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Shoalhaven Starches

Ethanol Production Upgrade

Preliminary Hazard Analysis

May 2008

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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GLOSSARY

DUAP – Department of Urban Affairs and Planning;

DoP – Department of Planning;

EPA – Environment Protection Authority;

SEPP – State Environmental Planning Policy;

PHA – Preliminary Hazard Assessment;

QRA – Quantitative Risk Assessment;

HIPAP – Hazardous Industry Planning Advisory Paper;

SAFETI – Software for Assessment of Fire Explosion and Toxic Impact;

IRPA – Individual Risk Per Annum;

ESD – Emergency Shutdown Device;

EA – Environmental Assessment.

DISCLAIMER

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The recommendation, opinions, assessments, analyses and summaries presented in this report are based exclusively on information, data, assumptions and advice provided and verified by Shoalhaven Starches Pty Ltd. This information has not been independently verified by GHD Pty Ltd, and where assumptions are identified and recommendations made these need to be verified and tested.

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1. Executive Summary

Introduction

Shoalhaven Starches, part of the Manildra Group, is proposing to increase the ethanol production capacity at their Shoalhaven plant from 126 million litres (ML) per year to 300 ML per year by upgrading the facility.

A Preliminary Hazard Assessment (PHA) for the proposed upgrade was prepared as part of the planning approval process required by the NSW Department of Planning (DoP).

Manildra Group commissioned GHD to complete the PHA for the proposed upgrade of the Ethanol Facility at the Shoalhaven site. The PHA was completed in accordance with the screening criteria detailed in the State Environmental Planning Policy (SEPP) 33 guideline of the then Department of Urban Affairs and Planning (DUAP), now the DoP. The Hazard Assessment was completed in accordance to Hazardous Industry Planning Advisory Paper (HIPAP) No 6.

The major hazards identified in the PHA were included in the Quantitative Risk Assessment (QRA), which was completed using SAFETI (Software for the Assessment of Fire, Explosion, Toxic Impact) and the risk criteria given in HIPAP No 4 for off site impact.

The QRA included the existing operation and the new hazards introduced by the proposed upgrade.

Hazard identification

The major hazards, introduced by the proposed upgrade, that have potential for off site impact are:

» Cogeneration Plant: Potential for fire and explosion associated with natural gas;

» Ethanol Loading Bay: Increased loading frequency associated with increased ethanol production leading to increased likelihood of release of ethanol due to human factors or mechanical failures;

» Gas Fire Boiler (150 tph steam).

The existing major hazards, included in the QRA, that have potential for off site risk are:

» Ethanol Storage Tank Farm: the storage capacity will not change;

» Ethanol Loading Pump: will operate more frequently;

» Distillation Units;

» Molecular Sieves;

» Gas Fired Boiler No 2.

The dust cloud explosion hazards are not included in this QRA. A separate risk assessment was completed for the dust cloud explosion during an earlier plant upgrade last year and was demonstrated not to have off site impact.

Frequency Analysis

The failure frequencies of equipment were calculated using failure rate data obtained from the UK Health and Safety Executive (HSE) for pipes and equipment. The UK HSE data is derived from off shore operations in a harsh environment and hence is considered to be conservative when applied to a clean on shore process.

Consequence Assessment

Thermal radiation with respect to fire, and overpressure with respect to explosion, associated with ethanol and natural gas were assessed.

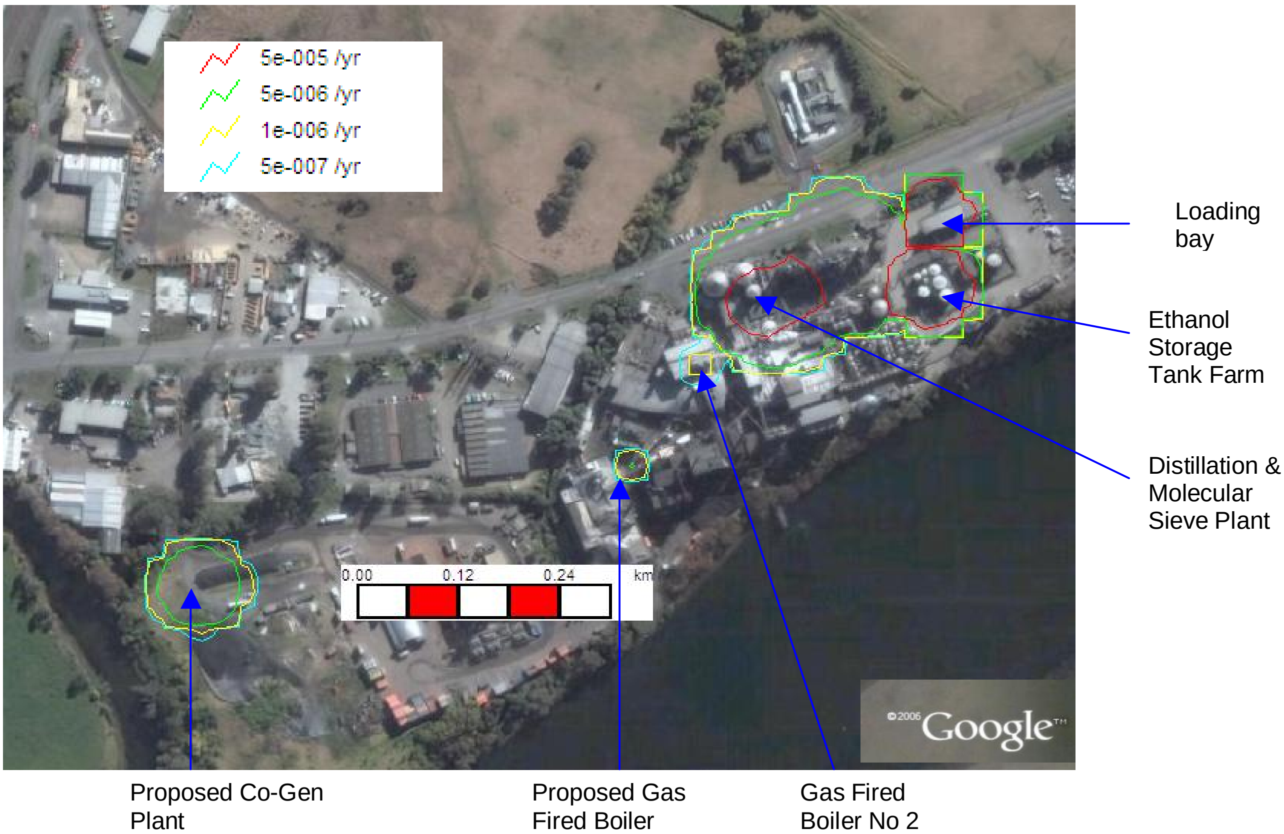
The ethanol fire was modelled as a pool fire and natural gas fire was modelled as a jet fire. Overpressure was modelled as a vapour cloud explosion with respect to ethanol vapour and natural gas.

Risk Assessment

The failure frequencies and consequences were combined in SAFETI to calculate the risk contours for the Shoalhaven facility.

Individual Fatality Risk contours were calculated and overlaid on the map of the Shoalhaven facility to show the impact zone. The Individual Risk results for the nominated risk criteria of HIPAP No 4 are given below.

Figure 1-1 Individual Fatality Risk Profile for the Shoalhaven Operation



The risk calculated for the existing operation and the proposed upgrade of the Shoalhaven facility is acceptable as the risk contours are in compliance with the nominated risk criteria of HIPAP No 4. There are no sensitive areas nearby the site affected by the operation.

There is no injury risk to the residential area from thermal radiation or explosion overpressure. Thermal radiation and explosion overpressure from the ethanol facility does not cause off site property damage.

2. Introduction

2.1 Background

The Manildra Group owns and operates the Shoalhaven Starches Factory located on Bolong Road at Bomaderry. The factory produces a range of products and ethanol is one of them. Currently, the factory has capacity to produce 126 ML of ethanol annually. The ethanol produced at the site is transported to the customers by road tankers.

Manildra Group envisages an increase in demand for ethanol in the near future due to NSW government's plans to increase ethanol blending in the petrol from the current levels of 2% to 10% by 2011. In anticipation of increased ethanol demand, the Manildra Group is planning to increase the production capacity of ethanol to 300 ML per annum by implementing a number of changes to its Shoalhaven Factory.

The Shoalhaven plant currently uses coal in the boilers for steam generation but is moving towards natural gas for steam generation in order to reduce the greenhouse gas emission. A coal-fired boiler (No 2) has already been converted to gas-fired boiler. Further, the Manildra Group is considering installation of a gas fired cogeneration plant at the Shoalhaven site to further reduce the greenhouse gas emission and optimise energy consumption in the production facility.

The increase in ethanol production capacity and gas usage on site will change the risk profile of the site with respect to off site risk.

The Manildra Group commissioned GHD to complete the PHA of the Shoalhaven site as part of the EA (Environmental Assessment) process to demonstrate that the off site risk from the proposed increase in ethanol production remains acceptable.

2.2 Aims and Objectives

The aim of the PHA is to assess the total off site risk, generated from the existing operation at Shoalhaven Factory and from the proposed upgrade of the facility, with respect to harm to people and damage to properties.

The objectives of the PHA are:

- Identify all hazards from existing operation and from the proposed changes that have the potential for off site impact;
- Assess and quantify the off-site risks to people, property and the environment;
- Compare the risks generated with the nominated risk criteria of NSW Hazardous Industry Planning Advisory Paper (HIPAP) No. 4;
- Identify risk reduction or mitigation measures as required;
- Prepare a concise and clear report of the risk assessment and the results.

An increase in ethanol production capacity will result in increased truck movement to and from the site hence higher likelihood of traffic related incidents on the road i.e. collision and loss of containment. Transportation risk assessment is not included in this study.

3. Facility Description

3.1 Site Location

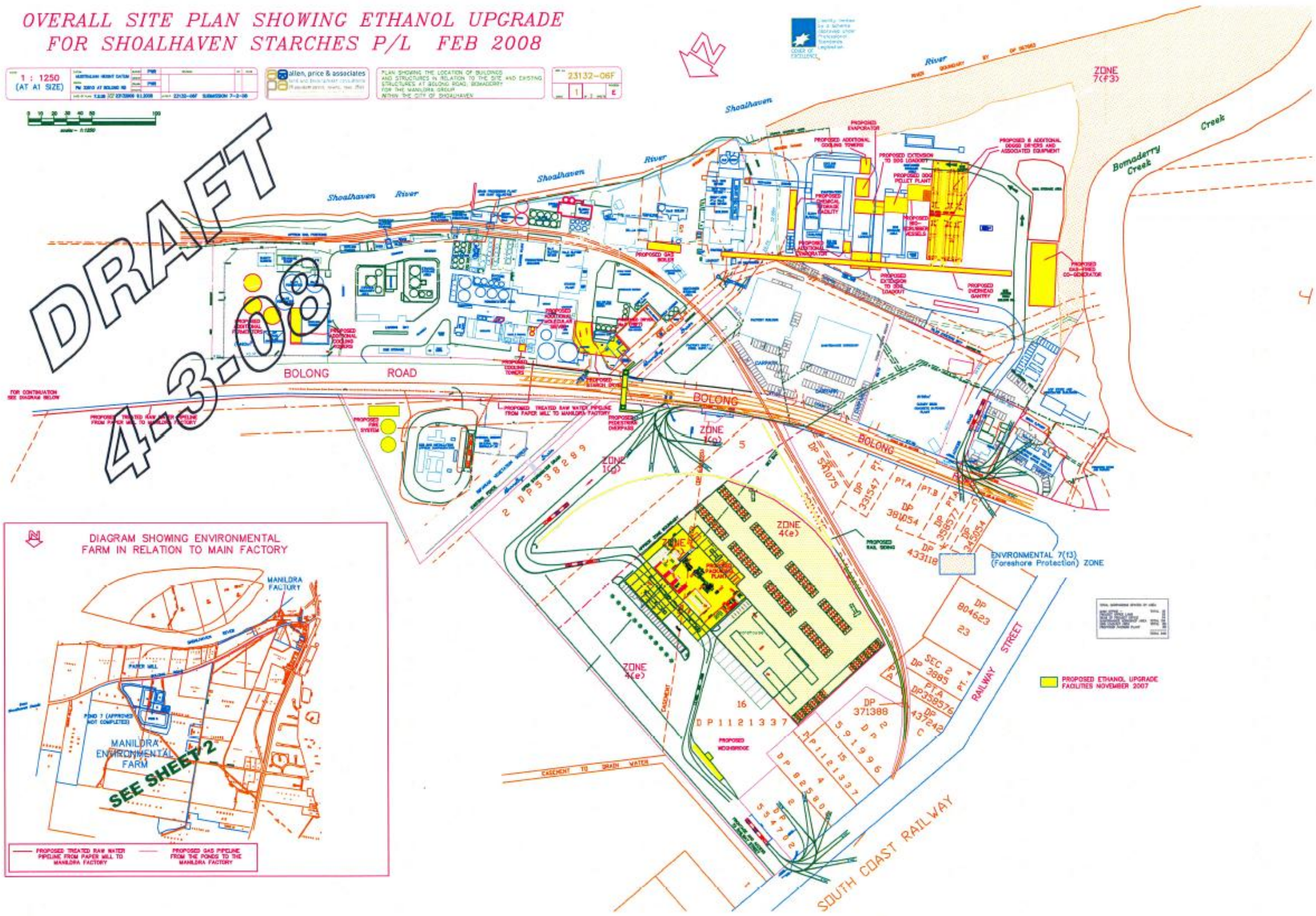
The Shoalhaven Starch Factory is located on the south side of Bolong Road on the northern bank of the Shoalhaven River. The site is located in an industrial area and there are small workshops, industrial outlets and storage yards on the adjacent blocks to the Starch Factory. The town of Bomaderry is located approx 0.5 km to the west of the site and the Nowra urban area is approx 2.0 km to the south west of the site.

There are no sensitive areas such as hospitals, child care facility, schools or residential areas close to the site.

3.2 Site Layout

The layout of the site with the proposed changes is shown in Figure 3-1 below.

Figure 3-1 Site Layout



NB: The areas marked in yellow are the proposed changes as part of the Ethanol production Upgrade.

3.3 Existing Operation

The raw materials used in the process are grain, flour and wheat transported to the site by road and rail. The existing plants and operating units on the site are:

» Starch Plant;

» Grain Plant;

» Flour Mill;

» Fermentation;

» Evaporation;

» Ethanol Plant and Storage Facility;

» Ethanol Loading Bay;

» Drying;

» Coal fired steam boilers.

The proposed upgrades that have potential to contribute to off site impact are listed below:

3.3.1 Ethanol Plant

The waste from the starch, gluten and syrups components feed the fermentation units, which produces ethanol. The ethanol is separated from 'beer' and water in the separation columns and molecular sieves to provide pure ethanol ready for sale. Ethanol so produced is pumped to storage tanks ready for loading and despatch by road tanker.

There are 7 storage tanks with the combined capacity to store 1.9 ML. Normally only half of the 7 tanks are full. The tanks are inside a bund. Any spill in the bund is pumped away to the underground recovery tank. There is a level alarm in the bund sump if the sump pump fails. There is a flow sensor in the discharge line from the sump to the recovery tank to alert the operators of spills in the bund.

The ethanol production unit and storage capacity will remain unchanged by the proposed upgrade.

A new set of molecular sieves and superheater are planned to be added in the future. This will bring the total molecular sieves to 4 sets.

3.3.2 Ethanol Loading Bay

The loading bay is located approx 20m from the storage tank farm. Ethanol is loaded into the B-Double road tanker or Single Road tanker and transported to the customer. The capacity of the tankers is:

» B-Double: 50,000L and

» Single: 34,000L

Typically, 6 B-Double and 1 Single tanker are loaded per day but this will more then double with the proposed doubling in the ethanol production rate. At 300 ML/year production capacity, the loading frequency is expected to be:

» 14 B-Double tankers per day; and

» 4 Single tankers per day.

Loading is by done by the tanker driver. Only a single tanker is loaded at a time. The loading bay has 2 drain points to allow any spillage to flow to an underground recovery tank.

The loading hose is steel braided. There is an excess flow valve on the liquid loading line to stop flow if the hose fails catastrophically or disconnects.

3.3.3 Co Generation Plant

A gas fired co-generation plant (15 MW) is proposed to be installed on the north west end of the site.

3.3.4 Gas Fired Boiler

Manildra is planning to move away from the coal fired boilers to gas fired boilers to generate steam in order to improve its performance against the green house gas release.

Therefore, a 150 tph gas fired boiler is proposed to be installed at the Shoalhaven site.

3.4 Previous Studies

A number of risk assessments have been completed for the Shoalhaven site in the past associated with plant upgrades. Some of the recent studies are listed below.

Table 3–1 Previous Relevant Hazard Studies

Study	Authors & Date	Purpose of the Study
PHA of Sorghum Plant	Ren Mahant, Bechtel Services Australia, Nov 2000	Hazard analysis of grain plant
PHA of Protein Isolate Plant	Ren Mahant, Bechtel Services Australia, Nov 2000	Hazard analysis of DDG Dryer
Hazard Analysis of Stillage Production Facility	Ren Mahant, Bechtel Services Australia, July 2002	Includes hazard analysis of Molecular Sieves.
PML Damage Contours	Matrix Risk Pty Ltd. Feb 2005	Consequence analysis of fire and explosion associated with ethanol production, storage and loading bay.
PHA of Proposed flour Mill Upgrade	Rebecca Freeman, GHD, May 2007.	Hazard analysis associated with the installation of Short Flour Mill.

4. Statutory Requirement

The current structure for project assessment is established by the *Environmental Planning and Assessment Act 1979* (the EP&A Act). This project is considered to be a major project under Part 3a of the EP&A Act, and therefore an Environmental Assessment (EA) is required to accompany the development application.

The Director-General's Requirements for the EA require a PHA as per *State Environmental Planning Policy No.33 – Hazardous and Offensive Development* (SEPP 33)[1]. A PHA broadly examines the likely potential hazards that may occur as a result of a hazardous or offensive development.

SEPP 33 requires developments that are potentially hazardous to be the subject of a PHA to determine the risk to people, property and the environment at the proposed location and in the presence of controls. Should such risk exceed the criteria of acceptability, the development is classified as 'hazardous industry' and may not be permissible within most industrial zones in NSW.

This PHA was prepared applying SEPP 33, and generally in accordance with the Department of Planning (DoP) (formerly Department of Urban Affairs and Planning) publications Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis (1992) (HIPAP 6)[2] and Hazardous Industry Planning Advisory Paper No. 4 – 'Risk Criteria For Land Use Safety Planning'.

This PHA considers risks associated with the development in terms of accidental loss scenarios and their potential for hazardous incidents. General handling of waste materials and emissions produced during normal operations are dealt with elsewhere in the EA.

The primary objectives of a PHA are to:

» Identify potential hazards associated with the proposal;

» Analyse the consequences of significant hazards on people and the environment, and the likelihood or frequency of these hazards occurring;

» Estimate the resultant risk to the surrounding land uses and environment; and

» Analyse the safeguards to ensure they are adequate, and therefore demonstrate that the operation can operate within acceptable risk levels to its surroundings.

5. Methodology

5.1 General

A PHA is to provide sufficient information and assessment of risks associated with the proposed development to show that it satisfies the risk management requirements of the proponent company and the relevant public authorities. Within this brief, the main objective of the PHA is to show that the residual risk levels are acceptable in relation to the surrounding land use, and that risk will be appropriately managed. This is done by systematically:

- » Identifying intrinsic hazards and abnormal operating conditions that could give rise to hazards;
- » Identifying the range of safeguards;
- » Assessing the risks by determining the probability (likelihood) and consequence (effects) of hazardous events for people, the surrounding land uses and environment; and
- » Identifying approaches to reduce the risks by elimination, minimisation and/or incorporation of additional protective measures.

With proper application, this method should demonstrate that the proposed plant can operate within acceptable risk levels in relation to its surroundings.

The PHA needs to be carefully and clearly documented with the assumptions and uncertainties of final design and operation defined.

5.2 Preliminary Risk Screening

The need for a PHA under SEPP 33 is determined by a preliminary risk screening of the proposed development. The preliminary screening methodology concentrates on the storage of specific dangerous goods classes that have the potential for significant off-site effects. Specifically the assessment involves the identification of classes and quantities of all dangerous goods to be used, stored or produced on site with an indication of storage depot locations. Details of the methodology are described in DoP's - Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines (1994).

5.3 Hazard Identification

The hazard identification for the proposed upgrade of ethanol production included the review of:

- » Various dangerous goods kept on the Shoalhaven site;
- » Location and type of storage;
- » Inventories of all chemicals and ethanol;
- » Processing units handling dangerous goods and flammable materials;
- » Process and ethanol loading operation;
- » Hazardous property of each chemical with respect to the Dangerous Goods code and reference to the MSDS;

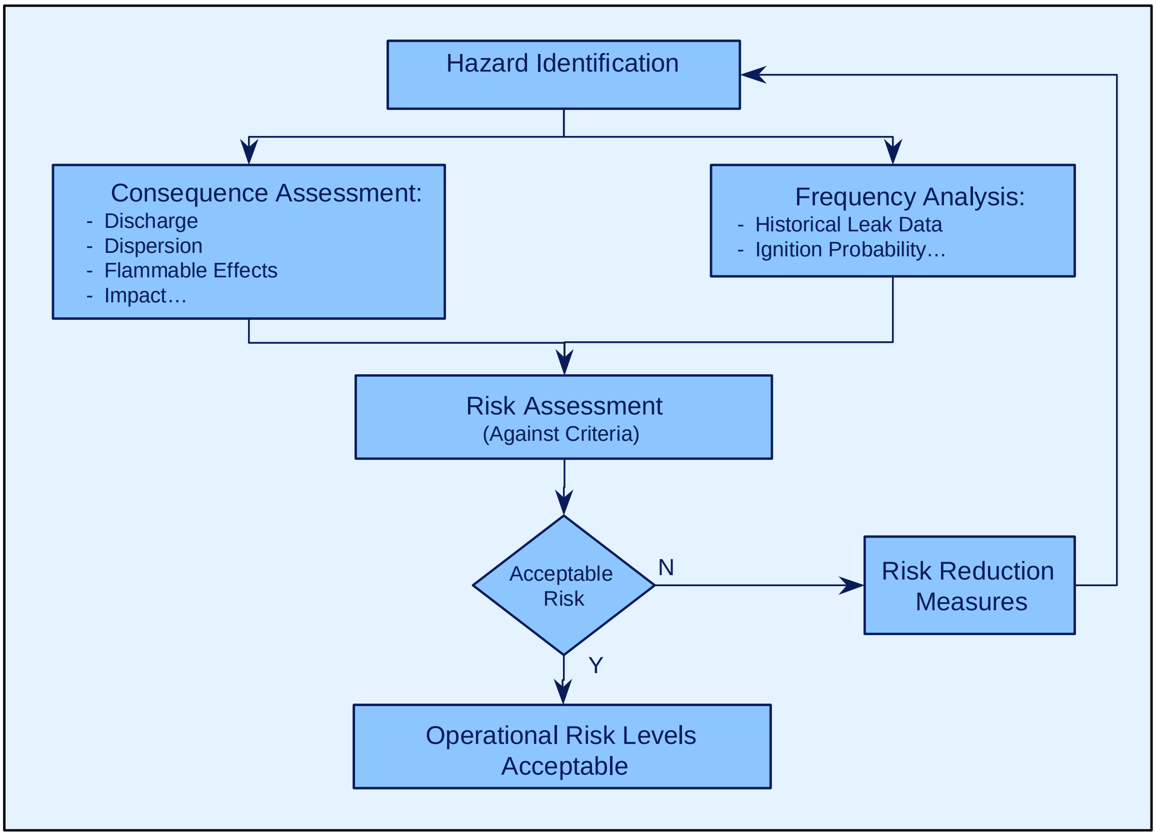
The focus of the exercise is to identify hazardous scenarios that could have potential offsite consequences.

The major hazards identified from the Hazard Identification above were included in the Quantitative Risk Assessment (QRA) to determine the off site risk in accordance to the nominated risk criteria of NSW HIPAP No 4

5.4 QRA Methodology

The methodology employed in this assessment is summarised below in Figure 5-1 The QRA Process.Each stage identified in the process is discussed in detail.

Figure 5-1 The QRA Process



5.4.1 Consequence Analysis

The objectives of the consequence analysis are to:

- Determine relevant toxic and flammable inventories;
- Analyse a representative set of spill or loss of containment cases;
- Determine the consequences of each spill with regards to the potential of fire and explosion and offsite impact to people, environment and properties.

The processes used to complete the analysis are;

- Discharge rate modelling;
- Dispersion Modelling; and

» Fire and Explosion Impact Modelling.

Spill, dispersion, and subsequent fire effects calculations are performed using the SAFETI (Software for the Assessment of Fire Explosion and Toxic Impact) commercial software package. The SAFETI package models have been extensively validated and a description of the consequence models employed in SAFETI is provided in Appendix B.

5.4.2 Frequency Analysis

The objective of the frequency analysis is to determine the frequency of each of the hazardous events. The process followed is:

» Selection of appropriate generic base leak frequencies from available industry data sources;

» Completion of a parts count of the plant to determine the number of components able to initiate the identified hazardous events;

» Selection of ignition probabilities for flammable releases from available data published for onshore plants; and

» Combination of release frequencies with immediate and delayed ignition probabilities (and applicable mitigation measures) enabling determination of a range of gas release and fire event frequencies.

The selection of leak frequency data, parts count, ignition probabilities and individual scenario leak frequencies can be seen in Appendix D.

5.4.3 Risk Calculation Methodology

This risk assessment is completed using SAFETI commercial software package. Individual risk per annum (IRPA) contours are plotted according to:

» Fire frequency;

» Location of release;

» Magnitude of consequence

  – Radiation exposure; and

» Local meteorology.

5.4.4 Project Risk Criteria

The risk levels calculated in the above step are compared against the nominated project risk criteria. The risk criteria chosen are those detailed HIPAP No 4 ‘Risk Criteria for Land Use Safety Planning’. The paper documents the risk criteria to be used for land use and safety planning issues.

Individual Fatality Risk

‘Individual Fatality Risk’ is the risk of death to a person at a particular point and the criteria is summarised in Table 5–1 Individual Fatality Risk Level Criteria.

Table 5–1 Individual Fatality Risk Level Criteria

Exposure Type	Risk Levels
Hospitals, schools, child-care facilities and old age housing developments	Half in a million per year (0.5 x 10^{-6} per year)
Residential developments and places of continuous occupancy (hotels/resorts)	One in a million per year (1 x 10^{-6} per year)
Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	Five in a million per year (5 x 10^{-6} per year)
Sporting complexes and active open space areas	Ten in a million per year (10 x 10^{-6} per year)
Industrial sites	Fifty in a million per year (50 x 10^{-6} per year)

The location of the Manildra facility is in an industrial area. The acceptable individual fatality risk level is fifty-in-a-million per year (50 x 10^{-6} per year) at the site boundary.

Injury Risk

» Incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year.

» Incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year.

Societal Risk

The societal risk analysis combines the consequences and likelihood information with population information. The result is presented in the form of 'F-N curve', which is a graph showing the cumulative frequency (F) of killing 'n' or more people (N).

Property Damage

» Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed a risk of 50 in a million per year for 23 kW/m^2 heat flux,

» Incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings should not exceed risk of 50 in a million per year for the 14 kPa explosion overpressure level

6. Hazard Identification

The first step in a risk assessment is to identify all potential sources of leakage on site. The focus is on hazardous or flammable materials, which can result in offsite consequences. Causes of potential leaks were identified as:

- Pipe and fittings failure;
- Pumps (seal/gland failure);
- Storage vessel/tank failure;
- Corrosion erosion (minor leaks);
- Loading Arm and Hose failure;
- Maloperation (eg not connecting hose properly);
- Incorrect plant and equipment modifications;

Individual failure modes of all equipment items used on the facility are discussed in Appendix D.

A plant visit was completed to review the process and the proposed modifications. The hazards were identified in a desktop exercise and reviewed and validated by Shoalhaven Starches personnel. The hazard identification involved review of the project scope and the changes to the inventory of the hazardous materials on the Shoalhaven site as a result of the project.

The hazard identification results are given in Table 6–1 Hazard Identification.

6.1 Hazardous Materials

A full list of hazardous materials kept on the site are given in Appendix A. Not all hazardous materials kept on site have the potential to cause off site impact and there are no changes to the inventory or type of chemical stored on site from the proposed ethanol plant upgrade. There is no increase in the ethanol storage capacity on site. However, there will be an increase in the handling of ethanol with respect to loading i.e. doubling the current tanker loading rate. This will increase the likelihood of ethanol release in the loading bay due to mechanical failure i.e. hose failure or human error.

There will be an increase in natural gas usage on site due to the co-generation plant.

The materials that are considered to cause off site impact and included in this risk assessment are:

- Ethanol; and
- Natural Gas.

The chemical and physical properties of these 2 materials are given in Appendix A.

Table 6–1 Hazard Identification

HAZARD IDENTIFICATION					
Project	Shoalhaven Ethanol Production Upgrade			Date: 27/08/07	
Present					
No	**Hazard Scenario**	**Causes**	**Consequence**	**Safeguards**	**Actions**
E1	**Ethanol release at the storage bay**. There are 7 ethanol storage tanks. Ethanol is stored at ambient temperature and atmospheric pressure. The combined storage capacity is 1.9 million litres of ethanol but the actual storage is normally 50% of the capacity. There is no change to ethanol storage capacity as part of the upgrade.	1. Tank catastrophic failure ; 2. Valve & Piping failure;	Ethanol vapour ignites and burns as a pool fire. Thermal radiation from the fire.	1. Tank and pumps are fully bunded.; 2. Any spill in the bund is automatically pumped away to the recovery tank. There is a flow alarm to seek operator attention; 3. Operator surveillance of the bund; 4. Foam injection into the tank to smother fire; 5. Fire monitor 2; 6. Hot work control and permit to work system; and 7. Inspection and Maintenance Systems.	

<table>
<tr><th colspan="6">HAZARD IDENTIFICATION</th></tr>
<tr><td colspan="2">Project</td><td colspan="2">Shoalhaven Ethanol Production Upgrade</td><td></td><td>Date: 27/08/07</td></tr>
<tr><td colspan="2">Present</td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>No</td><td>Hazard Scenario</td><td>Causes</td><td>Consequence</td><td>Safeguards</td><td>Actions</td></tr>
<tr><td>E2</td><td>Ethanol Release at the loading bay.

Ethanol is loaded into B-Double or Single road tankers and transported to the customer site. There are 3 loading pumps for 3 different grades of ethanol. Only one pump is used during loading of a product. A B-Double can hold 50,000 L of ethanol and a Single tanker can hold 34, 000 L.

Normally 6 B-Double and 1 Single tankers are loaded per day.

The loading rate is expected to increase to 14 B-Doubles and 4 Single tankers per day to meet the upgraded 3 ML per annum production capacity.

There are 2 drains in the loading bay to drain any spill to the underground storage tank.</td><td>1. Hose failure;
2. Hose not connected properly (human factors;
3. Pipe or flange failure (mechanical);
4. Drive away with hose connected (human factors).</td><td>1. Loading bay drains blocked or underground storage tank full leading to pool formation and pool fire in the loading bay.

2. Potential for explosion (flash fire) in the loading bay if the ethanol vapour fails to ignite immediately.</td><td>1. Steel braided hose for loading;
2. Hose inspection and testing program;
3. Driver in attendance during loading;
4. Emergency Stops (3) in the loading bay to shut down loading;
5. 2 IR flame detectors;
6. Foam sprinkler on the loading bay. Automatic foam activation upon break glass;
7. Fire break glass alarm;
8. Local fire authority automatic notification upon fire break glass activation; and
9. On site full time fire crew.</td><td></td></tr>
</table>

HAZARD IDENTIFICATION					
Project	Shoalhaven Ethanol Production Upgrade			Date: 27/08/07	
Present					
No	**Hazard Scenario**	**Causes**	**Consequence**	**Safeguards**	**Actions**
E3	**Ethanol release from the Molecular Sieve plant.** Release of 99.5% ethanol from the molecular sieve vessel or associated equipment. Ethanol from the Molecular Sieve is transferred/pumped to storage at 200 kPa and 160 ^{o}C. Ethanol will flash off and form vapour cloud leading to potential explosion in the distillation section building.	1. Vessel failure; 2. Pipe failure; and 3. Gasket or flange failure.	Ethanol is in vapour form in the mol sieve hence ethanol release from this section will be in vapour form. Potential for a vapour cloud explosion.	1. Operator surveillance; 2. Plant remote isolation; 3. Bund to contain the spill and automatic transfer to recovery system; 4. Foam application for fire fighting; 5. Spill in the bund will be detected via the flow meter on the bund transfer line to the recovery tank; and 6. Inspection and Maintenance System.	
E4	Ethanol release from ethanol pump inside the ethanol tank bund.	1. Gasket failure; 2. Flange failure; and 3. Pipe failure.	Formation of ethanol pool and potential pool fire.	1. Pump located within bund; 2. Operator monitoring; 3. Loss of flow alarm; and 4. Inspection and Maintenance System.	

HAZARD IDENTIFICATION					
Project	Shoalhaven Ethanol Production Upgrade			Date: 27/08/07	
Present					
No	**Hazard Scenario**	**Causes**	**Consequence**	**Safeguards**	**Actions**
E5	Ethanol release from the Distillation Columns (T680, T540, T660). Ethanol concentration: 92%.	1. Vessel failure; 2. Gasket failure; 3. Flange failure; and 4. Pipe failure,	Formation of ethanol pool and potential pool fire.	1. Bund to contain the leak; 2. Alarms & operator monitoring; 3. Inspection and maintenance program.	
E6	**Gas release at No 2 steam boiler** A 4" gas pipeline supplies gas to the burner. Due to the location of burner and the pipe line, there is potential for gas accumulation and delayed ignition resulting in explosion in the building. The utilities control room and the workshop are relatively close to the burner and could be affected by the explosion.	1. Pipe failure; 2. Gasket Failure; 3. Flange failure; and 4. Valve failure.	Delayed ignition resulting in vapour cloud explosion. Off site impact is not likely due to the separation distance from the public road.	1. Burner management system; 2. Burner management system and piping designed to code; 3. Safety shut off system; 4. Boiler trip testing; and 5. Routine inspection and maintenance.	

HAZARD IDENTIFICATION					
Project	Shoalhaven Ethanol Production Upgrade			Date: 27/08/07	
Present					
No	**Hazard Scenario**	**Causes**	**Consequence**	**Safeguards**	**Actions**
E7	**Gas release at the Cogeneration Plant.** A gas fired cogeneration plant is proposed for the Shoalhaven site. The plant will be located away from the main plants and buildings. There is potential for gas release leading to fire or explosion.	1. Pipe failure; 2. Gasket Failure; 3. Flange failure; and 4. Valve failure.	1. Jet fire and thermal radiation. 2. Potential for gas cloud explosion in the case of delayed ignition.	1. Burner management system; 2. Burner management system and piping designed to code; and 3. Routine inspection and maintenance.	
E8	A second gas fired boiler for steam generation is proposed as part of this expansion.	1. Pipe failure; 2. Gasket Failure; 3. Flange failure; and 4. Valve failure	Delayed ignition resulting in vapour cloud explosion. Off site impact is not likely due to the separation distance from the public road	1. Burner management system; 2. Burner management system and piping designed to code; 3. Safety shut off system; 4. Boiler trip testing; and 5. Routine inspection and maintenance	

HAZARD IDENTIFICATION					
Project	Shoalhaven Ethanol Production Upgrade			Date: 27/08/07	
Present					
No	**Hazard Scenario**	**Causes**	**Consequence**	**Safeguards**	**Actions**
E9	**Gas release at the metering station**. A gas metering station is proposed to be installed across the road from the production facility. The pipe line from the metering station will run underground to the site. The station is owned by a third party and is not in Manildra's boundary, therefore, it was not included in the modelling.	1. Pipe, flange or gasket failure; 2. Collision with pipe; and 3. Object dropped on the pipe.	Release of gas resulting in jet fire and potential for thermal radiation. A public road runs approximately 20m from the metering station.	1. Metering station fenced to prevent collision or vandalism.	
E10	**Diesel Storage Tank** There is a diesel storage tank for the fire water pumps. Tank capacity 5000 L. Not included in the model due to small inventory.	1. Tank failure.	Diesel pool fire. Off site impact from thermal radiation not expected due to small inventory.	1. Away from vehicle access way (collision protection and no ignition source). 2. Fire monitors nearby.	

6.2 Hazardous Scenarios

The hazardous scenarios that have the potential to cause off site impact and included in the model are given below:

1. Ethanol storage tank catastrophic failure and release of ethanol in the bund resulting in a pool fire in the bund (E1);
2. Ethanol release in the loading bay due to hose and equipment failure resulting in a pool fire (E2);
3. Ethanol vapour release from the Mol Sieves and associated equipment resulting in jet fire or vapour cloud explosion (E3);
4. Ethanol release from the ethanol loading pump resulting in a pool fire near the storage tank (E4);
5. Ethanol release from the distillation unit resulting in pool fire in the distillation section (E5);
6. Natural gas release from the gas fired boiler (No 2 & proposed boiler) resulting in delayed ignition and explosion (E6/E8); and
7. Natural gas release from the pipe line & fittings at the Cogeneration Plant resulting in jet fire (E7).

The gas metering station across the road is not included in the model as it is owned by the gas supplier and is not on Manildra's property.

Table 6-1 Hazardous Scenarios and Process Conditions

Event ID	Description	Isolation	Condition	Consequence
E1	Single Ethanol Storage Tank catastrophic failure in the storage bund. Most of spillage will be pumped away into the underground recovery tank.	Spill: 217,000 kg Failure of largest tank)	Temp: 20 ^{o}C Press: atmospheric	Pool Fire
E2	Ethanol release in the loading bay (hose failure).	Isolation Time: 1800s (Spill: 10,000 kg)	Temp: 20 ^{o}C Press: atmospheric	Pool Fire
E3	Ethanol release in the plant (Molecular Sieve)	Isolation Time: 3600s (Max spill: 10,240 kg	Temp: 155 ^{o}C Pressure: 500 kPag	Vapour Cloud Explosion
E4	Ethanol release in the bund from loading pump.	Isolation Time: 1800s (Spill: 10,000 kg)	Temp: 20 ^{o}C Press: 400 kPag	Pool Fire
E5	Ethanol release from the distillation section.	Isolation Time: 3600s (Max spill: 10,240 kg)	Temp: 160 ^{o}C Pressure: 600 kPag	Pool Fire & VCE

E6/E8	Natural gas release at boiler 2 and proposed boiler.	Max Gas release: 1000 kg	Temp: 20 ^{o}C Press: 210 kPag	Jet Fire & Vapour Cloud Explosion
E7	Natural gas release at the Cogeneration Plant	Max gas release: 5000 kg	Temp: 20 ^{o}C Press: 2300 kPag	Jet Fire & Vapour Cloud Explosion

7. Study Assumptions

A number of assumptions were made in completing the risk model. These assumptions are listed below:

- Liquid ethanol is modelled as a pool fire;
- Gas leak is modelled as jet fire;
- Unignited ethanol vapour cloud is modelled as vapour cloud explosion;
- An isolation time of 60 minutes assumed for process units (distillation and mol sieve). For ethanol loading pump and loading bay, an isolation time of 30 minutes is assumed because personnel (driver) would be present at the scene to detect the event and take action to stop the leak or pump.
- Fumes generated from the fire will be carried upwards by the heat of the fire. They are therefore assumed to have no contribution to fatalities for offsite risk;
- Dust cloud explosion not considered in this study as there is no change to storage of raw materials (starches) used in the production of ethanol. A PHA for the flour mill was completed during the flour mill upgrade;
- It is assumed that 50% content of the largest ethanol tank will be involved in a pool fire for the catastrophic tank failure scenario (E1), the rest of the ethanol will be pumped away into the underground storage tank;
- Hazard scenarios and the parts count have been verified by Shoalhaven staff;
- A bund of (10m x 10m) was used to model the pool fire in the loading bay;
- A bund of (20m x 10m) was used to model the pool fire in the ethanol tank storage bund;
- Ignition probability of Cox, Lees and Ang used;
- Release from molecular sieve is ethanol vapour;
- Only the major equipment in the distillation and molecular sieve sections are considered in the failure scenarios.

8. Results and Discussions

Modelling of each of the hazardous scenarios was completed in order to assess the severity of the impacts. In all cases the consequences and likelihood of occurrence were determined and combined together with the site layout and local meteorological conditions to determine the risk levels.

8.1 Frequency Analysis

The leak frequency data obtained from the UK HSE was used in the assessment of the failure frequencies of equipment associated with the hazardous scenarios in this study. UK HSE data is based on the leak frequencies of equipment in off shore operation which is in a harsh environment. The details of the frequency assessment can be found in Appendix D.

8.2 Consequence Modelling

Consequence of each hazard scenario were assessed using SAFETI (Software for Assessment of Fire, Explosion and Toxic Impact). The following consequences were considered in the risk assessment:

- Pool Fire (Thermal Radiation) for Fire Events associated with Ethanol pool fire;
- Jet Fire (Thermal Radiation) for gas release;
- Vapour Cloud Explosion.

Levels of thermal radiation included in this risk assessment were 4.7 kW/m^2, 12.6 kW/m^2 and 35 kW/m^2. The radiation effects as given in HIPAP No 4 are:

- 4.7 kW/m^2: potential to cause injury;
- 12.6 kW/m^2: potential to cause fatality for extended exposure;
- 35 kW/m^2: potential to cause fatality instantaneously.

For each of the identified hazardous scenarios, the distances to consequences of interest are determined. The consequences of interest are based on human impact criteria i.e. the exposure to thermal radiation for periods of time.

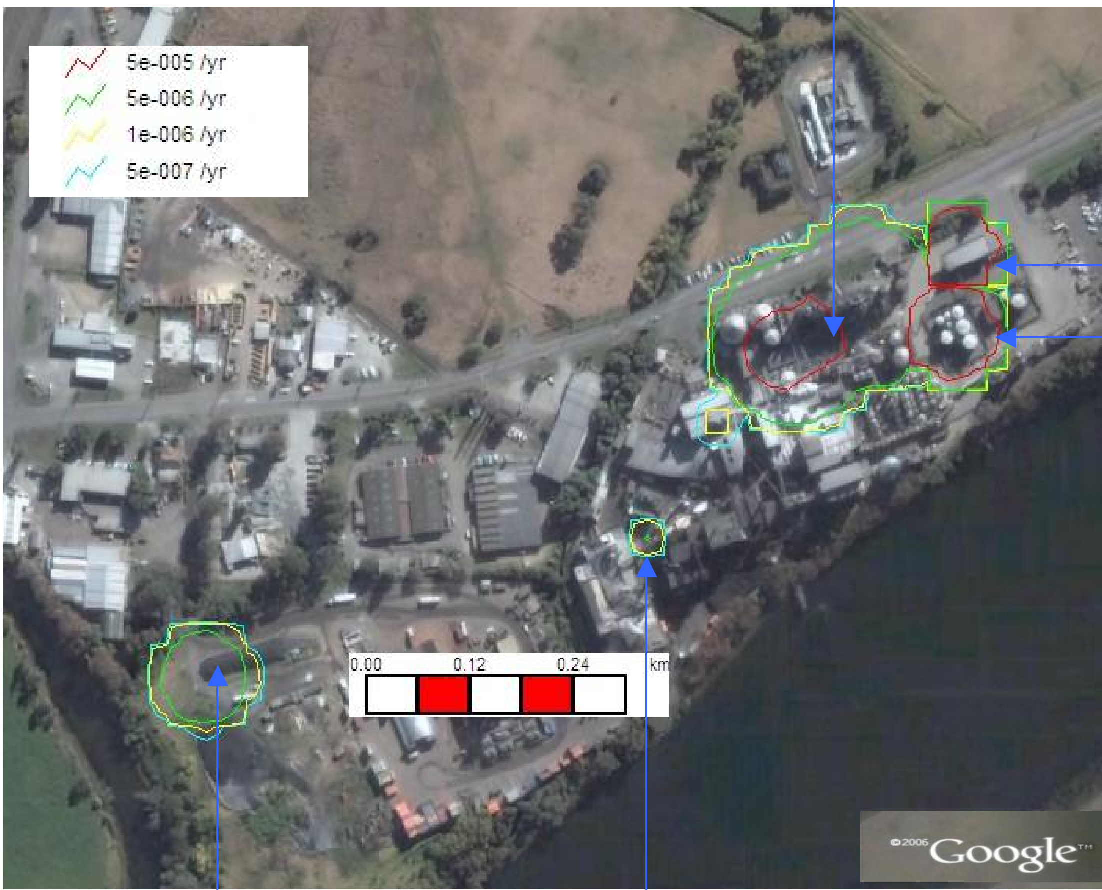
The consequences of hazardous scenarios and input data for scenarios are reported in Appendix C.

8.3 Risk Assessment

8.3.1 Individual Risk of Fatality

The Individual Fatality Risk is the risk of death to a person while standing at a particular point. The Individual Fatality Risks calculated for the Shoalhaven site are given in Figure 8-1 below. The risk contours are the nominated risk criteria for land use safety planning of NSW DoP (HIPAP No 4).

Figure 8-1 Individual Fatality Risk



The individual fatality risk from the proposed upgrade of the Shoalhaven facility in Bomaderry does not breach any of the nominated risk criteria of NSW HIPAP No 4.

The key information from the Individual Fatality Risk profile are:

- 50×10^{-6} /yr risk contour around the ethanol production and storage facility is within the site boundary. The industrial sites around the Manildra plant are not affected;
- The 5×10^{-6}/yr to 0.5×10^{-6} /yr risk contours go over the Bolong Road but does not breach the risk criteria;
- The Cogen plant to be located in the south corner of the site does not breach any risk criteria.

The off site risk from the existing operation and the proposed modification is acceptable. However, opportunities for risk reduction should be continuously reviewed and implemented.

8.3.2 Societal Risk

There are no residential or sensitive population close to the site to be affected by a large incident on the site. The closest residential area is over 350 m away to the west beyond the railway line.

8.3.3 Injury Risk

The closest residential area is over 350 m away from the ethanol facility and the maximum distance from an explosion or fire is.

» 4.7 kW/m^2 (70 m)

» 7 kPa (110 m)

Therefore, injury risk to people in the residential area is not possible from a fire or explosion event in the ethanol facility.

8.3.4 Property Damage

There are no hazardous industries close to the site to cause escalation issue from an incident on the Manildra site.

» The overpressure of 14 kPa does not extend more than 70 m from the ethanol facility. The explosion overpressure (14 kPa) from the co-generation unit does not exceed the boundary. Figures C1 and C2 in Appendix C shows the explosion overpressure contours for the cogeneration unit and mol sieve.

» The thermal radiation of 23 kW/m^2 does not extend beyond the site.

Therefore, there is no possibility of property damage beyond the site boundary, using the criteria for property damage as given in Section 5.4.4.

9. Recommendations

The off site risk assessment completed for the proposed ethanol production upgrade is in compliance with the DoP risk criteria given in HIPAP No 4. However, it is recommended to identify opportunities during the design phase of the project to improve the safety of the process. This can be achieved through design reviews and appropriate safety studies.

The following recommendations are made to improve the safety of the proposed upgrade:

1. Complete the Hazard and Operability (HAZOP) for the new plants i.e. co-generation, gas fired boiler and mol sieve at the completion of the detail design;
2. Review the impact of the increased production capacity on the existing process units (vessels and pipes) with respect to mechanical integrity;
3. Consider completing a traffic risk assessment with respect to increased traffic movement associated with raw materials and ethanol movement to and from the site;
4. Review the fire fighting capability with respect to new plant and equipment such as the co-generation plant and gas fired boilers;
5. Review the emergency shutdown system and emergency procedures with respect to the new plants (co-generation and boiler).

10. Conclusion

The Quantitative Risk Assessment (QRA) as part of the Preliminary Hazard Analysis (PHA) was completed for the proposed Ethanol Facility upgrade at the Shoalhaven site. The QRA incorporated the proposed ethanol production upgrade and the existing operation to show the total risk associated with the site.

The hazardous materials and hazardous operations that have potential for off site impact were included in the QRA. The new hazards with potential for off site impact introduced by the proposed upgrade are:

- » Cogeneration Plant; and
- » Increased ethanol loading frequency, as a result of doubling of ethanol production capacity, which increases the likelihood of release of ethanol in the loading bay.

The PHA was completed in accordance with the State Environmental Planning Policy (SEPP) 33 guideline of NSW DUAP (now DoP) and HIPAP No 6 guideline for Hazard Analysis. The QRA was completed using the Risk Criteria for Land Use Safety Planning given in HIPAP No 4.

Individual Fatality Risk was calculated using SAFETI (Software for the Assessment of Fire, Explosion and Toxic Impact) and the risk is demonstrated to be acceptable as all the risk contours are in compliance with the nominated risk criteria of HIPAP No 4.

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Appendix A

Background Data

A I. Site Layout

A II. Register of Hazardous Materials Register

A III. Properties of Hazardous Material

A IV. Weather Data

A I . Site Layout

An aerial photograph and site layout of the Manildra Ethanol plant are given in Figure A 1 below.

Figure A 1 Shoalhaven Site Aerial Photograph

A II . Hazardous Material Register

The hazardous materials identified on the site are given in Table A II 1 below.

Table A II 1 Hazardous Materials

Hazardous Material	Location	UN Code	Class	Quantity
Sulfuric Acid	Farm	2796	8	15,000 L
Acetic Anhydride	Zone 1A	1715		3,000 L
Hypochlorite Solution	Zone 1A	1791	8	30,000 L
Hydrogen Peroxide (solution)	Zone 1B	2014	5.1	1,000 L
Butanol	Zone 2A	1120	3	5,000 L
n-Propanol	Zone 2A	1274	3	5,000 L
n-Propyl Acetate	Zone 2A	1276	3	5,000 L
Butanol	Zone 2B	1120	3	1,800 L
Methyl Isobutyl Ketone	Zone 2B	1245	3	1,800 L
n-Propanol	Zone 2B	1274	3	3,600 L
n-Propyl Acetate	Zone 2B	1276	3	3,600 L
Ethanol	Zone 2C	1170	3	2,970,000 L
Dimethyl Ether	Zone 2D	1033	2.1	100,000 L
Petrol	Zone 2E	1203	3	5000 L
Methanol	Zone 2E	1230	3	5000 L
Methyl Isobutyl Ketone	Zone 2E	1245	3	5000 L
Hydrochloric Acid	Zone 4			30,000 L
Sodium Hydroxide Solution	Zone 4			52,000 L
Ammonia Solution	Zone 4	2672	8	35,000 L
Sulfuric Acid	Zone 6	2796	8	2,700 L
Hydrochloric Acid	Zone 7	1789	8	20,000 L
Phosphoric Acid	Zone 7	1805	8	36,000 L
Sodium Hydroxide Solution	Zone 7	1824	8	20,000 L

A III . Properties of Hazardous Materials

Natural Gas

Natural gas is used on the site mainly for steam generation in the boilers and is proposed to be used in the Co-Generation plant.

Natural gas is a non toxic, colourless gas at ambient conditions. It is odourless , however, an odourant is normally added before it is shipped to end users. Natural gas is lighter than air. It is highly flammable, with flammability ranging from 5% to 15% volume in air. If it does not immediately ignite upon release, it can form an explosive mixture with air. If it is burned in limited supply of air, carbon monoxide may be produced. While it is regarded as being stable, it is not compatible with strong oxidising agents.

The physical and chemical properties of natural gas are given in Table A III 2.

Ethanol

Ethanol is highly flammable, the vapours can form an explosive mixture when mixed with air. The physical and chemical properties of ethanol are given in Table A III 2 below.

Table A III 2 Physical & Chemical Properties of Ethanol & Natural Gas

Material	Boiling Point (^{o}C)	Specific Gravity	Vapour Pressure KPa (at 20 ^{o}C)	Flash Point	LEL %	UEL %	Melting Point (^{o}C)	Auto Ignition Temp (^{o}C)
Ethanol	78	0.790	5.7	13 ^{o}C	3.3	19.0	-117	N/A
Natural Gas	-162	0.615	N/A	-218	5.0	15.0	NA	540

A IV . Weather Data

Weather is classed according to wind speed and weather stability class. Table A IV 1 below shows the different weather stability classes.

Table A IV 1 Weather Stability Classes

Class	Type	Description
A	Very Unstable	Daytime – sunny, light winds (strong insolation)
B	Unstable	Daytime – moderately sunny, light to moderate winds
C	Unstable / Neutral	Daytime – moderate winds, overcast or windy and sunny
D	Neutral	Daytime – windy, overcast or Night-time - windy
E	Stable	Night-time - moderate winds with little cloud or light winds with more clouds

Class	Type	Description
F	Very Stable	Night-time - light wind, little cloud (strong temperature inversion)

Local meteorological data was obtained from the Nowra weather station for the Shoalhaven site.

The weather classes and wind speeds selected for this QRA are:

Wind 1.5 m/s, weather stability class F;

Wind 3 m/s, weather stability class C;

Wind 5 m/s, weather stability class D;

Wind 7 m/s, weather stability class D;

Average Temperature: 21 ^{o}C;

Relative Humidity: 70%

Appendix B

Consequence Models

Consequence Modelling

A part of the risk assessment process involves generating consequences for the release events identified. The steps involved in determining consequences are:

- » Determine release conditions based upon materials involved, process conditions and available inventory etc;
- » Based on release conditions, determine the types of events which will occur (eg jet fire, toxic cloud, evaporating pool etc);
- » Calculate the extent of the consequences; and
- » Establish the impact of the consequence (e.g. proportion of people killed when exposed to a toxic dose)

The consequences are calculated using empirically derived models, which can then be used to determine which release cases generate offsite effects and should be included in the risk model. The level at which fatal consequences are considered to occur will directly influence the risks.

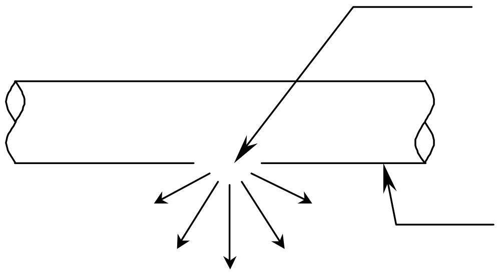
This Appendix discusses basic concepts and theory behind the various consequence models used in the analysis. The models discussed are:

- » Discharge Modelling;
- » Dispersion;
- » Flammable Effects:
    - § Jet Fire;
    - § Flash Fire;
- » Toxic Effects.

B I. Discharge Modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure or static head is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, eg, vapour or liquid, velocity of release etc. Figure B 1 illustrates an example scenario.

Figure B 1 Typical Discharge



The discharge can be considered to have two stages; the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.

The conditions at the orifice are calculated by assuming isentropic expansion, ie, entropy before release = entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate ($\dot{m}$) and discharge velocity (u_0) are then given by:

$$\dot{m} = C_d A_o \rho_o \sqrt{-2(H_0 - H_i)}$$

And $$u_0 = C_d \sqrt{(-2(H_0 - H_i)}$$

Where

- C_d = Discharge coefficients;
- A_o = Area of the orifice;
- ρ_o = density of the material in the orifice;
- H_o = Enthalpy at the orifice; and
- H_i = Enthalpy at initial storage conditions.

The discharge parameters passed forward to the dispersion model are as follows:

- release height (m) and orientation;
- thermodynamic data: release temperature (single phase) or liquid mass fraction (two-phase), initial drop size;
- other data;
  - for instantaneous release: mass of released pollutant (kg), expansion energy (J)
  - for continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s).

B II. Dispersion

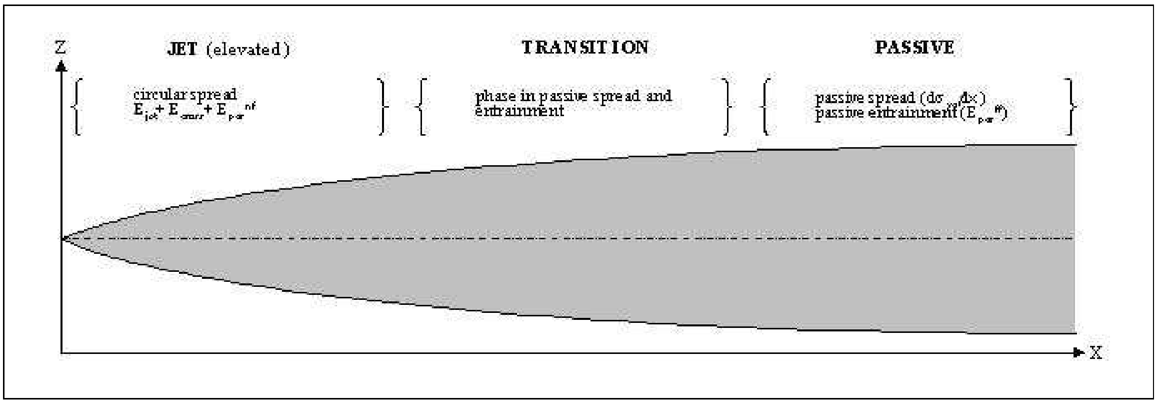
When a leak occurs, the material will be released into the atmosphere. Upon being released it will start to disperse and dilute into the surrounding atmosphere. The limiting (lowest) concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

The consequence modelling package PHAST utilises the Unified Dispersion Model (Witlox *et al*, 1999). This models the dispersion following a ground level or elevated two phase unpressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation.

B II.1 Jet Dispersion

For a continuous, pressurised release, the material is released as a jet, ie, high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure B 2 below shows a typical release and the various phases involved.

Figure B 2 Jet Dispersion



The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the mixing is turbulent and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

» Material released, specifically molecular weight;

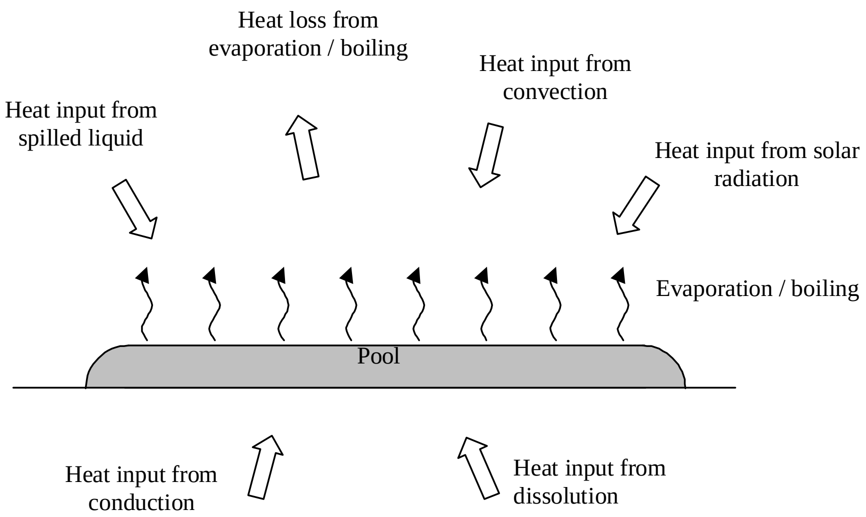
» Discharge conditions including phase(s) of release, velocity etc;

Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).

B II Dispersion from Pool Evaporation

If a rupture occurs from a refrigerated tank or vessel, the refrigerated liquid product will leak out and form a pool on the ground. This pool will evaporate and the resulting vapour cloud disperses as a low momentum cloud. Due to the low momentum, the cloud is not turbulent, which is a significant factor in air entrainment and dilution of the cloud. Figure B 3 below shows a typical release and some of the inputs into the calculation.

Figure B 3 Pool Evaporation Heat Balance



The rate of the evaporation depends on numerous factors, the most important ones being:

- Surface it is released onto (eg its thermal properties and temperature);
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds);
- Boiling point of the liquid; and
- Pool size.

The concentration of interest is normally related to the flammable, or toxic limits or specified Emergency Response Planning Guideline (ERPGs) limits set for the contained hazardous material.

B III Flammable Effects

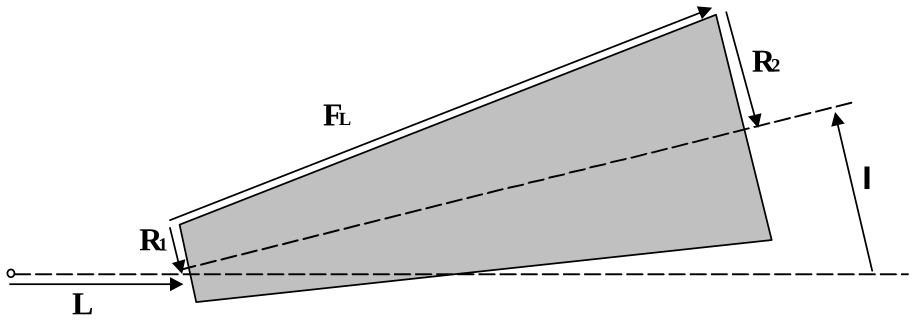
If the release is of a flammable material, it is possible for the release to be ignited. The type of fire which results (eg jet, pool, explosion etc) depends on the physical properties of the release and whether the ignition is immediate or delayed. The various flammable effects are discussed below.

B III.1 Jet Fire

Jet fires are a result of high momentum releases. If a flammable release is ignited instantaneously, a jet fire will result. The flame will have a degree of 'lift off' as the flammable mixture has to dilute to be within the flammable limits. This section briefly discusses the model used for jet fires as well as key parameters in the calculation.

The jet fire calculation utilises the Chamberlain model (Chamberlain 1987). In this model, jet fires are modelled as a conical flame, with the ignited portion lift off, inclination and shape being determined by the material being released, the pressure at which it is being released and the hole size that it is being released through. These release parameters are the main inputs to the jet fire radiation calculations. Figure B 4 below shows a graphical representation of the jet fire model.

Figure B 4 Truncated Cone Jet Fire Model



Where;

L = Lift off;

I = Flame Inclination;

R_1 = Flame Base Radius;

R_2 = Flame End Radius; and

F_L = Flame Length.

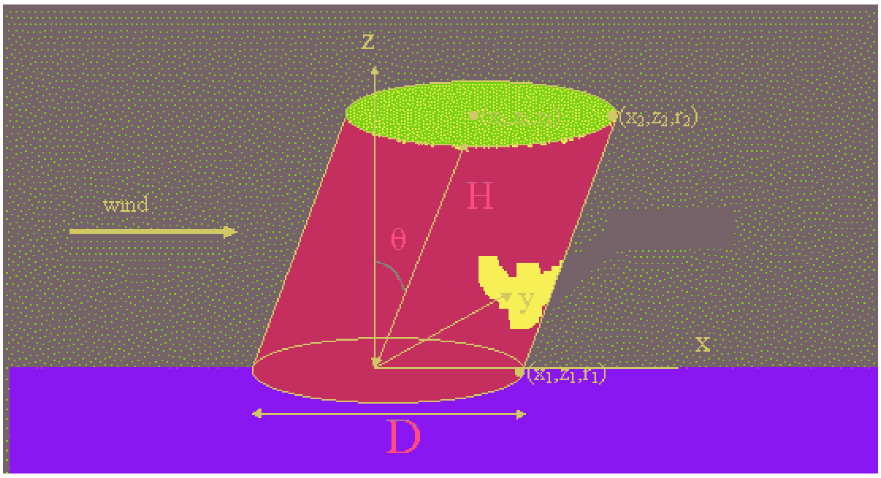
The jet fire calculations model radiation from the entire surface of the ignited portion of the jet. This includes radiation from the cone forming the body of the flame, as well as from the ends of the cone. The amount of radiation that a nearby receiver is exposed to is determined by its distance from the flame surface, as well as by the orientation of the flame relative to the receiver. The key parameters in the calculation of the radiation exposure of a receiver are therefore the flame lift off, the flame inclination, and the dimensions of the ignited portion of the jet (i.e. flame length and end radii).

B III.2 Pool Fires

If a flammable/combustible liquid spill ignites it will form a pool fire. Pools can also form if a pressurised liquid is released and then 'rains out' to form a pool. Pool fires have low momentum flames and therefore their direction is dependent on wind conditions. This section describes the pool fire model and the equations used in calculating size and radiation emitted from a pool fire.

Pool fire flames are modelled as cylinders sheared in the direction of the wind, with diameter D, height *H* and tilt angle *q* (measured from the vertical). The flame is described by three circles (c1, c2, c3) arranged along the centreline of the flame, each defined by the downwind co-ordinate x and elevation *z* of the centre of the circle, and by the radius *r*. These flame-circle co-ordinates are the main input to the radiation calculations. Figure B 5 below shows a graphical representation of the pool fire model.

Figure B 5 'Sheared Cylinder' Pool Fire Model



With these three circles, the radiation calculations will model radiation from two surfaces: from the side of the flame between c1 and c2, and from the top of the flame between c2 and c3. This approach ensures that the bottom of the pool fire is not treated as a radiating surface.

The flame length H, flame diameter D and tilt angle θ are used to calculate three co-ordinates of the flame, as follows:

$x_1 = 0.0$	$x_2 = H \sin \theta$	$x_3 = H \sin \theta$
$z_1 = d_{elev}$	$z_2 = H \cos \theta + d_{elev}$	$z_3 = H \cos \theta + d_{elev}$
$r_1 = D/2$	$r_2 = D/2$	$r_3 = 0.0$

Where:

d_{elev} = elevation of flame surface above ground

B III.3 Flash Fire

Flash fires are transient in nature and are the product of delayed ignition of a dispersing cloud in an unconfined environment. In a delayed ignition from vertical release the fireball formed dies back to a steady state jet flame from the source.

B IV Multi Energy Explosion Model

The Multi Energy Model gives overpressure of an explosion as a function of distance from the explosion. The explosion is modelled as a sphere and overpressure is calculated based on scaled distance from the centre. This section explains the key parameters involved in the multi energy model.

The energy released by the explosion, E, is calculated as the product of the mass of fuel in the cloud and the heat of combustion. This assumes a stoichiometric mixture of fuel and air.

The distance scaling factor, S, is related to the energy released by the explosion and the atmospheric pressure by

$$S = \left[\frac{E}{P_a}\right]^{1/3}$$

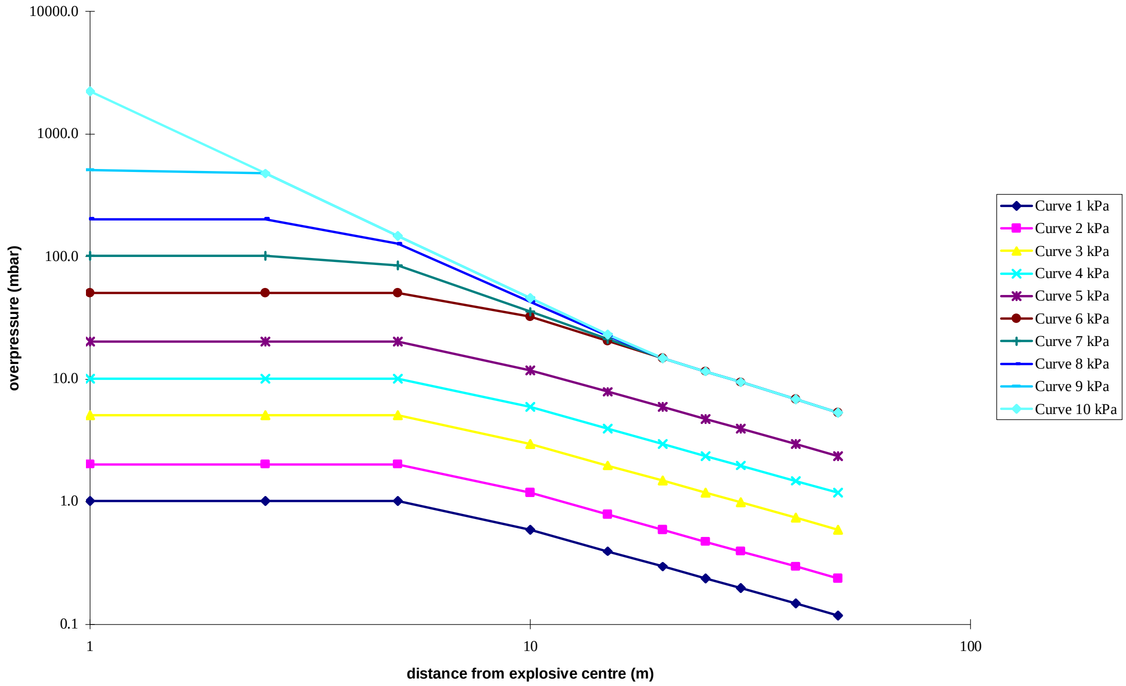
The scaled distance r is then given by

$$r = \frac{d}{S}$$

where d is the actual distance of the receiver from the cloud centre.

To calculate overpressure a set of 10 curves is used. The actual curve used depends on the degree of confinement, with a confinement of 1 being least confined and 10 most confined. Process plants generally have a confinement factor of 7, though it needs to be assessed for each individual process. The graph showing the 10 curves is included in Figure B 6 below.

Figure B 6 Multi Energy Curves



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Appendix C

Consequence Results

Consequence Results

This section presents the consequence results of the hazardous events included in the study. The consequences assessed in this study were:

» Thermal radiation - kW/m^2 (pool fire for ethanol and jet fire for natural gas); and

» Overpressure from vapour cloud explosion (VCE). Multi Energy Model was used for explosion modelling.

C I Thermal Radiation

This section presents the thermal radiation results for 4.7 kW/m^2 (potential injury) and 12.6 kW/m^2 (potential fatality) from the various fire scenarios assessed in this study. The results are for wind condition 1.5F, which represents the worse case scenario.

Table C 1 Thermal Radiation Consequence Results

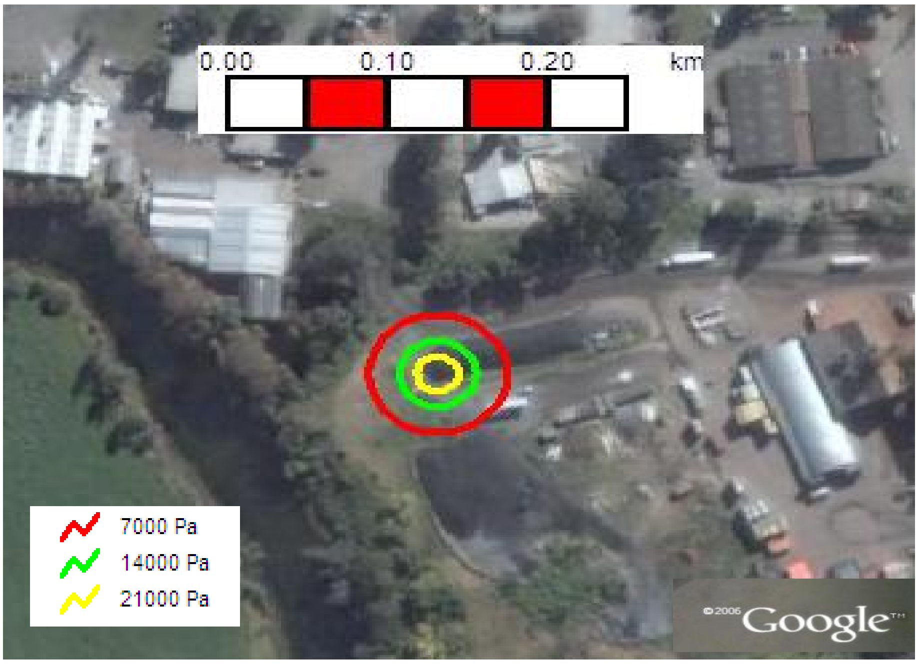
Event	Section Description	Bund (m)/Hole Size (mm)	Process Conditions		Thermal Radiation Distances (m)		Release (kg)
			P (kPa,g)	T (°C)	12.6 kW/m^2	4.7 kW/m^2	
E1	Ethanol release from the largest storage tank. Liquid Pool Fire	20 X 10	atm	25	33	49	217,000
E2	Ethanol release in the Loading Bay (Duration: 1800s) Liquid Pool Fire	10 X 10	400	25	25	37	10,000
E3	Ethanol Release from Mol Sieve Section (Duration: 3600s) Vapour Jet Fire	100 mm	200	150	53	63	10,240
E4	Ethanol release from Ethanol loading pump (duration; 1800s) Liquid Pool Fire	10 X 5	400	25	18	28	10,000
E5	Ethanol release from Distillation Unit (3600s) Liquid/Vapour Jet Fire	100 mm	450	155	60	70	10,240
E6	Gas release from the boiler No 2 (duration: 3600s) Jet Fire	5 25 50	21	20	- 6 12	- 7 14	50 185 1000

Event	Section Description	Bund (m)/Hole Size (mm)	Process Conditions		Thermal Radiation Distances (m)		Release (kg)
			P (kPa,g)	T (°C)	12.6 kW/m^2	4.7 kW/m^2	
E7	Gas release from Cogen Plant (duration: 600s) Jet Fire	5 25 50	2300	20	- 27 53	- 32 56	1000 1000 5000
E8	Gas release from the proposed boiler (duration: 3600s) Jet Fire	5 25 50	21	20	- 6 12	- 7 14	50 185 1000

C II Explosion Overpressure

This section presents the explosion overpressure of scenarios of interest with the largest impact.

Figure C 1 Gas Explosion Overpressure for Cogeneration plant



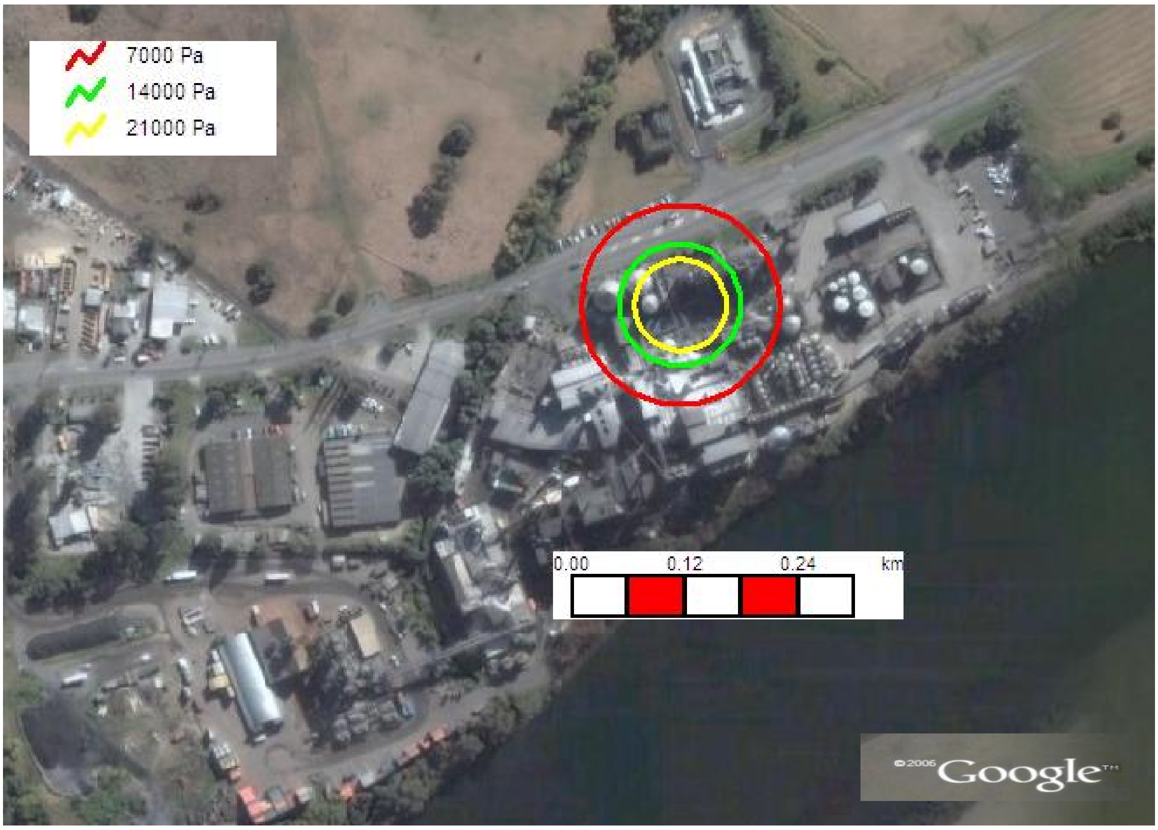


Figure C 2 Ethanol Vapour Explosion Overpressure for the Molecular Sieve

Table C 2 Summary of Explosion Consequences

Descriptor	Inventory (kg)	Confined Strength	Confined Volume (m^3)	Distances to Overpressure (m)		
				21 kPa	14 kPa	7 kPa
Cogeneration Plant	5000	5	600	-	24	44
Molecular Sieve	10240	7	200	53	70	110

Appendix D

Frequency Analysis

Frequency Assessment

This Appendix describes the leak frequencies employed by GHD as the basis for determining the relative likelihood of releases from the process in the ethanol plant and gas line at the boiler.

Leak frequency data is an essential requirement of Quantitative Risk Assessments (QRAs). A wide variety of data sets exist and the findings of a risk analysis are highly dependent upon the data that is employed. During the 1990s, the offshore process industry in the North Sea made the most comprehensive collection of leak frequency data that is currently available in any industry, and this has now become the standard data source for offshore risk analyses (HSE 2005). After careful consideration of the strengths and limitations of different data sources, and the expected differences in leak frequencies in offshore and onshore industries, GHD has concluded that it is appropriate to use the high-quality *offshore* data for *onshore* QRAs with very few exceptions, until verifiable onshore experience becomes available. The relevant arguments are summarised below.

The UK Health & Safety Executive data cover a large population of equipment over a considerable period of time, providing a valid statistical basis for estimating the frequency with which different sizes of leaks occur. Data previously collected was frequently from indirectly related sources, inconsistently collected and representative of a poorly defined equipment population – factors which combine to introduce considerable uncertainty. The UK HSE data set was initially collected over 15 years from 1990 – 2005 and is updated every year taking account of some of the most recent technology developments and current industry best practice.

The HSE 2005 data provides a detailed breakdown of hole sizes for individual equipment items. Different size leaks occur more or less frequently than others. For example, full bore rupture is expected to occur much less frequently than a pin hole size leak. Given the data is categorised into different leak sizes, an accurate calculation can be made of leak frequencies for various hole sizes.

The operating environment that offshore equipment operates in is harsher than the environment that the onshore plant equipment is used in. The offshore environment frequently has more sand or other impurities in the process streams than onshore plants, which can lead to corrosion / erosion leaks. Moreover, the salt water environment means the atmosphere is also more corrosive. In addition to this, the closely spaced nature of an offshore plant can lead to increased leaks from eg collisions / impact. However, the HSE data set on leak causes shows that corrosion / erosion is a minor contributor, with operational / procedural faults and mechanical defects being the primary causes.

D I Parts Count

In order to estimate the leak frequency, a parts count is required to identify all pieces of equipment and associated fittings where a release could potentially occur. Within each section, the number of valves, flanges, lengths of pipe, vessels etc and their individual sizes are counted. For each type of equipment, selected failure data is used to aggregate the release frequency into a hole size distribution, specific to the facility. The frequency of release size is then summed for all the parts in an identified section prior to location on the study grid.

The parts count for the ethanol system and gas system are given in Table D 1.

Table D 1 Parts Count for Ethanol and Gas Leak

	E1	E2	E3	E4	E5	E6	E7	E8
Tank	7							
Loading Arm		2						
Pipe 100 (m)		10						
Flange100		10						
MV100		5						
AV100		2						
Vessel			6		3			
Heat Exchanger			6					
Pump			1	2	1			
Pipe75 (m)						20		20
Flange75						5		5
MV75						4		4
AV75						2		2
Pipe50 (m)							50	
AV50							2	
MV50							5	
Flange50							10	

D II Leak Size Group

This QRA is a preliminary analysis, focussing on offsite affects. Therefore only events which can impact offsite are included. Small releases will only have local effects, and are not included in this analysis. This analysis only consider releases of 5 mm or greater. In this Appendix, leak frequencies are given for representative hole sizes, as shown in Table D 2. The nominal size for each leak size range is the suggested size of a hole to be used in discharge and consequence modelling.

Table D 2 Leak Size Groups

Range	Nominal Size
< 5 mm	Small
5–25mm	Medium
25-50	Medium to Large
50 -100 mm	Large
> 100 mm	Catastrophic

D III Failure Frequencies

The failure frequencies used for components in this QRA is given in Table D 3.

Table D 3 Failure Frequencies

	5mm	25mm	50mm	100mm	Rupture
Hose	4.5E-05	4.5E-05	0.00	9.0E-06	0.00
Vessel	1.5E-04	3.8E-04	0.00	3.9E-05	2.6E-05
Tank	1.3E-03	1.6E-04	8.0E-04	0.00	1.6E-04
Pipe100	2.7E-04	2.0E-05	1.5E-05	3.4E-06	0.00
Flange100	2.5E-04	1.5E-05	1.3E-05	1.3E-05	0.00
MV100	1.7E-04	3.5E-05	2.1E-05	0.00	0.00
AV100	1.4E-03	1.2E-04	1.0E-04	1.9E-05	0.00
Pipe75	1.0E-03	1.2E-04	5.6E-05	1.1E-05	0.00
Flange75	1.6E-04	1.5E-05	1.5E-05	1.4E-06	0.00
MV75	3.3E-04	7.1E-05	4.2E-05	0.00	0.00
AV75	1.4E-03	1.2E-04	1.0E-04	1.9E-05	0.00
Pump-C	1.6E-02	1.2E-03	1.5E-04	0.00	0.00

The parts count data in Table D 1 is then combined with the failure frequencies in Table D 3 to give a total leak frequency for each section given in Table D 4 and the frequency of occurrence of each hole size within each section.

Table D 4 Failure Frequency of the Hazardous Events

Event	Scenario	5mm (/yr)	25mm (/yr)	50mm (/yr)	100mm (/yr)	Rupture (/yr)
E1	Ethanol Tank (Tank farm)	9.0E-03	1.12E-03	5.62E-03	0.00	1.12E-03
E2	Loading Bay	2.81E-03	2.8E-04	3.02E-04	5.2E-05	1.02E-05
E3	Mol Sieve	1.1E-05	1.8E-04	0.00	1.94E-05	1.3E-05
E4	Ethanol loading pump	1.57E-02	1.18E-03	1.47E-04	0.00	0.00
E5	Distillation Unit	9.6E-03	1.2E-03	5.5E-04	1.1E-04	2.1E-04

Event	Scenario	5mm (/yr)	25mm (/yr)	50mm (/yr)	100mm (/yr)	Rupture (/yr)
E6	Gas Fired Boiler No 2	5.85E-03	7.02E-04	3.84E-04	0.00	0.00
E7	Cogen plant	1.09E-02	1.4E-03	5.83E-04	0.00	0.00
E8	Proposed Gas Fired Boiler	5.85E-03	7.02E-04	3.84E-04	0.00	0.00

D IV Failure Frequency of Loading Operation

The ethanol loading operation will double as a result of doubling in the ethanol production. The likelihood of release of ethanol during the loading operation as a result of human factors has been calculated as given in Table D 5 below.

Table D 5 Failure Frequency due to Operational Factors

	Target Production	300,000,000	L	pa	
		5,769,231	L/week		
		824,176	L/day		
	B-Double Capacity	50,000	L		
	Single Capacity	34,000	L		
	14 B-Doule/day	700,000	L		
	4 single	136,000	L		
		836,000	L		
	No of B Double Operation pa	5096	pa		
	No of Single Operation pa	1456	pa		
	Total Operation pa	**6552**	pa		
	Initiating Frequency	6552	/yr		
Human Error	Completely familiar, well designed, highly practised routine task, oft-repeated and performed by well-motivated, highly trained individual with time to correct failures but without significant job aids.	0.0004			
	Minor leaks	2.62	/yr	5	months
	Major Leak (1 in 100 operations resulting in major leak)	0.026	/yr	38	yrs
Failure Freq - human factors	Large pool of ethanol in loading bay	2.62E-02		38	yrs

NB: Human Error Frequency obtained from: James Reason; Human Error, Cambridge University Press, Cambridge, 1990, p.63-65.

D V Probability of Ignition

The probability of ignition as given by Cox, Less and Ang [1] was used in calculating the frequencies for fire and explosion, these probabilities are:

Table D 6 Ignition probability of flammable materials

	Gas	Liquid
Minor Leak (< 1kg/s)	0.01	0.01
Major Leak (1-50 kg/s)	0.07	0.03
Massive Leak (>50 kg/s)	0.3	0.08

Table D 7 Probability of Explosion

	Probability of Explosion
Minor Leak (< 1kg/s)	0.04
Major Leak (1-50 kg/s)	0.12
Massive Leak (>50 kg/s)	0.3

Reference:

Lees F. P., Loss Prevention in the Process Industries, 2nd Edition, 1996.

GHD Pty Ltd ABN 39 008 488 373

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

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1	Pilar Gallardo & Raj Chatiar	Chris Griffoen	*	James Ellaway	*	11/8/08

* Denotes Signature