PRELIMINARY HAZARD ANALYSIS, ETHANOL DISTILLERY MODIFICATIONS, TWO NEW ETHANOL TANKS AND BOILER, SHOALHAVEN STARCHES, BOMADERRY, NSW CONSENT NUMBER: MP 06_0228 MOD 18

Prepared by: Dean Shewring
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Pinnacle Risk Management Pty Limited
ABN 83 098 666 703

PO Box 5024 Elanora Heights
NSW Australia 2101
Telephone: (02) 9913 7284
Facsimile: (02) 9913 7930

Preliminary Hazard Analysis, Shoalhaven Starches, Two New Ethanol Tanks and Boiler

Disclaimer

Rev	Date	Description	Reviewed By
A	4/5/20	Draft for Comment	Shoalhaven Starches
B	13/5/20	Final Revision	Shoalhaven Starches
C	14/5/20	Boiler Layout Updated	Shoalhaven Starches

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EXECUTIVE SUMMARY

The Shoalhaven Starches factory located on Bolong Road, Bomaderry, produces a range of products for the food, beverage, confectionary, paper and motor transport industries including starch, gluten, glucose and ethanol.

In April 2020, Manildra were asked by the Federal Department of Industry Sciences and Energy to produce more hand sanitiser alcohol.

Manildra has the ability to meet this request in the distillery without exceeding the approved 300 ML per annum ethanol capacity by rearranging the mix of manufactured grades. However, more steam is required to make the higher-grade ethanol for hand sanitiser.

Manildra has planning approval for a gas-fired boiler to be located at the boiler house, however, it will need to be relocated nearer to the distillery to minimise piping runs and heat losses.

In addition to the gas-fired boiler, Manildra will need to install two additional ethanol tanks to store the hand sanitiser grade ethanol.

As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required for the boiler and two additional tanks. This PHA is an update of the beverage grade distillery Final Hazard Analysis as this allows ready assessment of propagation risks within the distillery.

The risks associated with the proposed modifications at the Shoalhaven Starches Bomaderry site have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year	Yes
Fatality risk to residential and hotels	1×10^{-6} per year	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year	Yes
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year	Yes
Fatality risk to be contained within the boundary of an industrial site	50×10^{-6} per year	Yes
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 or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6} per year	Yes

Description	Risk Criteria	Risk Acceptable?
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year	Yes
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year	Yes
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year	Yes

Societal risk, area cumulative risk and environmental risk is also concluded to be acceptable.

The primary reasons for the low risk levels from the modifications are that significant levels of radiant heat from potential fires are contained on-site and the likelihood of catastrophic equipment failures leading to off-site impact from flash fires and explosions is acceptably low.

There are no further recommendations from this PHA review.

Note: As this PHA is an update of the beverage grade distillery Final Hazard Analysis then any new or modified text is shown in blue text. This is to simplify the assessment of the report for the reader.

GLOSSARY

API	American Petroleum Institute
AS	Australian Standard
DG	Dangerous Good
DoP	NSW Department of Planning
ENA	Extra Neutral Alcohol
FHA	Final Hazard Analysis
HAZAN	Hazard Analysis
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
IBC	Intermediate Bulk Container
ISO	International Standards Organisation
LEL	Lower Explosive Limit
PHA	Preliminary Hazard Analysis
QRA	Quantitative Risk Assessment
ROSOV	Remotely Operated Shut-off Valve
SEP	Surface Emissive Power
UEL	Upper Explosive Limit

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Shoalhaven Starches is a member of the Manildra Group of companies. The Manildra Group is a wholly Australian owned business and the largest processor of wheat in Australia. It manufactures a wide range of wheat-based products for food and industrial markets both locally and internationally.

The Shoalhaven Starches factory located on Bolong Road, Bomaderry, produces a range of products for the food, beverage, confectionary, paper and motor transport industries including starch, gluten, glucose and ethanol.

In 2017, Shoalhaven Starches modified the existing Ethanol Distillery Plant to:

- ➢ Increase the proportion of beverage grade ethanol produced on the site to 110 ML/year. This modification included:
  - A new beverage grade ethanol plant;
  - Additional ethanol storage tanks (x5);
  - An emergency Isocontainer (for ethanol) storage area (located to the east of the relocated evaporator – see below);
  - Cooling water towers;
  - Electrical substation; and
  - Pipebridge (for fluids transfers to/from the additional syrup tank – see below); and
- ➢ Modify the type and location of the Water Balance Recovery Evaporator that was previously approved under MOD 2 adjacent to the Ethanol Plant.

To allow the beverage grade ethanol plant to be constructed, the existing fire pump station and water storage had been replaced by the previously approved pump station and water storage on the northern side of Bolong Road.

In April 2020, Manildra were asked by the Federal Department of Industry Sciences and Energy to produce more hand sanitiser alcohol.

Manildra has the ability to meet this request in the distillery without exceeding the approved 300 ML per annum ethanol capacity by rearranging the mix of manufactured grades. However, more steam is required to make the higher-grade ethanol for hand sanitiser.

Manildra has planning approval for a gas-fired boiler to be located at the boiler house, however, it will need to be relocated nearer to the distillery to minimise piping runs and heat losses.

In addition to the gas-fired boiler, Manildra will need to install two additional ethanol tanks to store the hand sanitiser grade ethanol.

As part of the project requirements, a Preliminary Hazard Analysis (PHA) is required.

Shoalhaven Starches requested that Pinnacle Risk Management prepare the PHA for the proposed modifications. This PHA has been prepared in accordance with the guidelines published by the Department of Planning (DoP) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (Ref 1) and is an update of the beverage grade distillery Final Hazard Analysis (FHA) (Ref 2).

1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the proposed modifications;
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 3);
- Evaluate the potential for propagation events;
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Shoalhaven Starches to ensure that the proposed modifications are operated and maintained at acceptable levels of safety and effective safety management systems are used.

1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the Shoalhaven Starches proposed modifications to the ethanol distillery with the potential for off-site impacts.

As the proposal changes the amounts of the different types of ethanol produced at the site but not the net volume then there is no net change in transport from the site. Therefore, transport is not reviewed in detail.

1.4 METHODOLOGY

In accordance with the approach recommended by the DoP in HIPAP 6 (Ref 1) the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the proposed modifications and their locations were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the potential hazardous events are located at a significant distance from other sensitive land users, the consequences of each potential hazardous event were estimated to determine if there are any possible unacceptable off-site impacts;

- Included in the analysis is the risk of propagation between the proposed equipment and the adjacent processes; and
- If adverse off-site impacts could occur, assess the risk levels to check if they are within the criteria in HIPAP 4 (Ref 3).

2 SITE DESCRIPTION

The Shoalhaven Starches factory site is situated on various allotments of land on Bolong Road, Bomaderry, within the City of Shoalhaven (see Figure 1). The factory site, which is located on the south side of Bolong Road on the northern bank of the Shoalhaven River, has an area of approximately 12.5 hectares.

The town of Bomaderry is located approximately 0.5 km to the west of the factory site and the Nowra urban area is situated 2.0 km to the south west of the site. The "Riverview Road" area of the Nowra Township is situated approximately 600 metres immediately opposite the factory site across the Shoalhaven River.

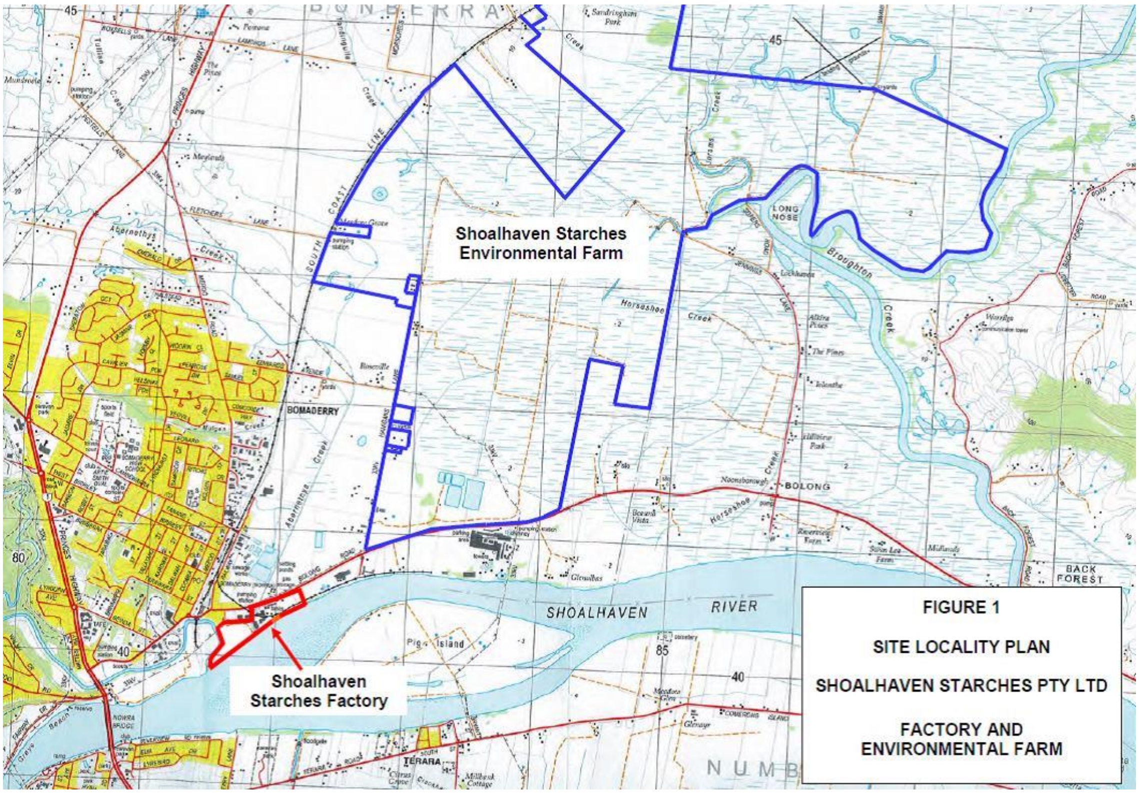
The village of Terara is situated approximately 1.5 kilometres to the south east of the site, across the Shoalhaven River. Pig Island is situated between the factory site and the village of Terara and is currently used for cattle grazing.

There are a number of industrial land uses, which have developed on the strip of land between Bolong Road and the Shoalhaven River. Industrial activities include a metal fabrication factory, the Shoalhaven Starches site, Shoalhaven Dairy Co-op (formerly Australian Co-operative Foods Ltd – now owned by the Manildra Group) and the Shoalhaven Paper Mill (also now owned by the Manildra Group). The industrial area is serviced by a privately-owned railway spur line that runs from just north of the Nowra-Bomaderry station via the starch plant and the former Dairy Co-op site to the Paper Mill.

The Company also has an Environmental Farm of approximately 1,000 hectares located on the northern side of Bolong Road. This area is cleared grazing land and contains spray irrigation lines and wet weather storage ponds (total capacity 925 Mega litres). There are at present six wet weather storage ponds on the farm that form part of the waste water management system for the factory. A seventh pond approved in 2002 was converted into the biological section of the new wastewater treatment plant has now been commissioned.

The Environmental Farm covers a broad area of the northern floodplain of the Shoalhaven River, stretching from Bolong Road in the south towards Jaspers Brush in the north. Apart from its use as the Environmental Farm, this broad floodplain area is mainly used for grazing (cattle). The area comprises mainly large rural properties with isolated dwellings although there is a clustering of rural residential development along Jennings Lane (approximately 1 kilometre from the site), Back Forest Road (approximately 500 metres to 1.2 kilometres to the west) and Jaspers Brush Road (approximately 1.2 kilometres to the north).

Figure 1 - Site Locality Plan



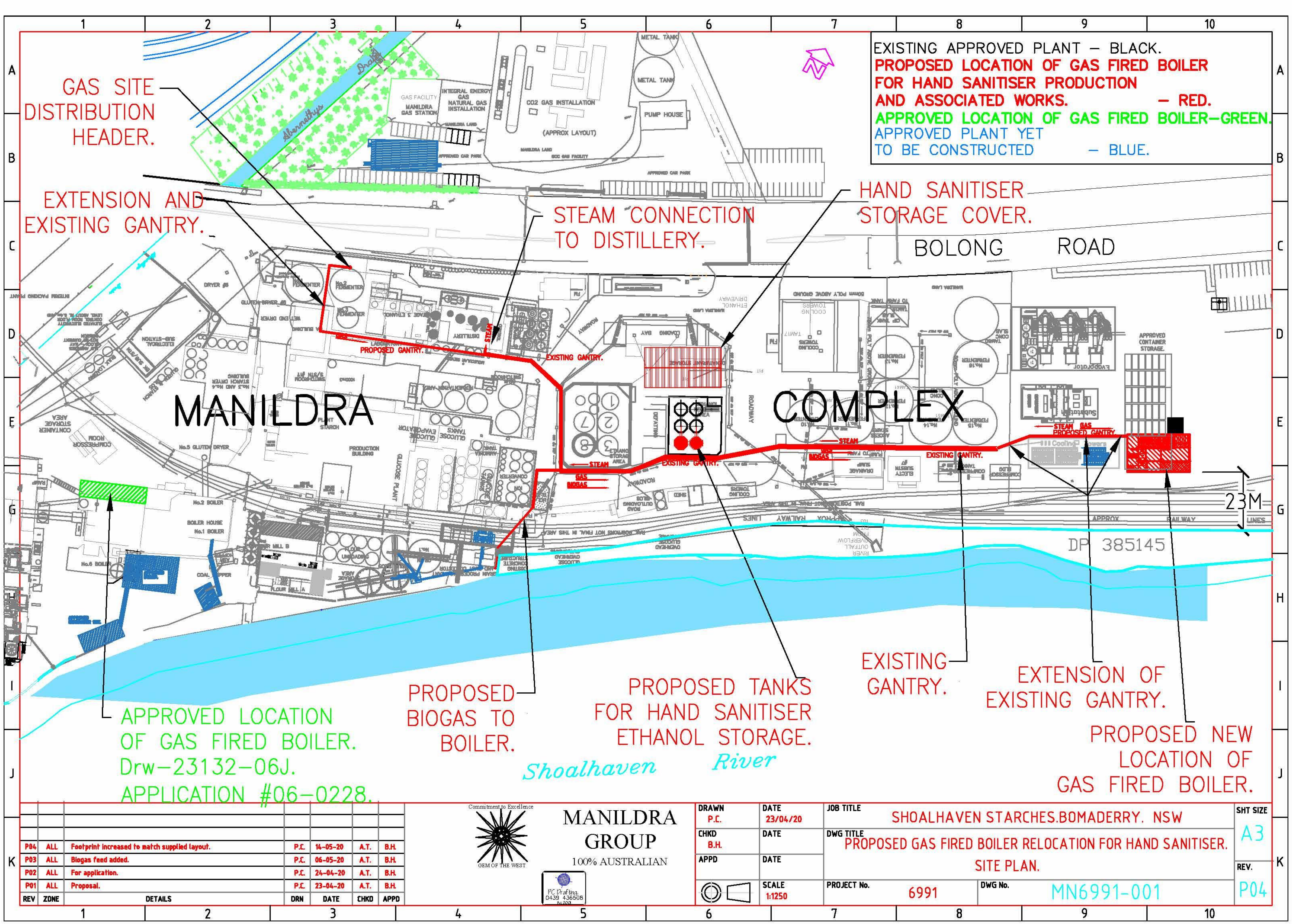
Security of the site is achieved by a number of means. This includes site personnel and security patrols by an external security company (this includes weekends and night patrols). The site operates 7 days per week (24 hours per day). Also, the site is fully fenced and non-operating gates are locked. Security cameras are installed for staff to view visitors and site activities.

There are approximately 126 people on site during Monday to Fridays 8 am to 5 pm and 88 people on site at other times.

The main natural hazard for the site is flooding. No other significant external events are considered high risk for this site.

A layout drawing showing the proposed location of the modifications is shown in Figure 2.

Figure 2 – Site Layout



3 PROCESS DESCRIPTION

3.1 GAS-FIRED BOILER

It is proposed to install an additional gas-fired boiler (Boiler 8) as shown on Figure 2. The boiler will increase steam production at the plant by 45 tonnes per hour. The supply pressure and temperature will be 12 bar and 192°C, respectively. The boiler will be a 30 MW gas-fired D type (i.e. vertical steam drum) water tube boiler.

The boiler will operate in a continuous state allowing for more stable steam production at the plant in the case that other boilers are down for maintenance or troubleshooting. The boiler will be a typical design involving a steam drum and a mud drum.

Water will be treated in water softeners and stored in a feedwater tank. It will then be pumped into the boiler to maintain level. The boiler design will include provision for blowdown to prevent high conductivity in the boiler water. The blowdown water will be treated at the Manildra waste water treatment plant.

Natural gas and biogas are the fuel sources for the furnace. Natural gas is already piped throughout the site. Biogas is available from the Manildra waste water treatment plant and is also already piped throughout the site. The fuel gas train to the boiler will be compliant with the relevant standards, e.g. AS3814, Industrial and commercial gas-fired appliances.

The gas supply pressure is 210 kPa and will be reduced at the boiler valve train. The gas flow is approximately 3,450 m^3/hr.

A forced-draught fan will supply air to the furnace. The flue gas will be vented to atmosphere via a stack (approximately 24 m high).

The boiler will be installed in an open area, i.e. a well-ventilated area. The boiler is intended to have a similar process and inherent safety design as per the three existing gas boilers at the site.

Boiler high pressure is to be protected with the control system and relief valves. Boiler low and high level and potential furnace explosion are to be protected via a boiler management system (hard-wired). This is to include an air purge prior to ignition of the burners. The control system will be compliant with AS2593, Boilers - Safety management and supervision systems, and the Australian Gas Association codes.

The boiler and associated piping and vessels will be constructed from carbon steel. All pipework and associated equipment will be designed to AS4041 or an equivalent standard.

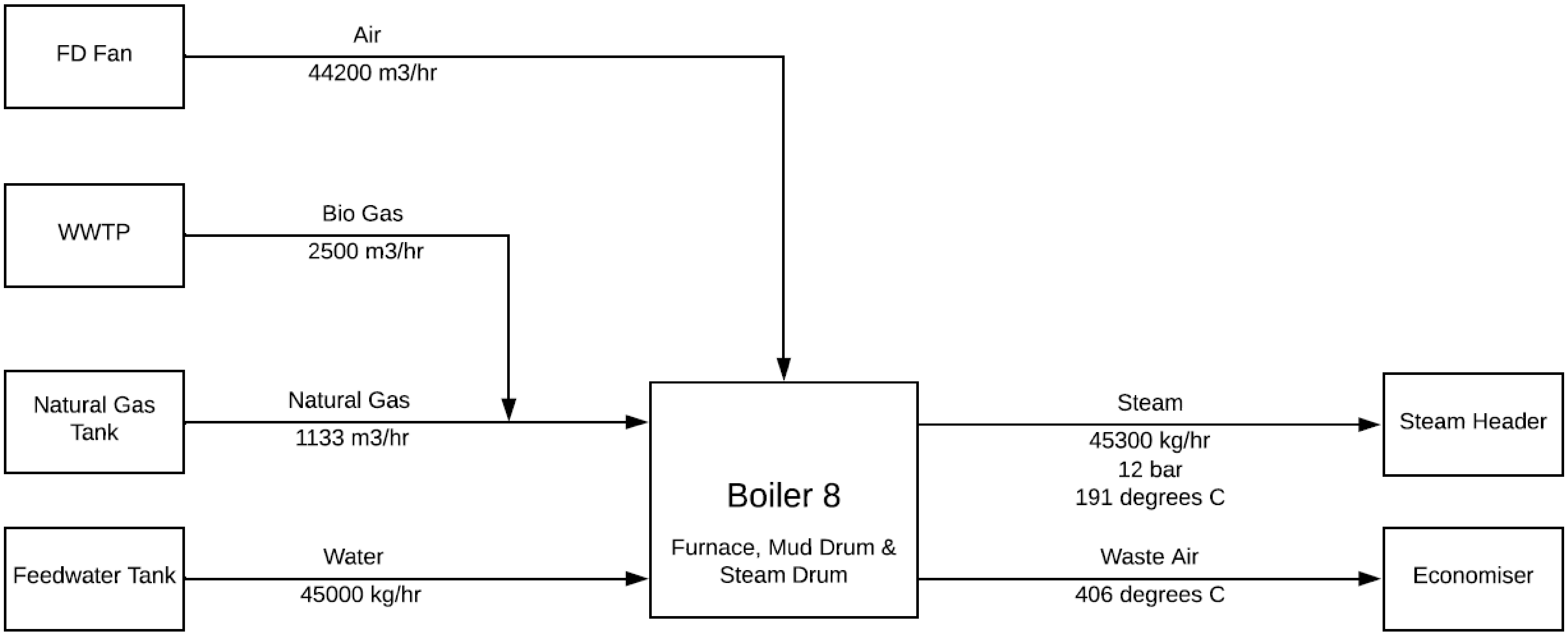
As the steam temperature is high and therefore a burn hazard if contact is made with hot surfaces then insulation will be installed to mitigate risk of injury.

An additional fire hydrant will be installed at the proposed location as well as additional fire extinguishers.

The boiler is to be located in a contained area. Any collected liquids will be disposed via the Manildra waste water treatment plant.

A process flow diagram for the boiler is shown in Figure 3.

Figure 3 – Boiler Process Flow Diagram



3.2 TWO ADDITIONAL ETHANOL STORAGE TANKS

It is proposed to install two additional hand sanitiser ethanol tanks (Tanks 14 and 15) in the existing ethanol tank farm that will increase the Extra Neutral Alcohol (ENA @ 96.5% vol ethanol) storage on site. The tanks will be constructed from 304L stainless steel and are fixed roof. The two tanks will be 236 m^3 each, i.e. identical to the existing four tanks that are located in the same bunded area. Their diameter will be 4.5 m and they will be 18 m tall. The tanks will be designed to AS1692 or an equivalent standard.

The tanks will be will be located within the existing day tank bund (formerly the ethanol recovery area bund). These two tanks will operate as batching tanks, i.e. any off-specification ethanol product from the plant is diverted from these tanks to other existing tanks or processes rather than flow to the larger bulk tank or the unloading facilities which should only handle on-specification product for the customer.

The hand sanitiser tanks are intended to have a similar process and fire safety design as well as similar equipment to the four existing beverage grade ethanol day tanks. The plant that feeds these tanks is design to produce 250 m^3/day so it will take approximately one day to fill each tank.

The ENA will be pumped to the tanks at approximately 35°C although the temperature in the tanks may change with the ambient conditions if the ethanol is stored for extended periods. The tanks will be bottom-filled to avoid static generation. With the inclusion of nitrogen blanketing (explosion prevention control), the tanks will have a pressure slightly higher than atmospheric pressure although this will be less than the vent lifting pressure during steady state. The tanks will have a vacuum / vent relief device to avoid over-pressurising or pulling vacuum in the tank.

Tank overfill protection will include a level transmitter and high level trip.

The inclusion of these tanks should not increase the number of road vehicles to or from the facility. These tanks do not change the production rate of the beverage grade distillery although they allow for more ENA storage on the site for use in hand sanitiser products.

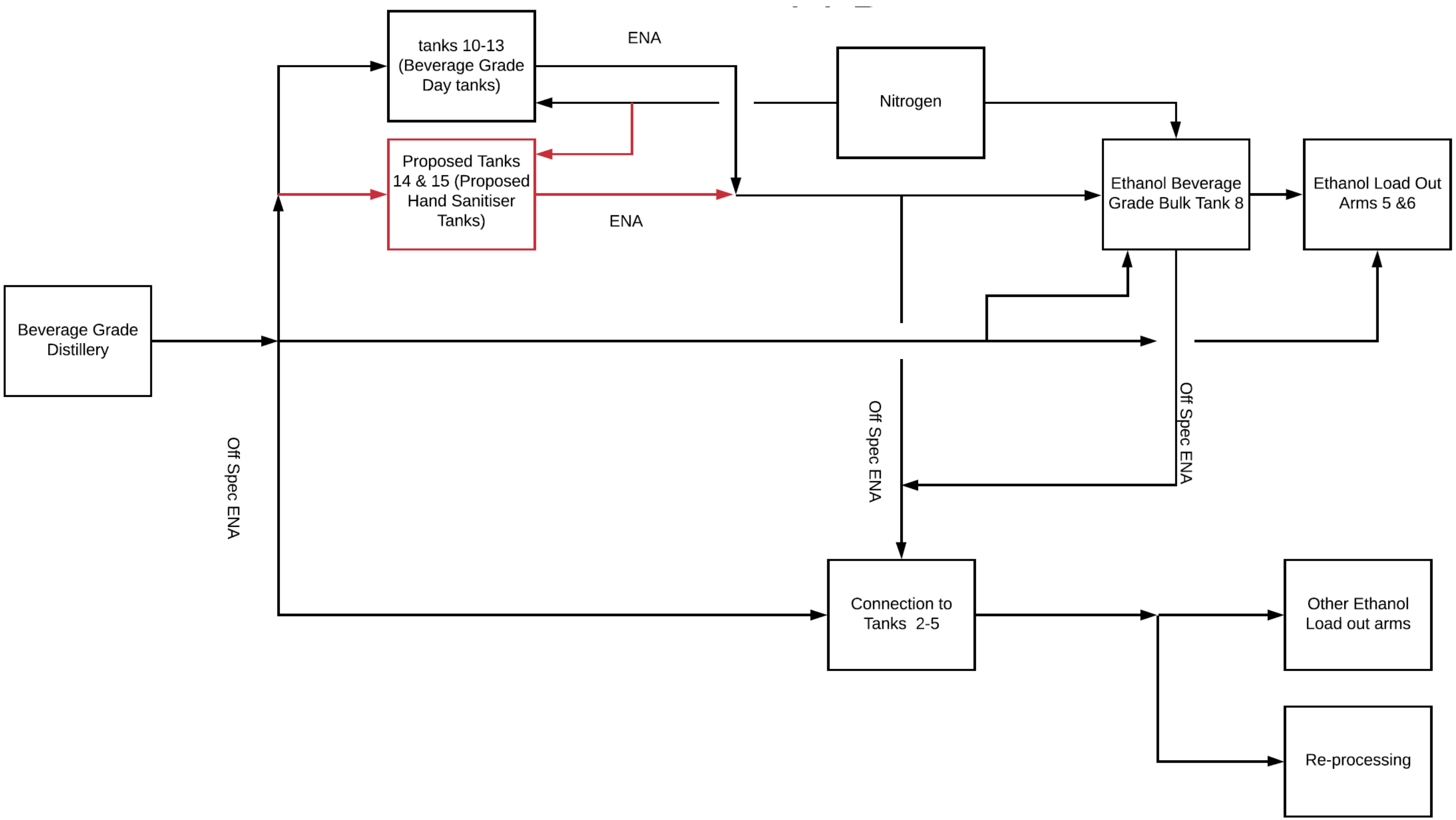
The tanks' systems will be designed to AS1940, the Australian Standard for the storage and handling of flammable and combustible liquids. The bund capacity has been checked and is 455 m^3. This is more than 110% of the largest tank volume (236 m^3). The tanks are not classified as a tank cluster as per AS1940 as the tanks are spaced apart by more than one-third of the tank diameter.

There are no new ethanol pumps as part of this modification.

There will be some minor modifications to the road tanker gantry to accommodate the proposed steam and natural gas lines. These changes do not alter how transfers are performed at the gantry.

A process flow diagram for the boiler is shown in Figure 4.

Figure 4 – Additional Ethanol Tanks Process Flow Diagram



3.3 EXISTING BEVERAGE GRADE ETHANOL PLANT

There are no changes to the following beverage grade ethanol plant description as a result of the two new tanks and boiler.

The production of beverage grade ethanol (96.5 vol%) from raw ethanol (92 vol%) is performed in a rectification process including the following steps. The plant is designed to produce 250 m^3/day of beverage grade ethanol. A process flow diagram is supplied in Appendix 1.

First Step: Purification Performed in the Hydroselection Column D530.

The raw ethanol at 80°C is transferred from a buffer tank (50 m^3) to the hydroselection column, i.e. a distillation column, via a vessel containing copper chips. The copper chips remove impurities such as trace levels of mercaptans. Raw ethanol contains other impurities in low concentrations such esters and aldehydes whose relative volatilities in ethanol increase when water is added. These are separated from the ethanol in the hydroselection column by having a high flow of water to the top of the column. The impurities are carried out the top of the column with the ethanol vapours and condensed. An impurities bleed stream is transferred to the existing dehydration unit (molecular sieves) through vessel R543 and pump P543. The hydroselection column bottoms contains approximately 10-12% ethanol by volume and importantly, the majority of impurities have been removed.

The hydroselection column operates at vacuum conditions (0.6 bara).

Second Step: Rectification Performed in Two Rectifications Columns D540 and D541.

Purified ethanol at 10-12% from the hydroselection column feeds the two rectifications columns, i.e. D540 and D541, which operate in parallel. Approximately 70% of the flow enters D540 with the remainder entering D541. The main functions of the rectification columns are:

- To strip the 10-12% ethanol in the hydroselection column’s bottoms stream to below 0.03% ethanol. This water stream is sent to the Manildra waste water treatment plant for processing;
- To concentrate the ethanol to obtain a concentration of at least 96.5 vol%; and
- To eliminate all of the residual heavy impurities.

D540 and D541 operate at different pressures to allow heat integration to be performed. For example, the overheads stream from D540 is at higher pressure and temperature than the lower pressure D541 column and hence is used in the reboiler for D541.

Some heads (impurities such as aldehydes and acetaldehydes) are concentrated on the top 3 or 4 trays of the two rectification columns. Therefore, a small bleed stream of heads is sent to the existing dehydration unit through vessel R543 and pump P543. The beverage grade ethanol stream is taken from trays 4 to 5 to avoid being off-specification in heads.

The ‘low oils’ (e.g. isoamylalcohol) or fusel oils are concentrated approximately 2 to 3 trays above the column feed nozzle. Therefore, a small bleed stream transfers the fusel oils to the existing decantor or to the existing dehydration unit through the vessel R543.

The ‘high oils’ (e.g. n-butanol, isobutanol and n-propanol) are concentrated on the trays above the low oils bleed take-off point. These high oils are taken from the rectification columns and also sent to the existing dehydration unit through the vessel R543 and its pump P543.

The operating pressures for the two rectification columns are:

- D540: 2.10 bara (i.e. above atmospheric pressure); and
- D541: 0.35 bara (i.e. at a partial vacuum).

The concentrated ethanol at the top of the columns D540 and D541 is at least 96.5 vol%.

Third Step: Refining Performed in the Refining Column D550

The ethanol from the two rectification columns D540 and D541 feeds the refining column D550.

The purpose of the refining column D550 is:

- To eliminate the last light impurities, i.e. mainly methanol remaining in the ethanol coming from the rectification columns; and
- To improve the sensor quality of the final ethanol.

The beverage grade ethanol is obtained at the bottom of the refining column D550 and is transferred to the ethanol storage tanks.

Effluent from the process flows to the Shoalhaven Starches waste water treatment plant for treatment.

The main materials of construction for the equipment items are stainless steel and copper.

For the vessels that vent to atmosphere, the streams flow through condensers, a washing column and then a scrubber. This is to avoid venting ethanol to atmosphere.

3.4 Existing Ethanol Storage – Tanks and ISO Containers

There are no changes to the following description as a result of the two new tanks and boiler.

As part of the beverage grade ethanol plant project, an additional tank was installed in the existing ethanol storage area (Tank 8) and four additional ethanol storage tanks were installed in the existing recovery tank area. The tanks are constructed from stainless steel and are fixed roof.

The capacity of Tank 8 is 777 m^3. It is 7.46 m diameter and 18 m high.

The four smaller tanks are 240 m^3 each.

The four smaller tanks operate as day tanks, i.e. any off-specification ethanol product from the plant is diverted from these tanks to other existing tanks or processes rather than flow to the larger tank which contains the on-specification product ethanol for the customers.

The product beverage grade ethanol is pumped into road tankers or ISO containers at the road tanker transfer area for delivery to the customers. Two dedicated parallel loading arms were installed for the beverage grade ethanol. Road tanker overfill is protected by the scully system and a modified hatch for the Isocontainers (these do not have scully leads).

3.5 EVAPORATOR

There are no changes to the following description as a result of the two new tanks and boiler.

The Water Balance Recovery Evaporator has been previously approved under MOD 2 adjacent to the Ethanol Plant.

The evaporation process for the sugar syrup uses low pressure water vapour (under vacuum). The maximum operating pressure is atmospheric for process units (piping and plate heat exchangers are under pressure on the cooling water supply side only). The sugar syrup is approximately 10 to 25% and is not a hazardous material. As the syrup is a solution (i.e. not dry) and the equipment handling the syrup is not confined then the risk of a sugar dust explosion is low. Given the low hazard potential for sugar syrup, i.e. it is not a fire, explosion or toxic hazard, then no further analysis of this process area is performed in this study.

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

The hazardous materials involved with the modifications are:

- Ethanol;
- 3 to 5 % caustic soda (sodium hydroxide);
- Ethanol streams containing impurities;
- Cooling tower dosing chemicals;
- Packaged products such as starch; and
- Natural gas and biogas.

Ethanol including the Impurities:

Ethanol is a Dangerous Good Class 3 flammable liquid. It is soluble in water.

Ethanol's flammability limits are LEL (lower explosive limit) 3.5% and UEL (upper explosive limit) 19%. The control measures regarding safe handling and storage of ethanol are similar to other Class 3 materials, e.g. elimination of ignition sources, including static. It burns with a near colourless flame. The vapour is heavier than air and can accumulate in low points. Explosions of confined vapours are possible. Ethanol combustion produces carbon dioxide and carbon monoxide. Fires involving ethanol are normally extinguished with alcohol resistant foam.

The impurities in the ethanol, e.g. the fusel oils, are at low concentrations only. The main issue with these impurities is odour which is why they need to be removed from the beverage grade ethanol.

Cooling Tower Dosing Chemicals:

The same cooling water dosing chemicals that are currently used at the site are used for the ethanol cooling tower. The storage volumes are relatively small, i.e. drums to IBC's (intermediate bulk containers), and these are stored within dedicated bunds to avoid any losses of containment impacting the environment or people. The dosing chemicals are located adjacent to the ethanol cooling tower. Given the relatively small volumes and that all containers are separately bunded then no further analysis of these materials is warranted.

Natural Gas and Biogas:

Natural gas and biogas are flammable, i.e. if released and ignited, there is a risk of jet fires, flash fires and explosions (if confined).

Natural gas is a Class 2.1 Dangerous Good (flammable gas).

Natural gas is a colourless hydrocarbon fluid mainly composed of the following hydrocarbons:

- Methane (typically 88.5% or higher);
- Ethane (typically 8%);
- Propane (typically 0.2%);

- Carbon dioxide (typically 2%); and
- Nitrogen (typically 1.3%).

For a typical natural gas, the TLV (threshold limit value) is approximately 1,000 ppm and the STEL (short term exposure limit) is 30,000 ppm (i.e. approaching 5 vol% which is the lower explosive limit).

The hydrocarbons are not considered to represent a significant environmental threat. Their hazard potential derives solely from the fact that they are flammable materials.

To enable ready leak detection, natural gas is normally odorised with mercaptans (sulphur containing hydrocarbons).

The flammability range is typically 5% to 15% v/v in air. The vapours are lighter than air and will normally disperse safely if not confined and/or ignited.

Products of combustion include carbon monoxide and carbon dioxide.

The composition of the biogas is typically:

- 65 - 75% methane;
- % 20 – 25 % carbon dioxide; and
- 0.07 % hydrogen sulphide

It burns with similar properties to natural gas.

4.2 POTENTIAL HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of *Guidelines for Hazard Analysis*, (Ref 1), it is necessary to identify hazardous events associated with the facility's operations. As recommended in HIPAP 6, the PHA focuses on "atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water".

In keeping with the principles of risk assessments, credible, hazardous events with the potential for off-site effects have been identified. That is, "slips, trips and falls" type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake.

The identified credible, significant incidents (in particular, with the potential for off-site impacts) for the proposed modifications are summarised in the Hazard Identification Word Diagram following (Table 1).

This diagram presents the causes and consequences of the events, together with major preventative and protective features that are to be included as part of the design.

Table 1 – Hazard Identification Word Diagram

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
	Distillery			
1	Loss of containment of flammable liquid with subsequent ignition in the bunded area	Losses of containment due to valves passing, pipe or vessels leaks, gasket failure (e.g. on a pipe or the plate heat exchangers), draining of vessels to the bund for maintenance and pump seal failure	Bund fire can lead to equipment damage and injury to people	All piping and equipment items are 304 stainless steel to reduce the risk of corrosion. Hazardous area assessment with suitably rated instruments and electrics. Operating procedures and training, e.g. prestart-up checklists, to ensure drain valves closed for start-up. LEL detectors which raise an alarm for operator response. Fire protection is to be assessed via a Fire Safety Study, however, the existing hydrant system can supply the firewater for foam use. Authority to Work Permits - Hot work permits. Vessels to be emptied by running the liquid out of the plant and then steam purging

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
2	Pump fire	Running a pump containing ethanol at flammable concentrations deadheaded, mechanical failure, e.g. hot bearings	Pump fire with the potential to propagate to the adjacent plant items containing ethanol	Operating procedures and training, e.g. prestart-up checklists, to ensure pump suction and discharge valves are open for start-up. Plant trips, e.g. on low flow from a pump or high level in the supply vessel. Pump routine maintenance
3	Catastrophic vessel failure	Vessel isolated and a fire occurs, column overpressure due to loss of the condenser, direct steam injection to some vessels	Potential for catastrophic vessel failure and hence a bund fire if the released ethanol is ignited. This can lead to equipment damage and injury to people. Missiles can also occur with the potential to propagate to the adjacent plant items	Vessels to be pressure protected as per AS1210. The maximum direct steam pressure is limited to 1.6 bara
4	Catastrophic vessel failure	Vacuum formation when the plant stops and vapours condense	Potential to implode the vessels and hence a bund fire if the released ethanol is ignited. This can lead to equipment damage and injury to people	All vessels designed for full vacuum

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
5	Release from the first rectification column	Losses of containment due to valves passing, pipe or vessels leaks and gasket	As the first rectification column operates at 1.1 barg at the top (1.5 barg at the bottom) then the ethanol could immediately ignite and form a jet fire or there could be delayed ignition with a flash fire or explosion	All piping and equipment items are 304 stainless steel to reduce the risk of corrosion. Hazardous area assessment with suitably rated instruments and electrics. Operating procedures and training, e.g. prestart-up checklists, to ensure drain valves closed for start-up. LEL detectors which raise an alarm for operator response. Fire protection is to be assessed via a Fire Safety Study, however, the existing hydrant system can supply the firewater for foam use. Plant can be tripped and isolated remotely
6	Internal explosion within the vacuum columns	Vacuum pump stops with reverse flow of air into column	Potential to form a flammable atmosphere with ethanol. If ignited, there will be a confined explosion	Non-return valves on the vacuum pumps. No sources of ignition within the columns

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
	Tanks and Road Tanker and Isocontainer Filling			
7	Loss of containment into the bund. This event also applies to the two additional ethanol tanks	Overfilling a tank. Tank failure, e.g. corrosion. Pipe failure, e.g. corrosion, flange failure. Tank drain valve left open	Pool fire if ignited. This can propagate to the adjacent tanks. For historical tank explosions, some tanks (fixed roofed only) have rocketed away from the foundations. Delayed ignition can result in a vapour cloud flash fire or explosion (if confinement exists). Impact to people (radiant heat and/or exposure to products) and property	Two level instruments installed on each tank to prevent overfill including an independent high level trip. These will trip a failed closed, actuated valve on the inlet to each tank. Tanks designed to API 650. Pipes designed to AS4041. Regular maintenance and inspection procedures. Tank and site fire protection facilities including foam pourers. Earthing of all tanks, no splash filling and ignition control procedures, e.g. Authority to Work Permits - hot work permits. Training and procedures to ensure valves in the correct position following maintenance

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
8	Tank top fire. This event also applies to the two additional ethanol tanks	Lightning strike, hot work	Pool fire if ignited. This can propagate to the adjacent tanks. For historical tank explosions, some tanks (fixed roofed only) have rocketed away from the foundations. Impact to people (radiant heat and/or exposure to products) and property	Tanks designed to API 650. Tank and site fire protection facilities including foam pourers. Earthing of all tanks, no splash filling and ignition control procedures, e.g. hot work permits
9	Pipeline failure external to the bunded area	Corrosion, flange failure or impact	Spillage of ethanol. Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property	Regular maintenance and inspection procedures. Emergency isolation valves Firefighting system (including foam) Pipes designed to AS4041. Pipes to be located on a piperack to avoid impact damage. Pipes to be fully welded where possible

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
10	Leak during filling of road tanker or Isocontainer (this is an existing event as ethanol is currently loaded into road tankers at this bay)	Failure of transfer hose. Leak from valves or fittings. Road tanker or Isocontainer overfill	Spillage of ethanol. Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property	High level of surveillance and use of flame detection and shutdown systems. Drivers are well trained (DG Licence) so as to minimise chance of operator error and ensure quick response to leaks. Road tanker bay fitted with automatic foam deluge system. Remote spill containment pit to avoid collection of flammables in the loading bay. Ignition sources controlled Scully truck overfill shutdown system and road tanker rated for the DG area
11	Road tanker drive-away incident (i.e. driver does not disconnect the hose and drives away from the loading bay). (this is an existing event as ethanol is currently loaded into road tankers at this bay)	Failure of procedures and hardware interlocks	Spillage of ethanol. Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property. Ignition source present (road tanker engine), hence fire more likely	Driver training. Driver not in cab during filling. Road tanker bays fitted with automatic foam deluge system. “Dry-break” hose couplings

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
12	Leak at ethanol pumps in the storage area	Pump seal, shaft or casing failures	Leak of ethanol in pump bays. Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property	Single mechanical seal. Condition monitoring and preventative maintenance of pumps. Gas detection system and alarm. Fixed firefighting monitors, with foam, located strategically for fighting fires. Pumps in contained area.
13	Leak from Isocontainer in the storage area	Valve passing, flange leak	Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property	Isocontainers are high integrity, international transport vessels with proven reliability. Training and procedures to ensure valves are closed following filling. Emergency response procedures for leaks including the application of foam

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
	Boiler			
14	Natural gas or biogas explosion within the boiler	Natural gas or biogas flow when the burners are offline	Buildup of natural gas or biogas in the furnace. If ignited, there is the potential for an internal explosion, i.e. damage to the furnace and boiler	Burner management system will be certified to Australian Standards which will include the need for adequate natural gas and biogas isolation and air purging prior to startup
15	Loss of containment of natural gas or biogas from the supply pipes	Pipe failure, e.g. corrosion or weld defect, gasket failure, valve leak, impact	If ignited, potential for a jet fire, flash fire or explosion which can impact personnel and equipment	The natural gas and biogas supply pipes are to be tied into the existing natural gas and biogas supply pipe systems that run through the site at present. This is an existing site risk. The pipes are to be protected from impact by locating them in piperacks. Minimum flanges used. Pipes to be included in the hazardous zone study. Remote isolation of the natural gas is possible at the gas metering station and biogas at the WWTP. The natural gas and biogas supply pipes are to be pressure tested following construction and protected against corrosion by painting. The natural gas and biogas piping and equipment items are to be compliant with the Australian Standards

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
16	Boiler rupture	Low level, loss of boiler feed water pumps, high and low factory demand for steam, failure of level control, control valve stuck closed, low level in feedwater tank	Catastrophic failure of the boiler, i.e. equipment damage and injury to on-site personnel if steam is released externally to the boiler	Australian Standard compliant low level protection, standby boiler feed water pumps, low and low-low level alarms, boiler trip on low-low level, maintenance on the valves and instruments), low level alarm and trip on the feedwater tank, operator checks on the boiler and feedwater tank sight glass
17	High pressure within the furnace	Tube failure within the furnace	Potential for flames to be emitted from the furnace openings and hence injure on-site personnel and damage equipment	PMs on the tubes (annual inspection), furnace trip logic to prevent high pressure (trips the forced draught fan), common alarm sounds on high pressure, fan maintenance
18	Boiler rupture	Corrosion, e.g. poor boiler feed water chemistry. Erosion, e.g. from two phase flow	Catastrophic failure of the boiler, i.e. equipment damage and injury to on-site personnel	Water softeners on the boiler feedwater supply, daily sampling, pH and TDS (total dissolved solids) checks, routine equipment inspections (weekly, monthly and yearly)
19	Failure of the steam drum or high pressure piping	Corrosion (e.g. under lagging corrosion), weld defect, safety relief valves stuck closed, failure of letdown valves	Catastrophic failure of the steam drum or piping, i.e. equipment damage and injury to on-site personnel	Routine inspections (piping and equipment), operator inspections, operator training (boiler emergency procedure to delay the re-introduction of water following a low-low water level event), redundant safety valves, certifications on equipment, high pressure alarm for operator response

5 RISK ANALYSIS

The assessment of risks to both the public as well as to operating personnel around the proposed modifications requires the application of the basic steps outlined in Section 1. As per HIPAP 6 (Ref 1), the chosen analysis technique should be commensurate with the nature of the risks involved. Risk analysis could be qualitative, semi-quantitative or quantitative.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc.

Having identified all credible, significant incidents, risk analysis requires the following general approach for individual incidents:

Risk = Likelihood x Consequence

The risks from all individual potential events are then summated to get cumulative risk.

For QRA (quantitative risk analysis) and hazard analysis, the consequences of an incident are calculated using standard correlations and probit-type methods which assess the effect of fire radiation, explosion overpressure and toxicity to an individual, depending on the type of hazard.

In this PHA, however, the approach adopted to assess the risk of the identified hazardous events is scenario-based risk assessment. The reason for this approach is the distances from the proposed modifications to residential and other sensitive land users are large and hence it is unlikely that any significant consequential impacts, e.g. due to radiant heat from fires, from the facility will have any significant contribution to off-site risk.

The risk criteria applying to developments in NSW are summarised in Table 2 on the following page (from Ref 3).

Table 2 - Risk Criteria, New Plants

Description	Risk Criteria
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year
Fatality risk to residential and hotels	1×10^{-6} per year
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year
Fatality risk to be contained within the boundary of an industrial site	50×10^{-6} per year
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 or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year

As discussed above, the consequences of the potential hazardous events are initially analysed to determine if any events have the potential to contribute to the above-listed criteria and hence worthy of further analysis.

5.1 POOL FIRE INCIDENTS

5.1.1 Fires Consequence Analysis

The credible hazardous events associated with the proposed modifications are largely pool fires due to potential losses of containment being ignited. The potential pool fire events associated with the plant, tanks and bunds are detailed in Table 3. This data is used in the fire modelling. A discussion on burndown rates and surface emissive powers (SEP) is given below.

Burndown Rates:

For burning liquid pools (Ref 4), heat is transferred to the liquid via conduction, radiation and from the pool rim.

Wind can also affect the burning rate (experiments have shown both an increase and decrease in burning rates due to the effects of wind) but also can affect flame stability (and hence average flame emissive power) (Ref 5). Therefore, average reported values for burndown rates are used in this study.

For very large pool fires with diameters greater than 5 to 10 m, there is some evidence of a decrease in burning rate.

Experimental data for the ethanol burndown rate is 1 mm/min (Refs 5 and 6).

The burning rate is used in the determination of flame height. Normally, the higher the burning rate, the higher the estimated flame height.

Surface Emissive Power:

Surface emissive power can be either derived by calculation or by experimentation. Unfortunately, experimental values for surface emissive powers are limited.

When calculated, the results can be overly conservative, particularly for large diameter fires, as it is assumed that the entire flame is at the same surface emissive power. This is not the case for large diameter fires as air entrainment to the centre of the flame is limited and hence inefficient combustion occurs.

For ethanol, a literature search indicates the following data:

SEP's of 50kW/m^2 for large fires (pool diameter => 25 m) and 60 kW/m^2 for pool fires less than 25 m in diameter appear reasonable.

The distances to specified radiant heat levels for the potential fire scenarios are shown in Table 3. The distances were calculated using the View Factor model for pool fires (Refs 5 and 6). This model was used as it better approximates the square / rectangular shapes of the potential bund fires. It will be slightly conservative for the tank top fires. Graphical representations of the estimated radiant heat contours are shown in Appendix 2.

As the two additional ethanol tanks will be installed in the same bund as four existing identical ethanol tanks then no further modelling is required.

Table 3 – Fire Scenarios Calculation Data and Results

Note that "Eq. D" is the equivalent diameter of the fire (4 x the fire area / the fire perimeter) and "SEP" is the surface emissive power (i.e. the radiant heat level of the flames). Where bund fires width is significantly different to the length, the top row results corresponds to the radiant heat predicted for an object perpendicular to the width and the bottom row results corresponds to the radiant heat predicted for an object perpendicular to the length.

Item No.	Item Description	Width, m	Length, m	Eq. D, m	Tank Height, m	Liquid Density, kg/m^3	SEP, kW/m^2	Distance to Specified Radiant Heat Level, m (from base of flame)			Maximum Ground Level Radiant Heat, kW/m^2 (for tank fires only)
								23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	
1	Distillery bund fire	13	19	15	-	790	60	6	11	21	-
2	Ethanol storage area bund fire	26	33	29	-	790	50	7	14	30	-
3	Ethanol recovery area bund fire (this is the bund where the two additional ethanol tanks will be installed)	21	23	22	-	790	60	7	13	26	-
4	Tank top fire – 240 m^3 tanks. This also applies to the two additional ethanol tanks	-	-	4.5	14.7	790	60	2	4	7	3 kW/m^2 at 2 m from the tank wall
5	Tank top fire – 777 m^3 tank	-	-	7.46	18	790	60	3	6	11	3.7 kW/m^2 at 3 m from the tank wall
6	Fire at the road tanker loadout bay or at an Isocontainer	7	25	7	-	790	60	3 5	5 9	10 18	-

Notes for Table 3:

1. The bund fires include releases from piping leaks which ignite as well as releases from tank failures.
2. Modelled as a channel fire, i.e. flame height estimated based on width.

The values of interest for radiant heat (DoP, HIPAP No. 4 and ICI HAZAN Course notes) are shown in Table 4.

Table 4 - Radiant Heat Impact

HEAT FLUX (kW/m^2)	EFFECT
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 15-30 seconds and second degree burns after 30 seconds. Glass breaks
12.6	30% chance of fatality for continuous exposure. High chance of injury Wood can be ignited by a naked flame after long exposure
23	100% chance of fatality for continuous exposure to people and 10% chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures to cause failure
35	25% chance of fatality if people are exposed instantaneously. Storage tanks fail
60	100% chance of fatality for instantaneous exposure

For information, further data on tolerable radiant heat levels is shown in Table 5.

Table 5 – Layout Considerations – Tolerable Radiant Heat Levels

Plant Item	Tolerable Radiant Heat Level, kW/m^2	Source
Drenched Storage Tanks	38	Ref 6
Special Buildings (Protected)	25	Ref 6
Cable Insulation Degrades	18-20	Ref 6
Normal Buildings	14	Ref 6
Vegetation	12	Ref 6
Plastic Melts	12	Ref 6
Escape Routes	6	Ref 6
Glass Breakage	4	Ref 7
Personnel in Emergencies	3	Ref 6
Plastic Cables	2	Ref 6
Stationary Personnel	1.5	Ref 6

The results in Table 3 are analysed as follows to check compliance with HIPAP 4 (Ref 3, Table 2) risk criteria.

For assessment of the effects of radiant heat, it is generally assumed that if a person is subjected to 4.7 kW/m^2 of radiant heat and they can take cover within approximately 20 seconds then no serious injury, and hence fatality, is expected.

However, exposure to a radiant heat level of 12.6 kW/m^2 can result in fatality for some people for limited exposure durations. Therefore, for the larger spills, appropriate emergency response actions are required to minimise the potential for harm to people. This should include moving people away from such releases to a safe distance.

Given that the 12.6 kW/m^2 contour remains on site for all ethanol pool fire scenarios and the large separation distance to the nearest residential area (approximately 500 m) then the following risk criteria (Table 2) are satisfied:

- The risk criteria for fatality and injury in residential area; and
- The risk criterion for fatality in neighbouring industrial and commercial facilities as well as open spaces.

The risk of propagation due to fires to neighbouring industrial areas (i.e. exceeding 23 kW/m^2) is not expected given the predicted results in Table 3, i.e. this contour remains on site. Therefore, the criterion of 50×10^{-6}/year for industrial propagation risk for exceeding 23 kW/m^2 (Table 2) is satisfied for fire events.

Given the limited off-site radiant heat impact as above, no further risk analysis of the identified ethanol pool fire scenarios is warranted in this study as compliance with the DoP criteria (Table 2) has been shown.

5.2 JET FIRES

The majority of the ethanol distillery operates at a partial vacuum. Therefore, should a leak occur, air will be drawn into the process. If a source of ignition was present then a confined explosion would occur. This is an unlikely event as there are no normal sources of ignition within the equipment.

Once the partial vacuum is lost then the process will not continue to operate as per the design intent. The energy sources to generate the ethanol product are lost, e.g. the overheads from one column provides the reboiler duty for another column.

As the first rectification column is the only ethanol vapour process that operates above atmospheric pressure then leaks in vessels and piping may result in a jet fire (if ignited). The first rectifier operates at 1.1 barg at the top of the column (where the highest concentration of ethanol exists). The bottom of this column contains mostly water and impurities (spent feints) and only 0.03% ethanol, i.e. it is not flammable.

A jet fire for a 50 mm hole is modelled in this study to determine if adverse off-site impacts can occur. If a catastrophic pipe failure was to occur then the column pressure would be lost and the process would be unable to continue to operate. Therefore, a catastrophic pipe break is not modelled.

The analysis (Ref 4) of a potential jet fire from the first rectification column is shown in Table 6. The ethanol pressure is taken as 1.1 barg at 98 C. Whilst the top of the column is approximately 40 m above ground level, the concentrated ethanol vapour is piped close to ground level. Therefore, jet fires can occur close to ground level and impact people.

Table 6 – Jet Fires

Stream	Estimated Release Rate, kg/s	Estimated Length of Jet, m
50 mm hole	1	8

The distance from the first rectification column to Bolong Road is approximately 21 m. For a vertical jet fire, the radiant heat flux is estimated to be 1 kW/m^2 at this location (it will be less for a horizontal jet fire). For this low level of radiant heat, no adverse off-site impact from a potential ethanol vapour jet fire is expected. Therefore, no further analysis of jet fires from the distillery is performed.

5.3 Flash Fires and Vapour Explosions

5.3.1 Flash Fires and Vapour Explosions - Distillery

Delayed ignition of ethanol vapour from the first rectification column can result in a flash fire or a vapour cloud explosion (if confined).

There are two credible cases for a flash fire:

1. Release from a 50 mm hole with delayed ignition; and
2. Catastrophic equipment failure with a release of the ethanol vapour within the first rectification column and overhead piping.

To assess if the lower explosive limit (LEL) can reach the nearest site's boundary and hence cause adverse off-site impact, the following typical weather / wind data for the site is used. This was sourced from Nowra weather station (Ref 8).

Weather Stability / Wind Speed (m/s):

F1.5

C3

D5

D7

For releases at or near ground level, the F1.5 will yield the largest impact distance. This was modelled with ALOHA using the 1 kg/s release rate for the 50 mm diameter hole.

For this low release rate, the accuracy of near field concentrations predictions is not high. However, ALOHA predicts the LEL may reach up to 18 m away from the point of release. As this is less than the distance to the site boundary (21 m), then no adverse off-site impact from a potential ethanol flash fire is expected from a continuous release from a 50 mm hole or smaller. Therefore, no further analysis of jet fires from holes in piping or equipment in the distillery is performed.

For catastrophic piping and column failures, the quantity of ethanol that can be released and form a flammable cloud is estimated to be 423 kg. The results of the instantaneous release dispersion calculations in ALOHA are shown in Table 7.

Table 7 – Flash Fires from Instantaneous Releases

Weather / Wind:	Distance to LEL, m
F1.5	53
C3	29
D5	26
D7	23

As the distance to the nearest site boundary is less than the values shown in Table 7, i.e. 21 m, then adverse off-site impact from a potential ethanol instantaneous release with delayed ignition is possible. This is for all dominant weather / wind conditions and when the wind is blowing from the south. The impact can be either from a flash fire or, if there is confinement, an explosion. The latter is less likely as there is little confinement along Bolong Road and to the north as well as the relatively small amount in the unconfined vapour cloud. The likelihood of this event is calculated as follows.

For piping and equipment failures, frequencies have been estimated either from data compiled and published by ICI (Ref 9) or from frequency estimates published by the Institution of Chemical Engineers (Ref 10). For the instantaneous release case, only catastrophic failure rate data is required.

Table 8 - Generic Equipment Failure Frequencies

Type of Failure	Failure Rate (x 10^6) per year
Pipelines	
Guillotine fracture (full bore): > 100 mm	0.1 / m
Vessels	
Catastrophic failure - Pressure Vessel	1

Given the above data, the catastrophic release likelihood is estimated as follows:

Release likelihood = Piping failure + column failure + condenser failure

$$= (0.1\text{x}10^{-7}/\text{m.yr x } 40 \text{ m}) + (2 \text{ x } 1\text{x}10^{-6}/\text{yr})$$

$$= 2.4\text{x}10^{-6}/\text{yr}$$

Given a probability of ignition for the vapour cloud of 0.07 or less (Refs 10 and 11), the likelihood of the ethanol vapour cloud forming a flash fire or an explosion is:

Flash Fire / Explosion Likelihood = 2.4×10^{-6}/yr x 0.07

= 1.7×10^{-7}/yr

The probability for weather / wind conditions should also be taken into account, however, as the above value is less than all the Department of Planning HIPAP 4 criteria in Table 2 then the risk of this event is acceptable and no further analysis is warranted.

5.3.2 Vapour Explosions due to Tank Overfills

It is noted that explosions involving the vapours from flammable liquids are possible and are acknowledged in Table 1. Two notable incidents involving releases of flammable liquids that have resulted in unconfined vapour explosions are detailed below.

One of the most recent incidents occurred at the fuel storage facility at Buncefield, UK. In the early hours of Sunday 11th December 2005, a number of explosions occurred at Buncefield Oil Storage Depot, Hemel Hempstead, Hertfordshire. At least one of the initial explosions was of massive proportions and there was a large fire, which engulfed a high proportion of the site. Over 40 people were injured; fortunately there were no fatalities. The explosion was the result of a large loss of containment of flammable liquid.

Another similar incident occurred at the Texaco Newark storage facility, January 7 (i.e. during winter again), 1983. The tanks involved here had little level protective instrumentation; tank level was primarily achieved via frequent dipping with subsequent checklist completion. The material was super unleaded gasoline. During a transfer operation, one tank overflowed at approximately midnight and a vapour cloud formed. It travelled approximately 300 metres towards an incinerator (most likely source of ignition given eye-witness reports) and then exploded. There was one fatality and twenty four people injured.

Issues in common with two events are:

- Overflow from height, spraying of the flammable liquid causing a mist;
- Cold ambient temperatures (Buncefield approximately -2 deg Cel, similarly for Newark);
- Low wind speeds (e.g. Buncefield - Pasquill stability class F);
- Rolling mist (e.g. Buncefield - 5 to 7 metres high mist with confinement, i.e. between buildings and amongst trees);
- Delayed ignition; and
- Large amounts lost - Buncefield approximately 300 tes and Newark approximately 450 tes.

The following summarised recommendations are from the Buncefield Safety Task Group's investigation. Comment is included on their applicability to the Shoalhaven Starches ethanol tank storage area.

- The overall systems for tank filling control need to be of high integrity, with sufficient independence to ensure timely and safe shutdown to prevent tank overflow and the overall systems for tank filling control meet AS 61511. *This will be achieved via tank differential pressure level monitoring with alarm, independent local level monitoring and an independent high level trip which stops the ethanol feed to the new tanks.*
- Management systems for maintenance of equipment and systems to ensure their continuing integrity in operation. *Shoalhaven Starches have a safety management system which includes equipment item maintenance, including instrumentation testing, requirements*. *This system will be modified to suit the project requirements.*
- Fire-safe shut-off valves should be used and remotely operated shut-off valves (ROSOVs) should be installed on tank outlets. *Shoalhaven Starches plan to use fire-safe valves and install ROSOVs on the tanks inlet and outlet lines.*
- Bunds are to be leak tight and the bund compliant with AS1940. *These recommendations are consistent with the Shoalhaven Starches bund designs*. *The existing bunds integrity will be checked and fixed if necessary during the project.*
- Site-specific planning of firewater management and control measures should be undertaken. *Firewater containment is afforded by the tank bunds and on-site waste water containment facilities. Beyond these measures, further emergency response is required.*
- Procedures exist for defining roles, responsibilities and competence, staffing and shift work arrangements (e.g. managing fatigue), shift handover, organisational change and management of contractors, performance evaluation and process safety performance measurement including procedures for investigation of incidents and near misses, and auditing. *Shoalhaven Starches have a safety management system which includes these requirements*. *This system will be modified to suit the project requirements.*
- Emergency procedures exist inclusive of firefighting requirements. *Shoalhaven Starches have an emergency response plan for their site which will be modified for the project*.

In summary, unconfined vapour cloud explosions resulting from the spillage of a hydrocarbon at ambient temperature and below its boiling point are rare (Ref 12). If enough hydrocarbon is spilt, particularly from height with low wind speeds to minimise dilution, then a vapour cloud is possible.

Given the measures proposed at the Shoalhaven Starches site, the expected likelihoods for these types of events are still expected to be rare and therefore do not pose significant off-site risks.

5.4 Natural Gas and Biogas Releases – Fires and Explosions

Releases from the natural gas or biogas piping can be ignited. The natural gas pressure throughout the site is 210 kPag. As this is higher than the biogas system then the analysis below is on the natural gas system, i.e. worst-case.

The analysis of potential jet fires is shown in Table 9. The mass rates were estimated using TNO's EFFECTS program and the flame length via the Considine and Grint equation (Ref 13). The pipe length used was 100 m. An 80 mm diameter pipe is assumed.

Table 9 – Natural Gas Jet Fires

Stream	Estimated Release Rate, kg/s	Estimated Length of Jet, m
Full bore failure (80 mm)	0.71	9
50 mm hole	0.55	8
13 mm hole	0.053	3

Notes: Jet flames modelled using methane.

Other than the tie-in point for the natural gas line, both the natural gas and biogas pipe runs are further away from Bolong Road than the potential jet fire lengths in Table 9.

Potential vapour cloud explosions and flash fires can occur from the natural gas or biogas line failures, i.e. delayed ignition.

The effects from explosion overpressures (Ref 3) are summarised in Table 10.

Table 10 – Effects 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

OVERPRESSURE, kPa	PHYSICAL EFFECT
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

For flash fires, any person inside the flash fire cloud is assumed to be fatally injured. As flash fires are of limited duration (typically burning velocity is 1 m/s, Ref 14) then those outside the flash fire cloud have a high probability of survival without serious injury.

The analysis of the potential vapour cloud explosions and flash fires from the natural gas pipe failures is shown in Table 11. The mass calculated in the flammable range is assumed to be 100% confined, i.e. all this gas is involved in the explosion calculations. As methane is not a high reactive flammable gas and the quantities involved are relatively small then a medium deflagration (Curve 5) is assumed in the explosion calculations (multi-energy method – TNO).

Table 11 - Natural Gas Vapour Cloud Explosions and Flash Fires

Stream	Mass of Natural Gas in the Flammable Range, kg	Radius of Flash Fire, m	Distance (m) to 14 kPa Explosion Overpressure	Distance (m) to 7 kPa Explosion Overpressure
Full bore failure (80 mm)	6.5	33 m	13 m	26 m
50 mm hole	4.2	27 m	11 m	22 m

Notes: 1. Pipeline failures assumed to be isolated within 30 minutes.

2. Radius of flash fires calculated to be the distance to LEL (lower explosion limit) at F weather stability and 2 m/s wind speed.

3. 13 mm holes not modelled as they are too small to generate gas clouds of any significant size.

For these releases of natural gas, choked flow exists and rapid jet mixing with air occurs. The result is a relatively small vapour cloud size with limited consequential impacts if ignited. The 30 minute release duration also has no significant impact on the release. Steady state conditions are reached soon after the release occurs (i.e. after approximately 4 minutes, the distance to the LEL does not change at steady state dispersion conditions).

Given these results for the natural gas vapour cloud explosions and flash fires, no adverse consequential impacts will be imposed off-site for the main pipe runs. The low likelihoods for these events are supported by the following data (Ref: UK HSE (Ref 15).

Table 12 – Piping Failure Frequencies

Failure Rates (per m per year) for Pipework Diameter (mm)					
Hole Size:	0 - 49	50 - 149	150 - 299	300 - 499	500 – 1,000
3 mm diameter	1×10^{-5}	2×10^{-6}			
4 mm diameter			1×10^{-6}	8×10^{-7}	7×10^{-7}
25 mm diameter	5×10^{-6}	1×10^{-6}	7×10^{-7}	5×10^{-7}	4×10^{-7}
1/3 pipework diameter			4×10^{-7}	2×10^{-7}	1×10^{-7}
Guillotine	1×10^{-6}	5×10^{-7}	2×10^{-7}	7×10^{-8}	4×10^{-8}

Typical probabilities of gas ignition are shown in the following table (Ref 16).

Table 13 – Gas Ignition Probabilities

Leak	Probability of Ignition
	Gas
Minor (<1 kg/s)	0.01
Major (1 to 50 kg/s)	0.07
Massive (>50 kg/s)	0.3

For example, the frequency of catastrophic (guillotine) pipe failure for an 80 mm pipe is 5×10^{-7} / m per year. If a probability of ignition of 0.07 is used, i.e. a major leak, then the combined fire and explosion likelihood is:

$$0.07 \times 5 \times 10^{-7} \text{ / m per year} = 3.5 \times 10^{-8} \text{ / m per year.}$$

This is a low level of risk, it is below the risk criteria shown in Table 2 and not considered intolerable. The ALARP (As Low As Reasonably Practicable) principle is achieved; primarily due to compliance with the Australian Standards for piping.

5.5 CUMULATIVE AND PROPAGATION RISK

The radiant heat contours for a potential tank top fire for one of the two additional ethanol tanks is shown Appendix 2. The adjacent new tank will have exactly the same contours. The contours show that tank-to-tank propagation is possible (this is the same propagation risk as per the existing four tanks in the bunded area). Propagation to other Manildra assets is not expected given that the significant levels of radiant heat do not extend far from the tank.

From an analysis of existing fire scenarios shown in Appendix 2 then propagation to the new tanks is also not a significant risk (primarily due to separation distances). As there are relatively small quantities of flammables and combustibles within the former Defatting Building then propagation to the new tanks is a low risk. To mitigate this risk, the tanks are to have spray water cooling and there are fixed and portable monitors available (i.e. the same fire protection as the existing identical four tanks in this bunded area).

Propagation from boiler incidents is a low likelihood, e.g. the pipe failure likelihoods in Table 12. Compliance and certification to the boiler codes ensures the risk of incidents achieves ALARP. There can be containers stored to the north of the proposed boiler and there is a cooling tower to the west, however, there are no significant propagation risks to or from the these areas for the proposed boiler.

Given that significant levels of radiant heat from potential pool fires remain on-site and that the likelihood of a catastrophic failure leading to a flash fire or explosion is acceptably low then it is reasonable to conclude that the beverage grade ethanol process does not make a significant contribution to the existing cumulative risk in the area.

Of the on-site risk propagation events, the main concern is the impact on the control room from potential pool fires in the distillery. During the HAZOP for the distillery, it was recommended to drain the distillery bund floor to a remote impoundment basin (or similar) to avoid ethanol pooling and hence a sustained fire. This recommendation is not reproduced in this report.

Propagation from bund fires to adjacent equipment is possible. Bund fire likelihoods are approximately $1x10^{-5}$/yr (Refs 17 and 18) and hence are normally acceptable provided good practice is achieved. For this site, compliance with the Australian Standards will be done.

5.6 SOCIETAL RISK

The criteria in HIPAP 4 for individual risk do not necessarily reflect the overall risk associated with any proposal. In some cases, for instance, where the 1 pmpy contour approaches closely to residential areas or sensitive land uses, the potential may exist for multiple fatalities as the result of a single accident. One attempt to make comparative assessments of such cases involves the calculation of societal risk.

Societal risk results are usually presented as F-N curves, which show 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 results for different risk levels, a societal risk curve can be produced.

In this study of the modified Shoalhaven Starches site, the risk of off-site fatality is below the HIPAP 4 risk criteria. As the nearest house is approximately 500 m away, the concept of societal risk applying to populated areas is therefore not applicable for this project.

5.7 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations. For this site, it is suitably located away from residential areas. However, due to the nature of the activities, there are operations, e.g. product transfers and road tanker filling, where losses of containment can potentially impact the environment.

For the proposed modifications, there are no solid or gaseous effluents that could significantly impact the environment.

Spills of ethanol from the process equipment, tanks, adjacent piping and road tanker filling bay are to be contained in the bunds and sumps. The bunded areas are to be sized to contain the entire contents of the single tank so that a total loss of contents does not spill over the bund, plus an allowance for rainwater, fire water, hosing down etc. Should the proposed secondary containment fail, Shoalhaven Starches have a drainage system that collects and transfers all waste liquids to their treatment plant at their farm on the north side of Bolong Road. Any major on-site spills can be contained here.

Whereas any adverse effect on the environment is obviously undesirable, the results of this study show that the risk of losses of containment is broadly acceptable.

5.8 Conclusion and Recommendations

The risks associated with the proposed modifications at the Shoalhaven Starches Bomaderry site have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year	Yes
Fatality risk to residential and hotels	1×10^{-6} per year	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year	Yes
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year	Yes
Fatality risk to be contained within the boundary of an industrial site	50×10^{-6} per year	Yes
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 or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6} per year	Yes
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year	Yes
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year	Yes
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year	Yes

Societal risk, area cumulative risk and environmental risk is also concluded to be acceptable.

The primary reasons for the low risk levels from the modifications are that significant levels of radiant heat from potential fires are contained on-site and the likelihood of catastrophic equipment failures leading to off-site impact from flash fires and explosions is acceptably low.

There are no further recommendations from this PHA review.

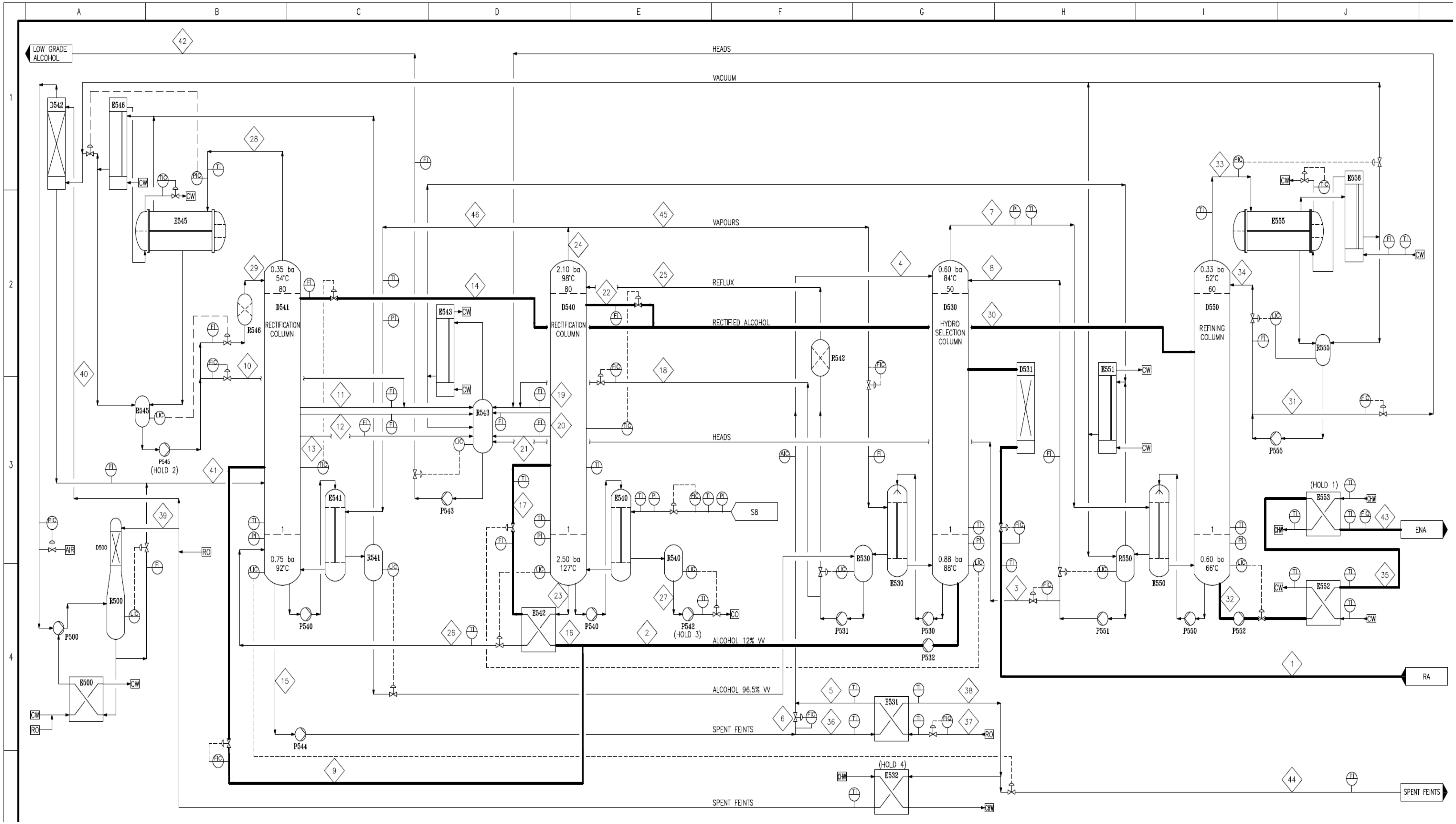
Appendix 1

Distillery Process Flow Diagram

Preliminary Hazard Analysis, Shoalhaven Starches,

Two New Ethanol Tanks and Boiler

Appendix 1 – Distillery Process Flow Diagram.

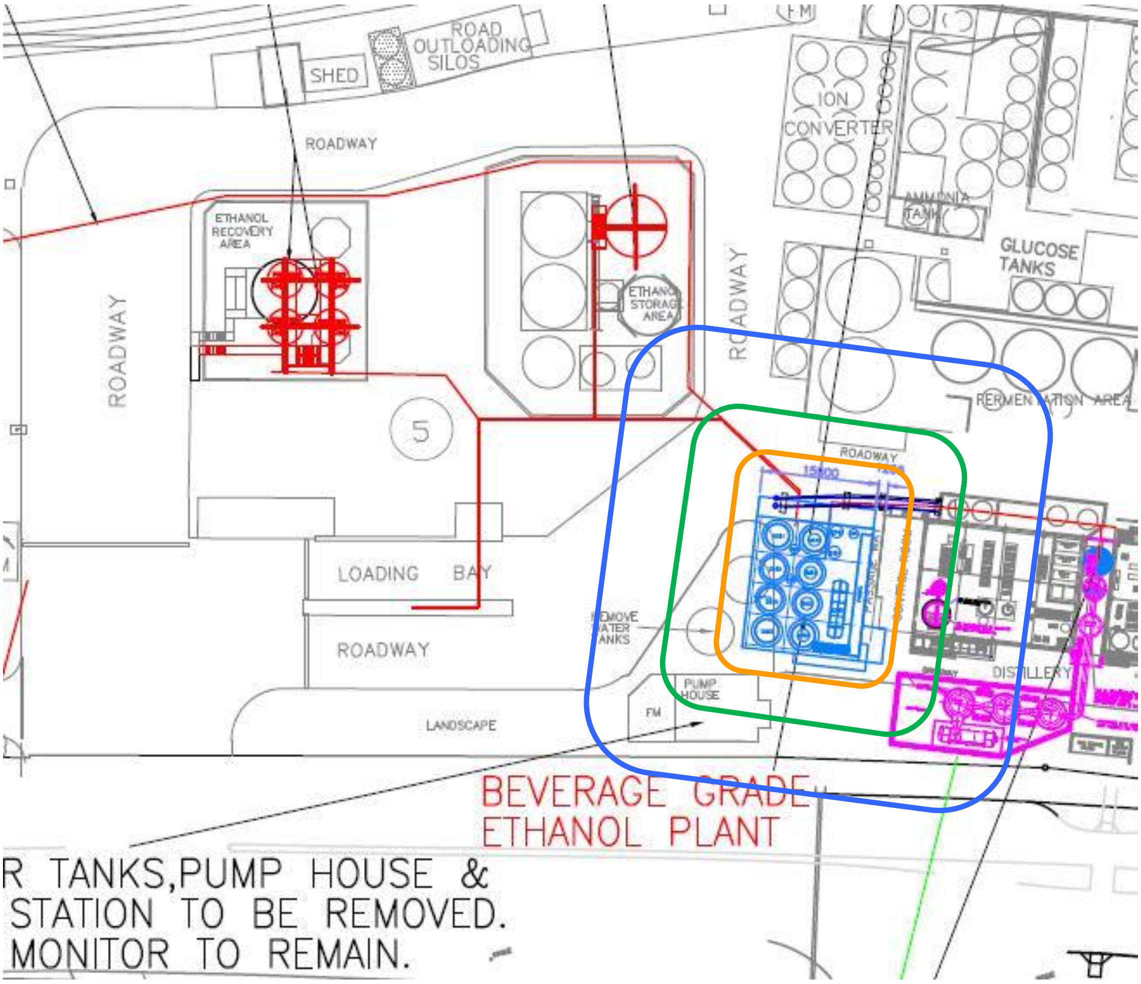


Appendix 2

Radiant Heat Contours

Appendix 2 – Radiant Heat Contours.

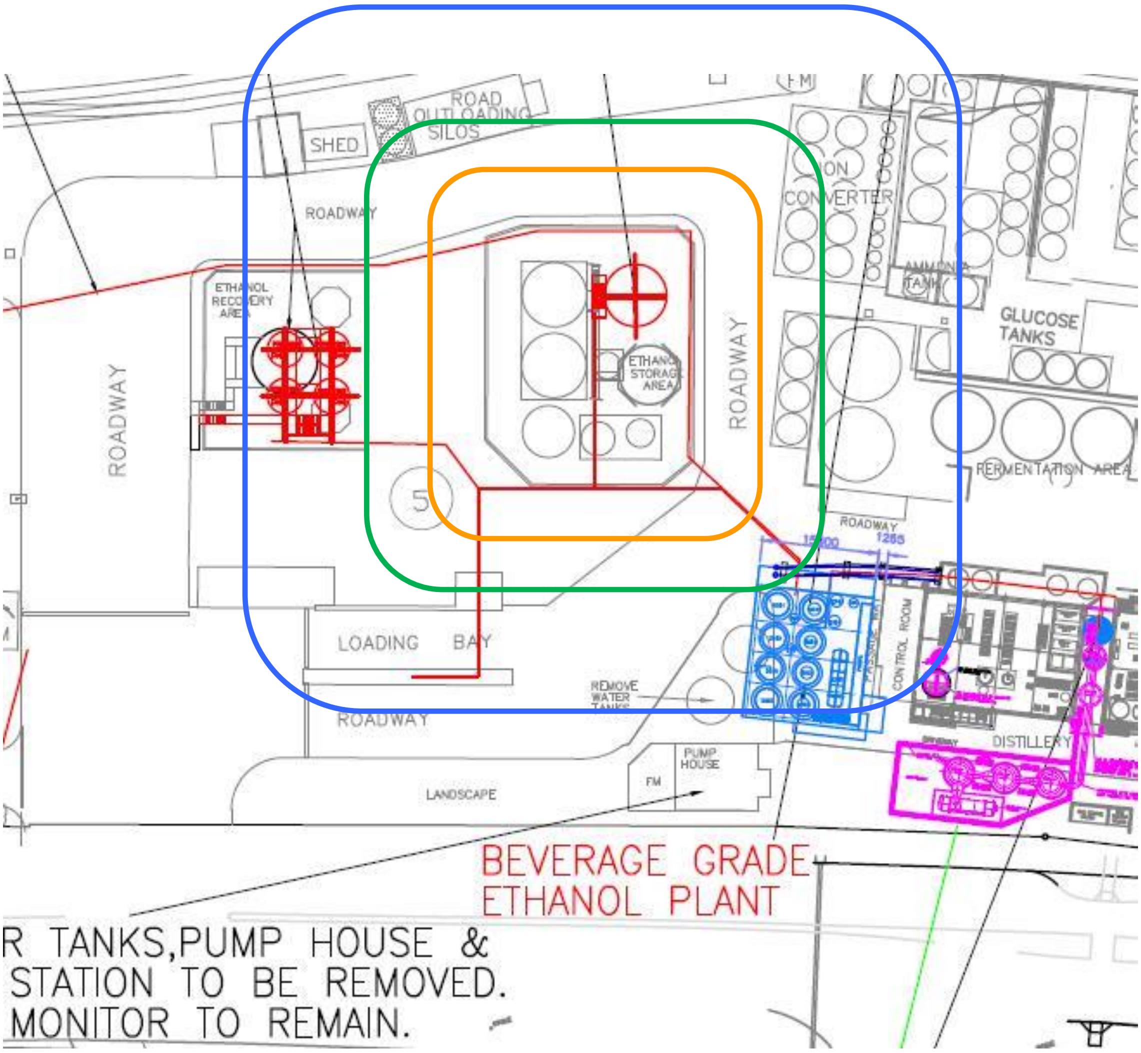
Scenario 1: Distillery Bund Fire



Key:

- 23 kW/m^2 (orange)
- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

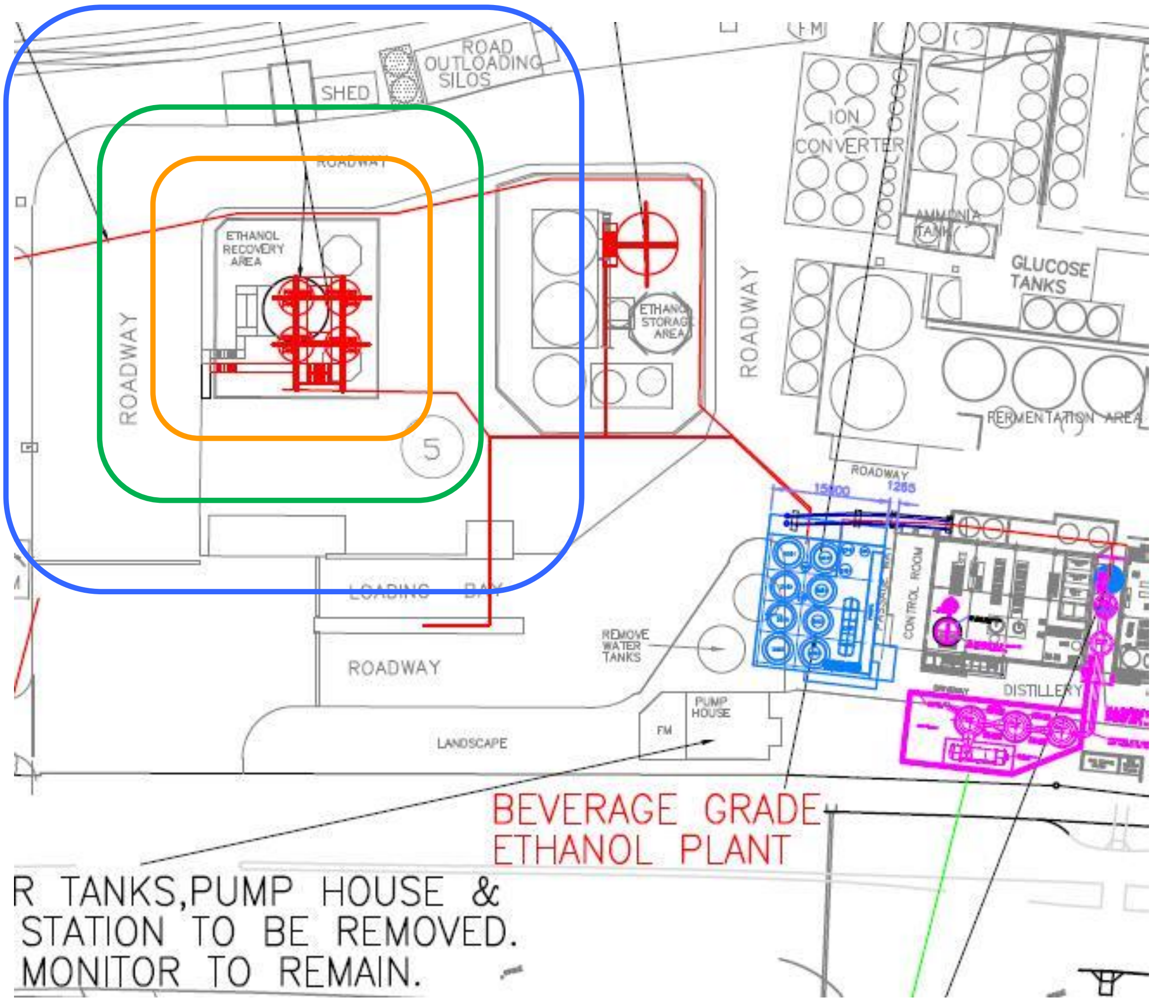
Scenario 2: Ethanol Storage Area Bund Fire



Key:

- 23 kW/m²
- 12.6 kW/m²
- 4.7 kW/m²

Scenario 3: Ethanol Recovery Area Bund Fire

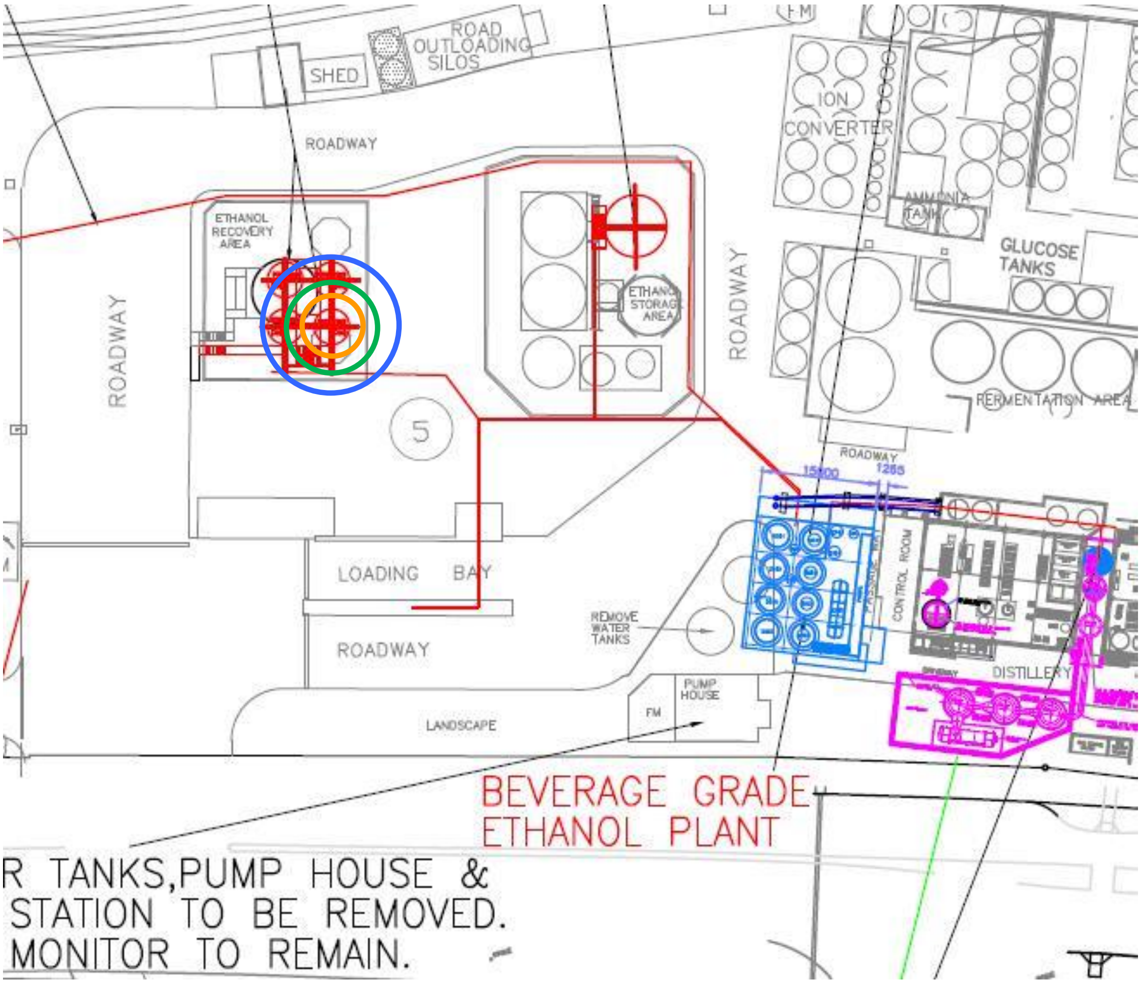


Key:

- 23 kW/m^2 (orange)
- 12.6 kW/m^2 (green)
- 4.7 kW/m^2 (blue)

Scenario 4: Existing Tank Top Fire –240 m^3 Tank

Contours are at tank height (not ground level)

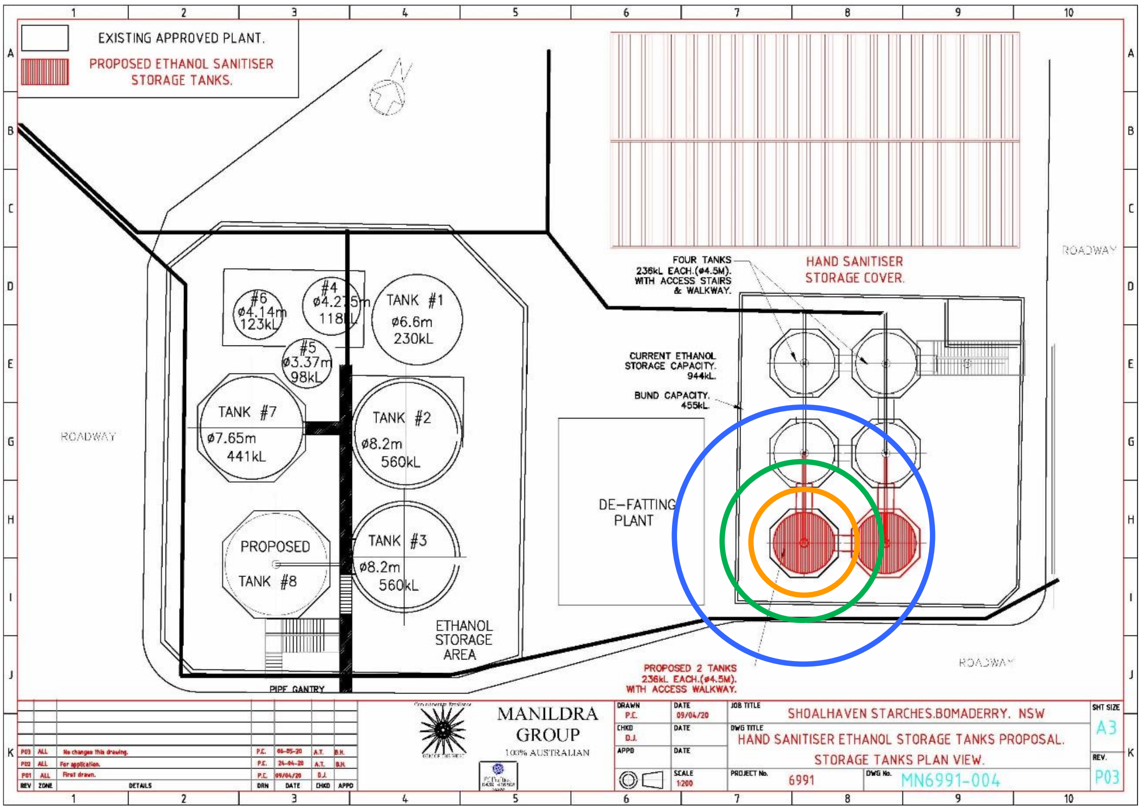


Key:

- **23 kW/m^2**
- **12.6 kW/m^2**
- **4.7 kW/m^2**

Scenario 4: Additional Tank Top Fires –240 m^3 Tank

Contours are at tank height (not ground level)

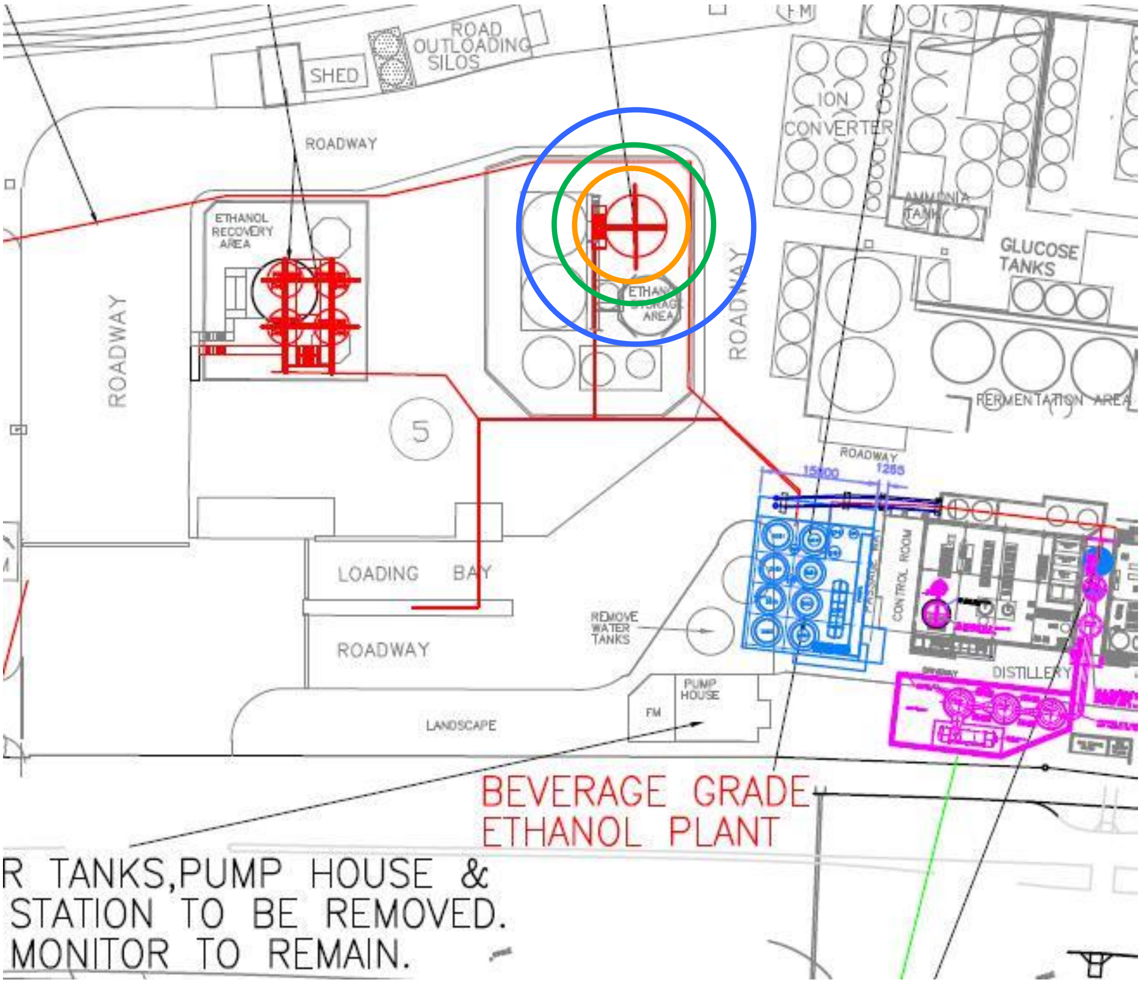


Key:

- 23 kW/m^2
- 12.6 kW/m^2
- 4.7 kW/m^2

Scenario 5: Tank Top Fire – 777 m^3 Tank

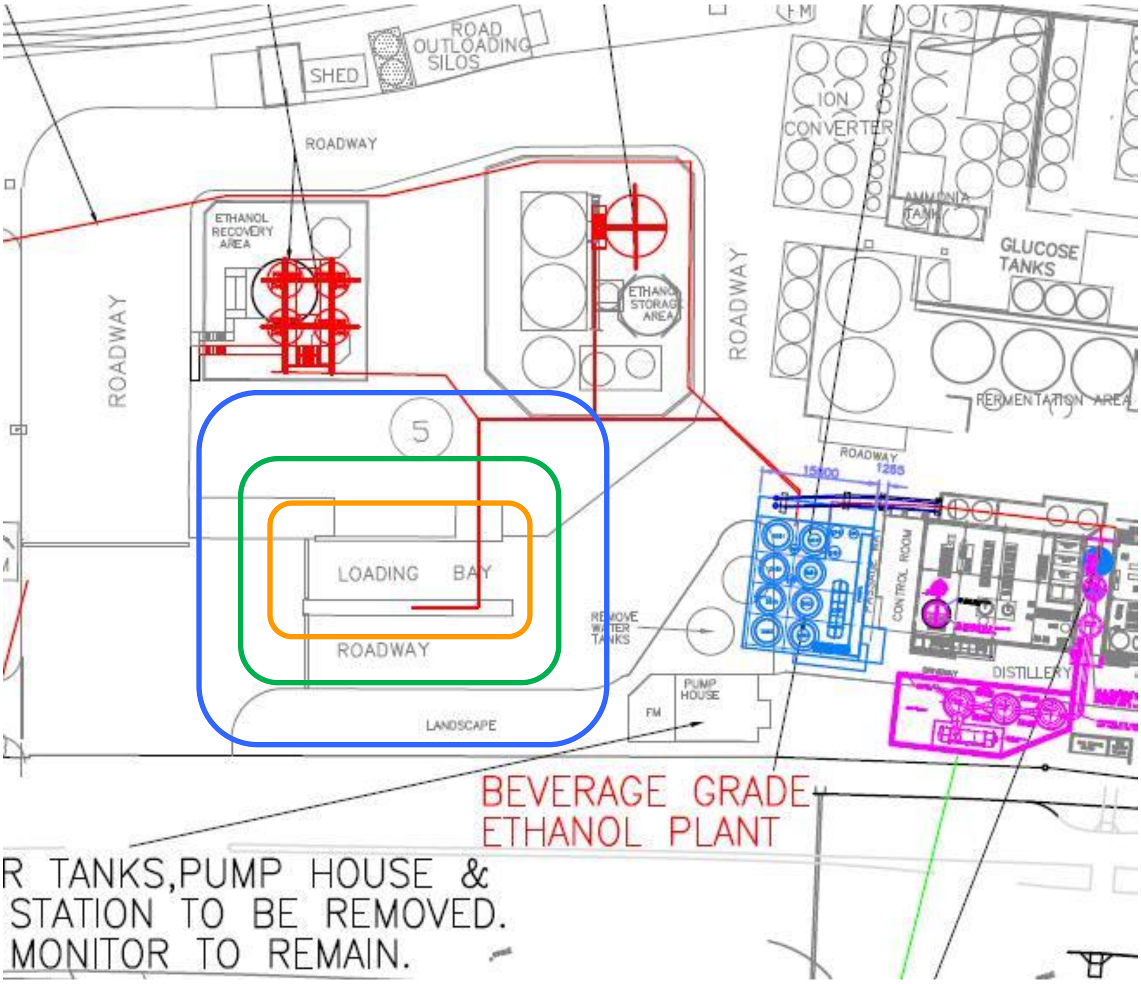
Contours are at tank height (not ground level)



Key:

- 23 kW/m^2
- 12.6 kW/m^2
- 4.7 kW/m^2

Scenario 6: Ethanol Road Tanker Bay Fire



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