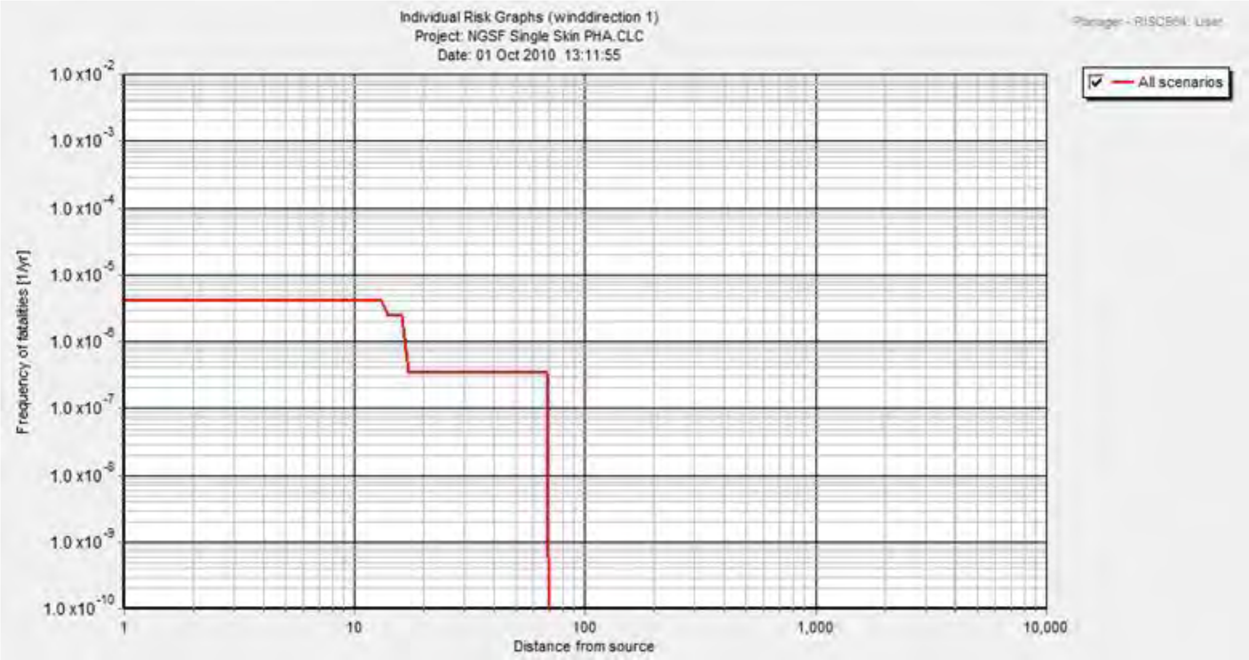


Figure 13 – Individual Fatality Risk Transect, NGSF Receiving Station



8 CONCLUSION AND RECOMMENDATIONS

8.1 OVERVIEW OF RISK

The main hazard associated with the proposed project is associated with the handling of natural gas and LNG which are flammable gases at atmospheric conditions.

Hazards may arise in fixed plant, storage, and pipelines. The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;
- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;
- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (for example a so called jet fire or a pool fire) or a flash fire. If there is confinement, such as in the cramped plant area at the liquefaction unit, vapour cloud explosion is possible;
- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result.

8.2 ADHERENCE TO RISK CRITERIA

The detailed design has not been completed as yet for this development. Despite the fact that many of the assumptions in this hazard and risk assessment are conservative, the results show that the risk associated with this development falls within acceptable limits.

The quantitative risk assessment (QRA) showed that all landuse criteria, as defined by the NSW DoP (Ref 1) are met. The risk at any nearby residential areas, open spaces and sensitive development is well below the maximum tolerable risk criteria. The risk associated with the NGSF does not preclude further industrial development in the vicinity of the site.

From an adherence to generally accepted risk criteria point of view the proposed site in Tomago near Newcastle is acceptable for the proposed Gas Storage Facility and for the interconnecting pipeline. The proposed site for the receiving station is also acceptable.

The most stringent risk criteria, as set by the NSW Department of Planning for acceptable risks in industrial installations, are adhered to.

8.3 ACCEPTABILITY OF OTHER RISKS AND HAZARDS

8.3.1 Natural Hazards

A. Seismic Hazard

The risk from seismic effects will be minimised through the use relevant Australian or International standards. To this regard, a seismic hazard review will be conducted for the site during the detailed design stage and for example the tank will be designed to meet the required earthquake characteristics of the site.

B. Land Subsidence

The risk of land subsidence is minimal and there are no known areas of mine subsidence under the proposed site for the NGSF, the Hexham receiving station or the interconnecting pipeline.

C. Lightning

The risk from lightning strike will be minimised through the use relevant Australian or International standards.

D. Bushfire

A bushfire risk assessment (Ref 29) determined a buffer zone of 25 meters to the NGSF in general and of 31m to the LNG storage sank to minimise the risk of a bushfire impacting on the site. This buffer zone will be maintained throughout the operation of the NGSF, minimising the risk of a bushfire initiating a fire at the NGSF.

The risk of an incident at the NGSF initiating a bushfire is minimal. Potentially hazardous consequences from the majority of the fire scenarios remain well within the site boundaries. The exception is the massive (barely credible) scenario where the LNG storage tank ruptures and fills the bund and then catches fire – while it is possible that such an incident could initiate a bushfire the likelihood of the event extremely low and the incremental risk of a bushfire from the NGSF is minimal compared with the inherent risk of bushfires in this area.

E. Storm Surges and Flooding

The NGSF, located well above sea level and at 10 km from the coast, is protected against any risk from storm surges, waves and other causes of flooding.

F. Tsunamis

The likelihood of a tsunami having a detrimental effect on the NGSF is considered very low.

G. Summary – Natural Hazards

The risk of impact from natural hazards, including seismic effects, bushfires and floods, has been shown to be minimised through use of relevant Australian or International standards.

8.3.2 External Hazards

A. Aircraft Crash

The risk associated with an aircraft crash is minimal and has been calculated to be similar to the risk of a meteorite strike.

B. Incident at the NGSF Causes Knock-on Effect at Neighbouring Facility

Consequence calculations show that heat radiation or overpressure from credible scenarios at the NGSF are highly unlikely to cause major structural damage at any neighbouring facility, including the TAC, the NGSF pipeline and the receiving station.

Propagation risk calculations show that the current criteria for maximum acceptable risk at neighbouring industrial facilities is met at the boundary of the NGSF. On this basis there are no limitations from a land use risk criteria point of view to limit industrial development around the NGSF site. Note that the cumulative effects of increased industrialisation in the Tomago area would need to be assessed on a case by case basis as part of Council and possible NSW DoP development requirements.

The risk of propagation at LNG storage tank due to the NGSF Pipeline is below the criteria for maximum acceptable risk at neighbouring industrial facilities.

B. Incident at Neighbouring Industrial Facility Causes Knock-on Effect at the NGSF

The risk of an incident at TAC causing domino effects at the NGSF is negligible.

8.3.3 Intentional Acts

A comparison on the risk of terrorist threats of the NGSF compared with other industrial facilities indicate that the Tomago site is lower in exposure compared to the other site LNG (and other industrial) locations. The (current) overall low threat environment in Australia is also a factor.

8.3.4 Road Transport Risk

The overall risk associated with the transport of dangerous goods associated with the proposed development is low and the proposed LNG tankers do not introduce an excessive additional risk to the risk associated with dangerous goods traffic at the Pacific Highway at Hexham.

8.3.5 Cumulative Risk

Currently there are no existing neighbouring industrial facilities immediately adjacent to the proposed NGSF, with the exception of TAC which is situated 800 meters to the southwest of the new facility.

However, the surrounding area is zoned industrial use and therefore it can be assumed that the area around the proposed site has the potential to be developed for future industrial use.

At this point there are no proposals regarding the nature of any developments, and hence no risk assessments of any other proposed facilities are available.

Regardless, examination of the risk contours presented in Figure 11 shows that the criterion for industrial land use (50 x 10^{-6} per year) is contained within the site boundary.

This suggests no or minimal risk of propagation from the NGSF onto any future industrial use neighbouring the proposed facility. It also suggests minimal impact to the risk contours of other facilities from the NGSF, assuming other facilities also meet the applicable risk criteria.

8.3.6 Risk to the Biophysical Environment

Risk to the biophysical environment from accidental releases of hazardous material will be minimised throughout the design, operation and maintenance process of plant and equipment. Bushfire breaks around the facility will be required to prevent fires from the facility impacting bush and vice versa – the bush fire breaks will be minimised while ensuring sufficient protection to and from the surrounding bushland. Further, spills outside of bunded areas will drain to the site drainage systems.

8.4 OVERALL CONCLUSION

The construction, commissioning and operation of the proposed development will be subject to a rigorous governmental scrutiny and to the safety case process, safeguarding delivery and operation of the development in a manner that minimises the risk to workers, contractors and the community.

The safety, efficiency and stability of the proposed NGSF will be achieved through the use of high level safety systems, regular preventative maintenance programs, detection and protective measures. Security measures will include security patrols, protective enclosures, lighting and monitoring equipment.

The preliminary hazard and risk assessment of the proposed NGSF and it's associated NGSF Pipeline has found that the levels of risks to public safety from the site are within generally accepted safety and risk guidelines.

From the point of view of adherence to land use risk criteria the proposed Tomago site would be acceptable for the proposed development. The potential for accidents is understood and the design of the facilities will emphasise minimisation of the probability of an incident happening and mitigating an incident if it did occur.

The present risk assessment has shown that the overall risk associated with the proposed development is low and does not introduce an excessive additional risk to the surrounding area.

8.5 RECOMMENDATIONS

Where possible, risk reduction measures have been identified throughout the course of the study in the form of recommendations, as follows:

Recommendation 1: The hazard and risk assessment to be reviewed once detailed design and HAZOPs have been completed for the proposed development to ensure that the assumptions made in this hazard and risk assessment remain valid though conservative.

Recommendation 2: An audit of AGL's Health, Safety and Environment Management System is conducted within 12 months after commissioning of the proposed NGSF. This audit should focus on the management of potential major hazards associated with the development. The DoP Hazard Audit Guidelines can be used as a basis for this audit.

Recommendation 3: AGL should develop an Emergency Response Plan and coordinate procedures with the adjacent industrial facilities and with local emergency planning groups; fire brigades; state and local Police; and appropriate governmental agencies. This plan should include, at a minimum:

- designated contacts with state and local emergency response agencies;
- scalable procedures for the prompt notification of appropriate local officials and emergency response agencies based on the level and severity of potential incidents;
- procedures for notifying adjacent industries, residents and recreational users within areas of potential hazard;
- evacuation routes/methods for residents, business users and other public use areas in the vicinity (including if the access road becomes unavailable);
- locations of permanent sirens and other warning devices;
- an ―emergency coordinator" to be available on site at all times;
- plans for initial and continuing training of plant operators and local responders, along with provisions for periodic emergency response drills by terminal emergency personnel; first responders; emergency response agencies; and appropriate federal, state, and local officials.

Further, reference to the MHF requirements for emergency planning should be made.

The appropriate governmental agencies (including the NSW WorkCover MHF Team and the NSW Fire Brigades) should review and approve the Emergency Response Plan.

Recommendation 4: A security assessment should be carried out to ensure security arrangements are acceptable for the NGSF as per the requirements for Major Hazard Facilities.

Recommendation 5: Investigate placing compressor in a shelter rather than fully enclosed (subject to noise criteria) to minimise risk of accumulation of flammable vapours.

Recommendation 6: The risk of cold metal brittle fracture should be considered in the design of the proposed plant and be verified during the

HAZOP and Safety Integrity Level (SIL) Studies. This initiating cause is not considered further in the present risk assessment and is effectively assumed to be negligible compared with other, more generic, failure events.

Recommendation 7: Review risk reduction from the use of insulating concrete inside the LNG impoundment trenches and sump.

Recommendation 8: Review risk reduction from additional mitigation of vapour generation in impoundment system.

Recommendation 9: During detailed design, determine need for automatic shutdown (trip) requirements.

Recommendation 10: Overfill protection system for tanker loading to be developed during detailed design.

Recommendation 11: Overpressure protection system for tanker loading to be developed during detailed design.

Recommendation 12: It is recommended that the detailed design of the flare system be reviewed using Hazard and Operability (HAZOP) study techniques, particularly for abnormal operations including flare operations.

Recommendation 13: Investigate lightning protection for the top of the tank.

Recommendation 14: Request restricted airspace.

Recommendation 15: Review need for aircraft warning light or other device on high point of facility.

Recommendation 16: Pipelines located in the same easement to be separated so as to protect the adjacent pipeline from radiative heating from a neighbouring pipeline.

Appendix 1

Properties of Hazardous Materials

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Appendix 1 – Properties of Hazardous Materials

A1.1 Physical Properties of Hazardous Materials

Below are listed the physical properties of the hazardous materials used at the NGSF.

Table A1.1 below lists the flammability of LNG and natural gas compared with several compounds. Table A1.2 compares the physical properties of some common hydrocarbons. Table A1.3 shows the typical composition of natural gas.

Methane (the main constituent of natural gas) and propane and butane (the main constituents of mixed refrigerants) are highlighted.

Table A1.1 - Flammability Limits for Common Fuel Compounds (at 25°C)

Fuel	Lower Flammable Limit (% by volume in air)	Upper Flammable Limit (% by volume in air)
Methane	5.5	14.0
Butane	1.6	8.4
Propane	2.1	9.6
Ethanol	3.3	19.0
Gasoline	1.4	7.8
Isopropyl alcohol	2.0	12.7
Ethyl ether	1.9	36.0
Xylene	0.9	7.0
Toluene	1.0	7.1
Hydrogen	4.0	75
Acetylene	2.5	8.5

Table A1.2 - Properties of Common Hydrocarbons

Fuel	Formula	Heat of Combustion (kJ/kg)	Ignition Temp (°C)	Boiling Point (°C)	Ignition Energy (mJ)
Methane	CH_4	55.5	650	-162	0.21-0.47
Ethane	C_2H_6	51.9	472	-89	0.24-0.42
Ethylene	C_2H_4	50.3	490	-104	N/A
Acetylene	C_2H_2	49.9	305	-84	N/A
Propane	C_3H_8	50.3	450	-42	0.25-0.31
Propylene	C_3H_8	48.9	455	-48	N/A
Propyne	C_3H_4	48.3	NA	-23	N/A
Octane	C_8H_{18}	47.9	NA	126	N/A

Table A1.3 - Typical Composition of Natural Gas

Component	Unit	Average
Methane	mole %	95.46
Ethane	mole %	0.84
Propane	mole %	0.12
i-Butane	mole %	0.01
n-Butane	mole %	0.01
i-Pentane	mole %	0
n-Pentane	mole %	0
Hexane+	mole %	0

Component	Unit	Average
N_2	mole %	1.65
CO_2	mole %	1.72
O_2	mole %	0.2

A1.2 Factors Influencing a Flammable Outcome

Assumptions made in addressing or analysing these variables can have a significant impact on estimates of the potential hazards associated with a spill are discussed in Table A1.4 below.

Table A1.4 - Factors Influencing a Flammable Outcome

Type Incident	Factors
Jet (or torch) fire	**Natural gas or gaseous phase of the mixed refrigerant:** In case of ignition at source the gas would burn in a so called *jet* (or *torch*) fire. The thermal radiation from a jet fire is largely determined by the length and width of the jet. The length and width depend on the size of the hole and on the pressure of the natural gas. Jet fires tend to have relatively small areas of impact.
Pool fire	**LNG and liquid phase of the mixed refrigerant:** In case of ignition at source released material would burn in a so called *pool fire.* The thermal radiation hazard from a pool fire is largely determined by the flame size and flame brightness which will vary with pool diameter. The flame height depends on how well the flame can entrain air for combustion. This in turn depends on the upward momentum and buoyancy of the upward flow of fuel and hot combustion gases. This risk assessment has assumed that in case of an ignition of a pool of LNG or mixed refrigerant, the pool will burn as a single, coherent pool fire which can be maintained also for scenarios of large pool diameters. This is a conservative assumption as shown in the Sandia report (Ref 26) due to the inability of air to reach the interior of a fire and maintain combustion on a large LNG pool. Instead, the flame pool envelope would break up into multiple pool fires (referred to as *flamelets*), resulting in shorter flame heights, less heat radiation and thereby decreased size of the thermal hazard zone[14]. The Riskcurves software models the pool fire as a circular pool of equivalent diameter of the *dyke* or sump to which the flow of LNG or mixed refrigerant liquid would run as per the gradient of the floor surface.
Flash fire / Fireball	**Natural gas, LNG or mixed refrigerant:** If the vapour cloud is allowed to form without ignition at source and is then ignited at a distance away from the release it will cause the vapour to burn back to the spill source, resulting in a *flash fire*. Natural gas, being buoyant and much lighter than air would require confinement for a release to result in a flash fire. Natural gas is less reactive than other commonly used industrial fuels. Combustion will usually progress at low velocities and will not generate significant overpressure under normal conditions. A flash fire generates relatively low pressures having a low potential for pressure damage to structures. The heat radiation is very intense but over a very short time.
Explosions	**Natural gas, LNG or mixed refrigerant:** Certain conditions might arise causing an increase in burn rate that does result in overpressure. If the fuel-air cloud is confined (e.g. trapped between vessels or buildings), the flame front would be very turbulent as it progresses through or around obstacles, or

[14] In reality, L/D (height/pool diameter) would probably be much smaller than that assumed by the correlations in many studies, which predict an L/D ratio between 1.0 and 2.0. A more realistic ratio could be less than 1.0 (Ref [Zukoski 1986] [Corlett 1974] [Cox 1985])

.

Type Incident	Factors
	encounters a high-pressure ignition source, a rapid acceleration in burn rate might occur which could result in a pressure event. Methane is normally the main constituent of the vapour and methane is the least reactive of the common hydrocarbon fuels. It has a lower burning velocity, a tendency to undergo flame quenching at high turbulence levels and a large detonation cell size (Ref 48). Explosion experiments with LNG in large congested regions found that it is only the portion of the methane cloud that overlaps the congested region that contributes to the generation of significant overpressure. This is in marked contrast to fuels such as the mixed refrigerant (methane, propane, ethylene, butane, i-pentane and nitrogen) where much more of the cloud will participate in the explosion. The factors that influences the severity of the explosion include the following: (1) the concentration and composition of the gas within the mixture; (2) the amount and type of any congestion present (size, orientation); (3) the amount and type of confinement present (size, failure pressure); (4) nature of the ignition source; (5) size of the cloud. Factors such as the volume blockage and size of the obstacles within the congested region were identified as important parameters in congested explosions. The probability of a vapour cloud explosion involving natural gas and LNG is minimised by the open, spacious layout of the facility but it is possible in case of a release around the processing units or where a release enters a building. The potential for vapour cloud explosion is taken into account in the present risk assessment on a scenario-by-scenario basis where the effects of an explosion involving the flammable portion of the cloud located within the processing unit is assessed in terms of probability and consequence.
Roll Over	**LNG tank only:** Roll over is a phenomenon which can occur in cryogenic storage tanks where the material is allowed to sit for a long period of time. Heat leaks into the walls and is dissipated from the surface layers by evaporation. Evaporation from the lowest layers is prevented by the hydraulic pressure and stratification may occur (with a dense, cold layer over the top of a warm, less dense layer). Eventually, in the absence of continuous mixing, the warmer layer rises to the top, changing places with the cooler layer. Because the warmer layer is now no longer subject to the former hydraulic pressure, extensive vaporisation occurs. This can result in major vapour releases from atmospheric relief valves and severe tank vibration. Roll over is a known phenomenon in LNG tank design and is prevented through design and through procedural control. Any damage to the tank, should it occur, is prevented through pressure relief design.
Rapid Phase Transitions (RPT)	**Not applicable for this development:** The *Rapid Phase Transitions* (RPT) phenomenon is not considered applicable for the present risk assessment. RPT occur typically in case of a release of LNG on water when the temperature difference between a relatively hot liquid (water) and a cold liquid (LNG) is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid (Ref **Error! Bookmark not efined.**). A release of LNG on water is not considered as a credible event for the present development.

Type Incident	Factors
Asphyxiation	**Natural gas, LNG and mixed refrigerant:** Natural gas is considered a simple asphyxiant. It has low toxicity to humans. Due to its buoyancy, any release of natural gas in credible proportions from operations of this scale, in the open, would not present an asphyxiation hazard. With standard confined space entry procedures and appropriate security arrangements to prevent unauthorised access, the risk associated with asphyxiation from natural gas should be minimal. In a large-scale LNG or mixed refrigerant release, the cryogenically cooled liquid LNG would begin to vaporize upon release. If the vaporising gas does not ignite, the potential exists that the vapour concentrations in the air might be high enough to present an asphyxiation hazard to the operators, maintenance workers, emergency response personnel, or others that might be exposed to an expanding vaporization plume. Although oxygen deficiency from vaporization of a spill should be considered in evaluating potential consequences in an emergency, this should not be a major issue because flammability limits and fire concerns will probably be the dominant effects in most locations. Nitrogen is a gas used under pressure. It has many uses and is often found in industrial applications. It is considered a simple asphyxiant that is without other significant physiologic effects. Inhalation of nitrogen is dangerous only when it lowers the available oxygen in air to below life-sustaining levels. The principal hazard associated with liquid nitrogen is rapid freezing of fingers, hands, or other tissues that contact the liquid (Ref 49).
Cryogenic Burns and Structural Damage	**LNG, mixed refrigerants and nitrogen:** If LNG, mixed refrigerants or nitrogen comes in contact with the skin, it can cause cryogenic burns. A breach of the vessels and pipes containing these materials may have negative impacts on people and property near the spill, including operators, maintenance personnel or emergency personnel. Extremely cold fluids such as LNG can have a very damaging impact on the integrity of many steels and common plant structural connections, such as welds.
Boiling Liquid Expanding Vapour Explosion (BLEVE)	**Mixed refrigerant storage only:** Existing knowledge rules out the formation of a BLEVE in the case of LNG. Hence, the dangers of BLEVEs are not considered applicable for LNG. However, the mixed refrigerants will be stored in pressure vessels and BLEVEs are possible for these materials.

Appendix 2

Industry Standards / Regulatory Compliance

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Appendix 2 – Industry Standards / Regulatory Compliance

All systems handling dangerous goods will need to comply with the appropriate Acts, Regulations and Codes in their latest edition. Some of the most relevant are listed below (note that this list is not exhaustive and it is the responsibility of the designers to ensure that the appropriate codes and standards are met):

- New South Wales Occupational Health, Safety and Welfare Act and its associated legislation including but not limited to the Dangerous Goods Regulations, Construction Safety Regulations, and the Factories Shops and Industries Regulations.
- NOHSC:1015 (2001) - National Occupational Health & Safety Commission (NOHSC): Storage and Handling of Workplace Dangerous Goods.
- NOHSC:1014 (2002): Control Of Major Hazard Facilities.
- NOHSC:2016 (1996): National Code of Practice.
- AS 3961 - Liquefied Natural Gas Storage and Handling.
- NFPA 59A - Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).
- EN 1472 LNG Code.
- AS1596 – The Storage and Handling of LP Gas (for mixed refrigerant).
- AS1940 Storage and Handling of Flammable and Combustible Liquids.
- AS 1020 – The control of undesirable static electricity.
- AS 1692 - Tanks for flammable and combustible liquids.
- API 620 - Design and construction of large welded low-pressure storage tanks.
- AS 1074 - Steel Tubes & Tubulars.
- AS 1076 – Selection, installation and maintenance of electrical apparatus and associated equipment for use in explosive atmosphere.
- AS 1210 - Unfired Pressure Vessel Code.
- AS 1271 – Safety valves, other valves, liquid level gauges, and other fittings for boilers and unfired pressure vessels.
- AS1768 – Lightning protection.
- AS 1836 - Welded Steel Tubes for Pressure Purposes.
- AS 2177 – Radiography of welded butt joints in metal products.
- AS2430 – Classification of hazardous areas. Part 1 – Explosive atmosphere.
- AS 2885 – Pipelines – Gas and Liquid Petroleum
- AS2832 – Cathodic protection of metals. Part 1: Pipes and cables
- AS 2919, AS 3765.1 or AS 3765.2 - Protective clothing.
- AS3000 – Electrical installations.
- AS 3600 - Concrete Structures (for foundation and plinth).
- AS3862 – External fusion-bonded epoxy coating for steel pipes.
- AS 4041- SAA Pressure Piping Code (was CB18), for piping within the meter station and station pipework.
- AS 4853 – Electrical safety on metallic pipelines.

- API 650 - Welded steel tanks for oil storage.
- AS1345 - Identification of the Contents of Pipes, Conduits and Ducts.
- Building Code of Australia for any buildings and protected works.
- Australian Code for Transport of Dangerous Goods by Road and Rail (ADG Code), 7th Ed.
- ANSI Z 358.1 for safety shower and eyewash facilities.

Pipe fittings, supports, and all other ancillary items will also need to comply with appropriate Australian Standards whether referenced above or not.

Appendix 3

Incident Scenarios Analysed, Consequences and Likelihoods

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Appendix 3 – Incident Scenarios Analysed

Abbreviation	Leak scenario	Material	State
NGSF PIPE	Leak in the 16" NGSF pipeline up to the receiving station and pressure reduction valve	NG	GAS
METERHP	Leak in the 16" HP pipeline (above ground) at the receiving / receipt station	NG	GAS
METERLP	Leak in the 12" LP pipeline (above ground) at the receiving / receipt station	NG	GAS
INLET	Leak in the 6" inlet pipe connecting the plant isolation valve with the liquefaction plant via the gas treatment.	NG	GAS
LIQST	Leak in 3" pipe or in the pressure vessel from the liquefaction unit to the LNG storage tank.C4	LNG	LIQ
LIQPV	Leak in pressure vessel in line from the liquefaction unit to the LNG storage tank.	LNG	LIQ
STGEN	Leak at the LNG storage tank due to generic failure scenarios	LNG	LIQ
STOFILL	Overfilling of the LNG tank resulting in a release of LNG (20 tonnes per hour).	LNG	LIQ
STOPRES	Overpressuring of the LNG tank resulting in a leak of either vapours or liquid natural gas.	LNG	LIQ
STUPRES	Creation of a partial vacuum in the LNG tank, resulting in a tank collapse.	LNG	LIQ
STVAP	Leak in the 8" pipe between the storage tank to the vaporisation unit.	LNG	LIQ
STTNKR	Leak in 8" pipe between the storage tank to the tanker filling.	LNG	LIQ
VAPPL	Leak in the 12" pipe transferring pressurised natural gas from the vaporisation unit back into the SEAgas/Epic pipelines.	NG	GAS
TNKROFILL	Overfilling of a LNG tanker resulting in a release of LNG (20 tonnes per hour).	LNG	LIQ
TNKRHOSE	Hose leak during tanker filling.	LNG	LIQ
LPG	Mixed refrigerant leak from process pipes and vessels.	LPG	LIQ
LPGSTC3	LPG Pressure Vessel	LPG	LIQ
LIQPV	Pressure vessel in liquefaction unit	LNG	LIQ

No	EQUIPMENT	TYPE	LENGTH metres	PRES-SURE (BAR)	TEMP (DEG C)	DIAM PIPE (M)	DIAM HOLE (M)
1	NGSF PIPE	PI (20mm)	5000	62	10	0.4	2.00E+01
1"	NGSF PIPE	PI (10% hole)	5000	62	10	0.4	0.1264911
2	NGSF PIPE	PI (rupt)	5000	62	10	0.4	0.4
1	METERHP	PI (10% hole)	25	62	10	0.4	0.1264911
2	METERHP	PI (rupt)	25	62	10	0.4	0.4
2	METERLP	PI (10% hole)	25	36	10	0.305	0.0964495
3	METERLP	PI (rupt)	25	36	10	0.305	0.305
2	LIQST	PI (10% hole)	50	36	10	0.148	0.0468017
3	LIQST	PI (rupt)	50	36	10	0.148	0.148
4	LIQPV	V (10mm hole)	n/a	36	-162		20
5	LIQPV	V (10min cat, bund)	n/a	36	-162		
6	LIQPV	V (cat rupt., bund)	n/a	36	-162		
7	STGEN	V (10mm hole)	0	0.069	10		1.00E-02
8	STGEN	V (10min cat, bund)	0	0.069	10		
9	STGEN	V (cat rupt., bund)	0	0.069	10		
11	STTOPFIRE	V (10min overfill, bund)	0	0.069	10		
12	STOFILL	V (10min fill rate, bund)	0	0.069	10	N/A	0.148
13	STOPRES	V (cat, bund)	0	0.069	10	N/A	0.148
14	STUPRES	V (cat, bund)	0	0.069	10	N/A	0.148
15	STVAP	PI (10% hole)	100	21.9	10	0.1944	0.0614747
16	STVAP	PI (rupt)	100	21.9	10	0.1944	0.1944
17	STTNKR	PI (10% hole)	400	21.9	10	0.0972	0.0307373
18	STTNKR	PI (rupt)	400	21.9	10	0.0972	0.0972
19	VAPPL	PI (10% hole)	200	129	15	0.305	0.0964495
20	VAPPL	PI (rupt)	200	129	15	0.305	0.305
21	TNKROFILL	V (10min overfill, bund)	50	129	15	n/a	
22	LPG	PI (10% hole)	50	40	15	0.1458	0.046106
23	LPG	PI (rupt)	50	40	15	0.1458	0.1458
24	LPGSTC3	V (10mm hole)	-	40	15	n/a	20
25	LPGSTC3	V (10min cat, bund)	-	40	15	n/a	
26	LPGSTC3	V (cat rupt., bund)	-	40	15	n/a	
27	LPGSTC3	BLEVE	-	40	15	n/a	

No	EQUIPMENT	TYPE	INITIAL LEAK RATE (KG/S)	LEAK RATE AFTER 1 SEC (KG/S)	AVERAGE LEAK RATE kg/s	EVAP. RATE (KG/S) F2	DURATION (S)	EVAP. RATE (KG/S) D5	DURATION (S)
1	NGSF PIPE	PI (20mm)	4.80E-01	4.80E-01	4.80E-01				
1"	NGSF PIPE	PI (10% hole)	1.87E+01	1.87E+01	1.86E+01				1429.5
2	NGSF PIPE	PI (rupt)	1.36E+03	1.36E+03	1170				20
1	METERHP	PI (10% hole)	1.87E+01	1.87E+01	1.87E+01				
2	METERHP	PI (rupt)	1.36E+03	1.36E+03	1224				
2	METERLP	PI (10% hole)	9.17E+01	89.92	89.92				
3	METERLP	PI (rupt)	6.02E+02	553.31	553.31				
2	LIQST	PI (10% hole)	6.40E+00	6.40E+00	6.40E+00	5.83	1862	5.80E+00	1802
3	LIQST	PI (rupt)	4.87E+01	4.87E+01	47	29	4271	29	4271
4	LIQPV	V (10mm hole)	6.40E+01	6.40E+01	6.10E+01	5.83	1862	5.80E+00	1802
5	LIQPV	V (10min cat, bund)	3.33E+00	3.33E+00	3.33E+00	29	4271	29	4271
6	LIQPV	V (cat rupt., bund)	2.00E+03	2.00E+03	2.00E+03	0.24937	3308.3	0.22216	5234.2
7	STGEN	V (10mm hole)	8.20E-01	8.20E-01	8.20E-01	0.79	3600	0.79	3600
8	STGEN	V (10min cat, bund)	5.0E+04	5.00E+04	5.00E+04	4040.9	3600	4040.9	3600
9	STGEN	V (cat rupt., bund)	30000000	3.00E+07	3.00E+07	626.89	3600	626.89	3600
11	STTOPFIRE	V (10min overfill, bund)	n/a						
12	STOFILL	V (10min fill rate, bund)	5.0E+04	5.00E+04	5.00E+04	4040.9	3600	4040.9	3600
13	STOPRES	V (cat, bund)	4.0E+07	4.06E+07		3.92E+05	7.70E+01	3.93E+05	7.64E+01
14	STUPRES	V (cat, bund)	1.00E+04	1.00E+04		3.92E+05	7.70E+01	3.93E+05	7.64E+01
15	STVAP	PI (10% hole)	8.13E+01	81.1	81.1	5.83	1862	5.80E+00	1802
16	STVAP	PI (rupt)	4.20E+02	413	413	29	4271	29	4271
17	STTNKR	PI (10% hole)	18.3	18.3	18.3	5.83	1862	5.80E+00	1802

No	EQUIPMENT	TYPE	INITIAL LEAK RATE (KG/S)	LEAK RATE AFTER 1 SEC (KG/S)	AVERAGE LEAK RATE kg/s	EVAP. RATE (KG/S) F2	DURATION (S)	EVAP. RATE (KG/S) D5	DURATION (S)
18	STTNKR	PI (rupt)	3.95E+01	3.95E+01	39.5	29	4271	29	4271
19	VAPPL	PI (10% hole)	9.17E+01	89.92	89.92				
20	VAPPL	PI (rupt)	6.02E+02	553.31	553.31				
21	TNKROFILL	V (10min overfill, bund)	5.56E+00	5.56E+00	5.56E+00	6.75E-01	5.88E+03	6.41E-01	1.02E+04
22	LPG	PI (10% hole)	2.40E+00	2.40E+00	2.40E+00	1.85	1495.3	1.9	1495.3
23	LPG	PI (rupt)	2.14E+01	2.14E+01	2.14E+01	5.89	16897	5.89	17628
24	LPGSTC3	V (10mm hole)	1.00E-01	1.00E-01	1.00E-01	0.08	16020	0.09	16520
25	LPGSTC3	V (10min cat, bund)	7.23E+00	7.23E+00	7.23E+00	3.2	15403	3.2	15852
26	LPGSTC3	V (cat rupt., bund)	8.50E+03	n/a	n/a	11.8	3599.5	11.6	3599.5
27	LPGSTC3	BLEVE	N/A	N/A	N/A	N/A	N/A	N/A	N/A

No	EQUIPMENT	TYPE	LEAK FREQ. per year	IGNITION (per year)	DELAYED IGNITION per year	DELAYED IGNITION FLASH FIRE FREQ. per year	DELAYED IGNITION EXPL. FREQ. per year	JET FIRE (per year)	POOL FIRE (/YR)
1	NGSF PIPE	PI (20mm)	2.0E-04	8.00E-06	8.19E-07	8.38E-08	0.00E+00	7.35E-07	
1"	NGSF PIPE	PI (10% hole)	3.8E-04	7.50E-06	1.64E-06	3.59E-07	0.00E+00	1.28E-06	
2	NGSF PIPE	PI (rupt)	1.0E-04	1.30E-05	5.53E-06	2.35E-06	0.00E+00	4.00E-06	
1	METERHP	PI (10% hole)	1.3E-05	2.20E-06	1.70E-06	1.70E-06	0.00E+00	5.00E-07	
2	METERHP	PI (rupt)	2.5E-06	5.65E-07	3.40E-07	3.40E-07	0.00E+00	2.25E-07	

No	EQUIPMENT	TYPE	LEAK FREQ. per year	IGNITION (per year)	DELAYED IGNITION per year	DELAYED IGNITION FLASH FIRE FREQ. per year	DELAYED IGNITION EXPL. FREQ. per year	JET FIRE (per year)	POOL FIRE (/YR)
2	METERLP	PI (10% hole)	1.25E-05	2.20E-06	1.70E-06	1.70E-06	0.00E+00	5.00E-07	
3	METERLP	PI (rupt)	2.50E-06	5.65E-07	3.40E-07	3.40E-07	0.00E+00	2.25E-07	
2	LIQST	PI (10% hole)	2.50E-05	2.21E-05	2.16E-05	1.29E-05	8.63E-06		5.00E-07
3	LIQST	PI (rupt)	5.00E-06	4.51E-06	4.31E-06	2.59E-06	1.73E-06		2.00E-07
4	LIQPV	V (10mm hole)	1.00E-04	8.83E-05	8.63E-05	5.18E-05	3.45E-05		2.00E-06
5	LIQPV	V (10min cat, bund)	5.00E-06	4.51E-06	4.31E-06	2.59E-06	1.73E-06		2.00E-07
6	LIQPV	V (cat rupt., bund)	5.00E-06	7.79E-07	6.79E-07	4.07E-07	2.72E-07		1.00E-07
7	STGEN	V (10mm hole)	1.00E-04	3.94E-06	1.94E-06	1.16E-06	7.76E-07		2.00E-06
8	STGEN	V (10min cat, bund)	5.00E-06	4.76E-06	4.31E-06	2.59E-06	1.73E-06		4.50E-07
9	STGEN	V (cat rupt., bund)	5.00E-06	4.76E-06	4.31E-06	2.59E-06	1.73E-06		4.50E-07
11	STTOPFIRE	V (10min overfill, bund)		0.00E+00		0.00E+00	0.00E+00		
12	STOFILL	V (10min fill rate, bund)	1.00E-06	9.53E-07	8.63E-07	5.18E-07	3.45E-07		9.00E-08
13	STOPRES	V (cat, bund)	1.00E-05	1.56E-05	8.63E-06	5.18E-06	3.45E-06		7.00E-06
14	STUPRES	V (cat, bund)	1.00E-05	1.56E-05	8.63E-06	5.18E-06	3.45E-06		7.00E-06
15	STVAP	PI (10% hole)	5.00E-05	7.79E-06	6.79E-06	4.07E-06	2.72E-06		1.00E-06
16	STVAP	PI (rupt)	1.00E-05	1.56E-06	1.36E-06	8.15E-07	5.43E-07		2.00E-07
17	STTNKR	PI (10% hole)	2.00E-04	3.52E-05	2.72E-05	1.63E-05	1.09E-05		8.00E-06
18	STTNKR	PI (rupt)	4.00E-05	7.03E-06	5.43E-06	3.26E-06	2.17E-06		1.60E-06
19	VAPPL	PI (10% hole)	1.00E-04	9.03E-05	8.63E-05	5.18E-05	3.45E-05	4.00E-06	
20	VAPPL	PI (rupt)	2.00E-05	1.91E-05	1.73E-05	1.04E-05	6.90E-06	1.80E-06	
21	TNKROFILL	V (10min overfill, bund)	1.00E-06	8.63E-07	8.63E-07	5.18E-07	3.45E-07		
22	LPG	PI (10% hole)	2.50E-05	5.49E-06	4.85E-07	2.91E-07	1.94E-07		5.00E-06

No	EQUIPMENT	TYPE	LEAK FREQ. per year	IGNITION (per year)	DELAYED IGNITION per year	DELAYED IGNITION FLASH FIRE FREQ. per year	DELAYED IGNITION EXPL. FREQ. per year	JET FIRE (per year)	POOL FIRE (/YR)
23	LPG	PI (rupt)	5.00E-06	2.60E-06	9.70E-08	5.82E-08	3.88E-08		2.50E-06
24	LPGSTC3	V (10mm hole)	1.00E-05	2.19E-06	1.94E-07	1.16E-07	7.76E-08		2.00E-06
25	LPGSTC3	V (10min cat, bund)	5.00E-07	2.60E-07	9.70E-09	5.82E-09	3.88E-09		2.50E-07
26	LPGSTC3	V (cat rupt., bund)	5.00E-07	3.60E-07	9.70E-09	5.82E-09	3.88E-09		3.50E-07
27	LPGSTC3	BLEVE	1.00E-06	N/A	N/A	N/A	N/A		N/A

No	EQUIPMENT	TYPE	FLAMMABLE EVENT (/KM/YR)	DELAYED IGNITION (/KM/YR)	FLASH FIRE (/KM/YR)	VCE (/KM/YR)	IMMEDIATE IGNITION (JET OR POOL FIRE) (/KM/YR)
1	NGSF PIPE	PI (20mm)	1.6E-06	1.6E-07	1.6E-07	0.0E+00	1.4E-06
1"	NGSF PIPE	PI (10% hole)	1.5E-06	3.3E-07	3.3E-07	0.0E+00	1.2E-06
2	NGSF PIPE	PI (rupt)	2.6E-06	1.1E-06	1.1E-06	0.0E+00	1.5E-06
1	METERHP	PI (10% hole)					
2	METERHP	PI (rupt)					
2	METERLP	PI (10% hole)					
3	METERLP	PI (rupt)					
2	LIQST	PI (10% hole)					
3	LIQST	PI (rupt)					
4	LIQPV	V (10mm hole)					
5	LIQPV	V (10min cat, bund)					
6	LIQPV	V (cat rupt., bund)					
7	STGEN	V (10mm hole)					
8	STGEN	V (10min cat, bund)					

No	EQUIPMENT	TYPE	FLAMMABLE EVENT (/KM/YR)	DELAYED IGNITION (/KM/YR)	FLASH FIRE (/KM/YR)	VCE (/KM/YR)	IMMEDIATE IGNITION (JET OR POOL FIRE) (/KM/YR)
9	STGEN	V (cat rupt., bund)					
11	STTOPFIRE	V (10min overfill, bund)					
12	STOFILL	V (10min fill rate, bund)					
13	STOPRES	V (cat, bund)					
14	STUPRES	V (cat, bund)					
15	STVAP	PI (10% hole)	7.8E-05	6.8E-05	4.1E-05	2.7E-05	0.0E+00
16	STVAP	PI (rupt)	1.6E-05	1.4E-05	8.1E-06	5.4E-06	0.0E+00
17	STTNKR	PI (10% hole)	8.8E-05	6.8E-05	4.1E-05	2.7E-05	0.0E+00
18	STTNKR	PI (rupt)	1.8E-05	1.4E-05	8.1E-06	5.4E-06	0.0E+00
19	VAPPL	PI (10% hole)	4.5E-04	4.3E-04	2.6E-04	1.7E-04	2.0E-05
20	VAPPL	PI (rupt)	9.5E-05	8.6E-05	5.2E-05	3.5E-05	9.0E-06
21	TNKROFILL	V (10min overfill, bund)					
22	LPG	PI (10% hole)	1.1E-04	9.7E-06	5.8E-06	3.9E-06	0.0E+00
23	LPG	PI (rupt)	5.2E-05	1.9E-06	1.2E-06	7.8E-07	0.0E+00
24	LPGSTC3	V (10mm hole)					
25	LPGSTC3	V (10min cat, bund)					
26	LPGSTC3	V (cat rupt., bund)					
27	LPGSTC3	BLEVE					

No	EQUIPMENT	TYPE	MAX SURFACE OF POOL (m2)	ACTUAL SURFACE OF POOL (m2)	TEMP AFTER EXPAN-SION (DEG C)	EXPLOSIVE MASS (KG)	SURFACE OF EXPLOSIVE CLOUD (M2)	LENGTH OF CLOUD BETWEEN LEL (M)	WIDTH OF CLOUD BETYWEEN LEL (M)
1	NGSF PIPE	PI (20mm)			9	9.3535	126.26	65.24	2.3991
1"	NGSF PIPE	PI (10% hole)			9	1458	1925	157	15
2	NGSF PIPE	PI (rupt)			9	7.29E+04		606	80
1	METERHP	PI (10% hole)			9	958	1925	157	15
2	METERHP	PI (rupt)			9	7.29E+04		606	80
2	METERLP	PI (10% hole)			9	6.11E+02	778.28	60.533	17.873
3	METERLP	PI (rupt)			9	9.90E+02	3882.6	198.1	25.496
2	LIQST	PI (10% hole)	120.96	50	-162	366.77	3970.3	100.56	55.568
3	LIQST	PI (rupt)	120.96	56	-162	3733.7	24627	261.38	130.01
4	LIQPV	V (10mm hole)	120.96	50	-162	366.77	3970.3	100.56	55.568
5	LIQPV	V (10min cat, bund)	120.96	56	-162	3733.7	24627	261.38	130.01
6	LIQPV	V (cat rupt., bund)	120.96	5.1076	-162	3.49E+00	91.625	1.3386	3.7504
7	STGEN	V (10mm hole)	52	34	-162	16.923	302	4	9
8	STGEN	V (10min cat, bund)	15000	7330.5	-162	1.36E+04	5.91E+04	414	180
9	STGEN	V (cat rupt., bund)	15000	13557	-162	3.11E+05	8.46E+05	1427.8	849.07
11	STTOPFIRE	V (10min overfill, bund)	1734	1734	-162				
12	STOFILL	V (10min fill rate, bund)	15000	7330.5	-162	2.59E+02	3587.9	109.6	39.683
13	STOPRES	V (cat, bund)	unbunded	13557	-162	311310	845610	1428	849
14	STUPRES	V (cat, bund)	1734	13557	-162	31131	845610	1428	849
15	STVAP	PI (10% hole)	120.96	50	-162	177.04	2212.1	6.9754	18.541
16	STVAP	PI (rupt)	120.96	56	-162	198.72	2406.5	7.11	7.11
17	STTNKR	PI (10% hole)	120.96	50	-162	19.302	370.44	19.302	2.8061

No	EQUIPMENT	TYPE	MAX SURFACE OF POOL (m2)	ACTUAL SURFACE OF POOL (m2)	TEMP AFTER EXPAN-SION (DEG C)	EXPLOSIVE MASS (KG)	SURFACE OF EXPLOSIVE CLOUD (M2)	LENGTH OF CLOUD BETWEEN LEL (M)	WIDTH OF CLOUD BETYWEEN LEL (M)
18	STTNKR	PI (rupt)	120.96	56	-162	21.42522	411.1884	21.42522	3.114771
19	VAPPL	PI (10% hole)			9	6.11E+02	778.28	60.533	17.873
20	VAPPL	PI (rupt)			9	9.90E+02	3882.6	198.1	25.496
21	TNKROFILL	V (10min overfill, bund)	17.64	4.9634	-162	16.4067	314.874	16.4067	2.385185
22	LPG	PI (10% hole)	120.96	67	-42	99.338	2296.1	51.631	61.101
23	LPG	PI (rupt)	120.96	5.1	-42	104.44	9122	104.44	119.6
24	LPGSTC3	V (10mm hole)	120.96	3.3	-42	-	-	-	-
25	LPGSTC3	V (10min cat, bund)	120.96	36.00	-42	213.5	4317.2	71.558	82.523
26	LPGSTC3	V (cat rupt., bund)	120.96	51.00	-42	1460	20998	159.58	179.86
27	LPGSTC3	BLEVE	N/A	N/A	N/A	N/A	N/A	N/A	N/A

No	EQUIPMENT	TYPE	EXPLOSIVE MASS (KG)	SURFACE OF EXPLOSIVE CLUD (M2)	LENGTH OF CLOUD BETWEEN LEL (M)	WIDTH OF CLUD BETYWEEN LEL (M)
1	NGSF PIPE	PI (20mm)	0.79896	17.533	14.46	1.4306
1"	NGSF PIPE	PI (10% hole)	262	925	100	8
2	NGSF PIPE	PI (rupt)	7.11E+04	23406	287	50
1	METERHP	PI (10% hole)	340	925	131.22	9.0592
2	METERHP	PI (rupt)	7.11E+04	23406	287	50
2	METERLP	PI (10% hole)	5.45E+02	878.38	77.492	14.712
3	METERLP	PI (rupt)	1.35E+03	2735.7	167.55	21.413
2	LIQST	PI (10% hole)	38.92	3600	5.4109	11.173

No	EQUIPMENT	TYPE	EXPLOSIVE MASS (KG)	SURFACE OF EXPLOSIVE CLUD (M2)	LENGTH OF CLOUD BETWEEN LEL (M)	WIDTH OF CLUD BETYWEEN LEL (M)
3	LIQST	PI (rupt)	575.5	2524.9	6.7394	15.57
4	LIQPV	V (10mm hole)	38.92	3600	5.4109	11.173
5	LIQPV	V (10min cat, bund)	575.5	2524.9	6.7394	15.57
6	LIQPV	V (cat rupt., bund)	4.01E-01	10.714	0.6569	1.3897
7	STGEN	V (10mm hole)	-	-	-	-
8	STGEN	V (10min cat, bund)	5.07E+05	3.25E+04	4.95E+02	6.73E+02
9	STGEN	V (cat rupt., bund)	4.59E+04	9.84E+04	6.55E+02	1.96E+02
11	STTOPFIRE	V (10min overfill, bund)				
12	STOFILL	V (10min fill rate, bund)	0.00E+00	-	-	-
13	STOPRES	V (cat, bund)	45934	98403	655	196
14	STUPRES	V (cat, bund)	45934	98403	655	196
15	STVAP	PI (10% hole)	15.763	212.71	15.763	3.8044
16	STVAP	PI (rupt)	990	220.68	3.4761	7.2342
17	STTNKR	PI (10% hole)	16.145	319.4	16.145	2.6265
18	STTNKR	PI (rupt)	17.92095	354.534	17.92095	2.915415
19	VAPPL	PI (10% hole)	5.45E+02	878.38	77.492	14.712
20	VAPPL	PI (rupt)	1.35E+03	2735.7	167.55	21.413
21	TNKROFILL	V (10min overfill, bund)	13.72325	271.49	13.72325	2.232525
22	LPG	PI (10% hole)	-	-	-	-
23	LPG	PI (rupt)	51.552	572.34	5.5405	11.773
24	LPGSTC3	V (10mm hole)	-	-	-	-
25	LPGSTC3	V (10min cat, bund)	17.13	2.63E+02	4.2558	9.1002

No	EQUIPMENT	TYPE	EXPLOSIVE MASS (KG)	SURFACE OF EXPLOSIVE CLUD (M2)	LENGTH OF CLOUD BETWEEN LEL (M)	WIDTH OF CLUD BETYWEEN LEL (M)
26	LPGSTC3	V (cat rupt., bund)	182.16	1394.7	6.2016	13.839
27	LPGSTC3	BLEVE	N/A	N/A	N/A	N/A

Appendix 4

Prevailing Meteorology

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Appendix 4 – Prevailing Meteorology.

The meteorological data were obtained from the CALMET model, a meteorological pre-processor endorsed by the US EPA. The meteorological conditions for the domain were run from hourly readings in 2008 and from meteorological data obtained from TAC for the 5 year period between 2005 and 2009. Observed hourly surface wind speed, wind direction, temperature and relative humidity, wind speed and direction data were used as input.

Summary of the annual and daily variation in wind is presented as wind roses in the Air Quality Impact Assessment (Ref 43).

An important aspect of plume dispersion is the level of turbulence in the atmosphere near the ground. Turbulence acts to dilute or diffuse a plume by increasing the cross-sectional area of the plume due to random motion. As turbulence increases, the rate of plume dilution or diffusion increases. Weak turbulence limits diffusion and is a critical factor in causing high plume concentrations downwind of a source. Turbulence is related to the vertical temperature gradient, the condition of which determines what is known as stability, or thermal stability. For traditional dispersion modelling using Gaussian plume models, categories of atmospheric stability are used in conjunction with other meteorological data to describe the dispersion conditions in the atmosphere.

The best known stability classification is the Pasquil-Gifford scheme, which denotes stability classes from A to F. Class A is described as highly unstable and occurs in association with strong surface heating and light winds, leading to intense convective turbulence and much enhanced plume dilution. At the other extreme, class F denotes very stable conditions associated with strong temperature inversions and light winds, such as those that commonly occur under clear skies at night and in the early morning. Under these conditions plumes can remain relatively undiluted for considerable distances downwind. Intermediate stability classes grade from moderately unstable (B), through neutral (D) to slightly stable (E). Whilst classes A and F are closely associated with clear skies, class D is linked to windy and/or cloudy weather, and short periods around sunset and sunrise when surface heating or cooling is small.

The stability classes were modelled in the Air Quality Impact Assessment using CALMNET.

The wind weather data file used for the project is included in the table below.

Table A4.1 – Wind Weather Data File

WEATHER CATEGORY	REP. WIND SPEED (M/S)	DAY	NIGHT	SSW	SWW	W	NWW	NNW	N	NNE	NEE	E	SEE	SSE	S
A (Very Unsta	1.35	6.64	0	5.34	2.67	2.84	14.2	12.65	28.56	6.01	5.68	5.01	3.67	5.68	7.69
B (Unstable)	1.63	22.39	0	5.29	2.14	4.53	27.16	14.39	14.85	3.71	3.46	4.53	6.26	4.93	8.75
C (Lightly Uns	2.08	13.76	1.23	7.75	1.6	3.57	28.72	14.39	11.17	3	2.3	7.27	9.3	3.2	7.73
D (Neutral)	2.93	5.71	0.73	10.07	1.94	1.24	13.43	1.41	12.7	0.53	3.89	11.66	11.48	14.13	17.52
E (Stable)	2.85	0.91	1.51	15.02	6.57	0.94	8.92	0.47	11.75	0.47	5.16	10.33	8.92	6.57	24.88
F (Very Stable	1.03	8.94	38.18	6.94	2.71	3.43	23.15	10.49	12.7	7.01	7.42	7.35	5.99	5.97	6.84

Appendix 5

Ignition Sources at the NGSF

Preliminary Hazard Analysis of AGL Energy's Newcastle Gas Storage Facility Project, New South Wales

Appendix 5 - Ignition Sources NGSF

A. Theory

According to the TNO document *Guidelines for Quantitative Risk Assessment (The Purple Book),* the probability of delayed ignition caused by an ignition source can be modelled as:

$$P(t) = P_{present} \cdot (1 - e^{-\omega t})$$

where:

P(t) the probability of an ignition in the time interval 0 to t (-),

$P_{present}$ the probability that the source is present when the cloud passes (-),

ω the ignition effectiveness (s-1), and

t time (s).

The ignition effectiveness, ω , can be calculated given the probability of ignition for a certain time interval.

Table A3.1 presents the probability of ignition for a time interval of one minute for those sources that are relevant for the NGSF site, as extracted from the TNO Guidelines.

Table A5.1 - Probability of ignition for a time interval of one minute for a number of sources

SOURCE	PROBABILITY OF IGNITION IN ONE MINUTE
POINT SOURCE	
MOTOR VEHICLE	0.4
FLARE	1
INDOOR BOILER	0.23
LINE SOURCE	
ROAD	NOTE 1
AREA SOURCE	
HEAVY INDUSTRY (USED IN QRA TO REPRESENT THE NEIGHBOURING INDUSTRIAL DEVELOPMENT)	0.7 PER SITE
POPULATION SOURCE	
RESIDENTIAL	0.01 PER PERSON
EMPLOYMENT FORCE	0.01 PER PERSON

Notes:

1. The ignition probability for a road near the establishment is determined by the average traffic density. The average traffic density, d, is calculated as:

d = N E / v

where:

N number of vehicles per hour (h-1)

E length of a road or railway section (km)

v average velocity of vehicle (km h-1).

If d ≤ 1, the value of d is the probability that the source is present when the cloud passes; the probability of an ignition in the time interval 0 to t, P(t), equals:

$$P(t) = d \cdot \ (1 - e^{-\omega t}),$$

Where:

ω the ignition effectiveness of a single vehicle (s-1)

If d ≥ 1, d is the average number of sources present when the cloud passes; the probability of an ignition in the time interval 0 to t, P(t), equals:

$$P(t) = (1 - e^{-d\omega t}),$$

where:

ω the ignition effectiveness of a single vehicle (s-1)

2. The probability of an ignition for a grid cell in a residential area in the time interval 0 to t, P(t), is given by:

$$P(t) = (1 - e^{-n\omega t}),$$

where:

ω the ignition effectiveness of a single person (s-1)

n the average number of people present in the grid cell

4. Where the model uses a time-independent probability of ignition, the probability of ignition is equal to the probability of ignition in one minute.

B. Calculation Results

The probability of ignition if the vapour cloud reaches the said sources, are presented in the table below.

Table A5.2 – Delayed Ignition Probability at NGSF

Wind Direction	Probability of Wind Direction	Probability of Delayed Ignition				Probability of delayed ignition if wind from given direction				Probability of delayed ignition any wind direction			
		Duration After Release				Duration After Release				Duration After Release			
		1min	2min	5min	10min	1 min	2 min	5 min	10 min	1 min	2 min	5 min	10 min
Very Large Cloud													
NNW, N, NNE	0.28	0.70	0.70	0.70	0.70	0.19398	0.19398	0.19398	0.19398	0.333613	0.333613	0.333613	0.333613
SWW, W, NWW	0.25	0.00	0.00	0.00	0.00	0	0	0	0				
NNE, E, SEE	0.20	0.70	0.70	0.70	0.70	0.139634	0.139634	0.139634	0.139634				
SSE, S, SSW	0.27	0.00	0.00	0.00	0.00	0	0	0	0				
Large cloud													
NNW, N, NNE	0.28	0	0	0	0	0	0	0	0	0.139634	0.139634	0.139634	0.139634
SWW, W, NWW	0.25	0	0	0	0	0	0	0	0				
NNE, E, SEE	0.20	0.70	0.70	0.70	0.70	0.139634	0.139634	0.139634	0.139634				
SSE, S, SSW	0.27	0	0	0	0	0	0	0	0				

Wind Direction	Probability of Wind Direction	Probability of Delayed Ignition				Probability of delayed ignition if wind from given direction				Probability of delayed ignition any wind direction			
		Duration After Release				Duration After Release				Duration After Release			
		1min	2min	5min	10min	1 min	2 min	5 min	10 min	1 min	2 min	5 min	10 min
Small Cloud													
NNW, N, NNE	0.28	0	0	0	0	0	0	0	0	0.0194	0.0194	0.0194	0.0194
SWW, W, NWW	0.25	0	0	0	0	0	0	0	0				
NNE, E, SEE	0.194	0.1	0.1	0.1	0.1	0.0194	0.0194	0.0194	0.0194				
SSE, S, SSW	0.27	0	0	0	0	0	0	0	0				

Taking into account the probability of a particular wind direction for the NGSF, the probability of a delayed ignition is presented in the table below. As the foot print of a vapour cloud is different depending on the size of the release, three types of releases have been defined, namely: Very Large (rupture scenarios of high pressure pipelines); Medium (ruptures of low pressure pipelines or large holes in high pressure pipelines) and Small clouds.

Table A5.3 – Delayed Ignition Probabilities for NGSF Vapour Clouds Corrected for Wind-Direction Probabilities)

Delayed Ignition Probability Depending on Time From Beginning of Release					
1 min	**2 min**	**3 min**	**3 min**	**5 min**	**Size of Cloud**
0.33	0.33	0.33	0.33	0.33	Very Large
0.14	0.14	0.14	0.14	0.14	Medium
0.02	0.02	0.02	0.02	0.02	Small

The probability of BLEVE of a pressurised mixed refrigerant vessel was taken as 70% of the total frequency of direct ignition. The mass in the BLEVE is set equal to the total inventory of the tank. The pressure at failure of the vessel is set as equal to 1.21 × the opening pressure of the relief device.

C. Reference:

Guidelines for Quantitative Risk Assessment, CPR 18E (*The Purple Book*), CPE, 1999

9 REFERENCES

1 Department of Urban Affairs and Planning, *Hazardous Industry Planning Advisory Paper No. 1: Risk criteria for land use planning*, 1993 Edition

2 Hazardous Industry Planning Advisory Paper No. 6 (HIPAP No. 6): *Guidelines for hazard analysis*, NSW Department of Planning

3 Australian Standard for Risk Management AS4360, Standards Australia, 2004

4 Preliminary Environmental Assessment - Newcastle Gas Storage Facility Project, Coffey Natural Systems, January 2010

5 NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

6 AS/NZS3961 Liquefied Natural Gas Storage and Handling and, when not specified in AS3961

7 EN 1473 - The European Norm standard EN 1473 Installation and equipment for Liquefied Natural Gas

8 State Environmental Planning Policy No 33—Hazardous and Offensive Development, NSW Department of Planning, 13 March 1992

9 *Control Of Major Hazard Facilities* - National Standard, National Occupational Health and Safety Commission (NOHSC:1014), 2002

10 *National Code of Practice* National Occupational Health and Safety Commission (NOHSC:2016), 1996

11 *Preliminary Contamination Assessment, Newcastle Gas Storage Facility Project, Tomago, NSW,* Report prepared by Coffey Environments Australia Pty Ltd for AGL Energy Limited. November 2010

12 Department of Urban Affairs and Planning, *Hazardous Industry Planning Advisory Paper No. 5: Hazard Audit Guidelines;* NSW Government, Sydney, 1993 Edition

13 Parfomak P, *Liquefied Natural Gas (LNG) Infrastructure Security: Background and Issues for Congress*, Resources, Science, and Industry Division, Order Code RL32073, CRS Report for Congress, September 9, 2003

14 Michot Foss M, *LNG Safety and Security*, (US) Centre for Energy Economics, October 2003

15 Socio-Economic Characterisation, AGL Energy Limited, Newcastle Gas Storage Facility Project, Major Project Application Number 10-0133, Coffey Natural Systems Pty Ltd, October 2010

16 AS/NZ1596 for LPG storage

17 AS1940 *The storage and handling of flammable and combustible liquids*

18 NFPA 30 Flammable and Combustible Liquids Code

19 Australian Standard AS2885.1, 2 and 3, *Pipelines – Gas and liquid petroleum*

20 Hazardous Industry Planning Advisory Paper No 1: *Industrial Emergency Planning Guidelines*, NSW Department of Planning 1993

21 Hazardous Industry Planning Advisory Paper No 2: *Fire Safety Study*, NSW Department of Planning 1993.

22 Building Code of Australia

23 *Australian Code for Transport of Dangerous Goods by Road and Rail* (ADG Code), 7th Ed, 2007

24 Yellow Book, *Methods for the Calculation of the Physical Effects of the Escape of Dangerous Material*, *CPR 14E, Parts 1& 2*, Committee for the Prevention of Disasters, TNO, 3rd edition 1997

25 Koopmana R, Ermak D, *Lessons learned from LNG safety research*, Hazard Analysis Consulting, reviewing research by the Lawrence Livermore National Laboratory (LLNL) under the sponsorship of the US Department of Energy, Department of Transportation, Gas Research Institute and others

26 Hightower M, Gritzo, Luketa-Hanlin A, *Guidance on Risk Analysis and Safety, Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water,* SANDIA REPORT, SAND2004-6258, December 2004

27 Luketa-Hanlin Anay, *A Review of Large-Scale LNG Spills: Experiments and Modelling*, Journal of Hazardous Materials A132 (2006) 119-140

28 AS 1768 Lightning Protection

29 Petersen D, *Bushfire Threat Assessment: AGL Gas Storage Facility Old Punt Road, Tomago, NSW*, ecobiological, January 2011

30 Rural Fires and Environmental Assessment Legislation Amendment Act 2002 (amends the Environmental Planning and Assessment Act 1979)

31 EN 1473:2007, Installation and Equipment for Liquefied Natural Gas – Design of Onshore Installations, NSAI 2007

32 Thomas C, Golaseweski R, *Tomago Gas Storage Facility Preliminary OSBL Flooding Assessment*, WorleyParsons, 6 October 2010

33 Dominey-Howes D, *Geological and historical records of tsunami in Australia*, Department of Physical Geography, Risk Frontiers, Macquarie University, Sydney, NSW 2109, Australia, as reported in Marine Geology 239 (2007) 99–123

34 ATSB Transport Safety Report, Aviation Research and Analysis Report - B2006/0002, *International Fatality Rates - A Comparison of Australian Civil Aviation Fatality Rates with International Data*, Australian Transport Safety Bureau, 2006

35 Annual Review of Aircraft Accident Data: U.S. General Aviation, Calendar Year 2001, National Transport Safety Board

36 Byrne, J. P., The Calculation of Aircraft Crash Risk in the UK, HSE\R150, 1997

37 *Master Plan, Newcastle Airport*, Newcastle Airport Limited, 2007

38 Nilsson K, *Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW*, Planager Pty Ltd, 13 October 2009

39 Statement of Environmental Effects – Modification of Development Consent – Proposed Production Capacity Increase – Tomago Aluminium Smelter, HLA-Envirosciences Pty Limited, 2001

40 Jiang Q, Lee D, Lee M, Adam W, *Pacific Highway Route Performance Report*, Parsons Brinckerhoff Australia Pty Limited (commissioned by NRMA Motoring & Services), November 2006

41 Exiting Conditions at the Interim Highway Corridor and the F3 Freeway, SKM, Chapter 3

42 Traffic, transport and economic investigations for the Pacific Highway Proposed Karuah to Bulahdelah Upgrade, Roads and Traffic Authority

43 *Air Quality Assessment – Newcastle Gas Storage Facility*, PAEHolmes January 2011

44 *Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*, Federal Energy Regulatory Commission (contract number FERC04C40196)

45 Uijt de Haag P.A.M. (Dr), Ale B.J.M. (Dr), *Publication Series on Dangerous Substances (PGS 3)*, *Guidelines for quantitative risk assessment*, Ministerie van VROM Ministerie van Verkeer en Waterstaat, December 2005

46 7th Report of the European Gas Pipeline Incident Data Group (7th EGIG Report 1970-2007)

47 Orica HAZAN Course, SHE Pacific, 1998

48 Cleaver P, Johnson M, Hob B, *A summary of some experimental data on LNG safety*, Journal of Hazardous Materials, 140 (2007) pages 429-438

49 United States Department of Labor, Occupational Health and Safety Administration, *Occupational Safety and Health Guideline for Nitrogen*, as published on their website