SHOALHAVEN STARCHES,

SITE HAZARD ANALYSIS,

CONSENT NUMBER: MP 06_0228, MOD 34

BOMADERRY, NSW

Revision 9
Date: 4/3/2026

Manildra Group, Site Hazard Analysis, Nowra, NSW

Revision History

Rev	Date	Description	Author	Reviewer	Approver
1	8/3/24	Initial Draft	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
2	30/12/24	Comments on Rev 1 Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
3	15/5/25	MOD 31 Included (Sections 1.1, 3.3, 3.9 and App H Updated)	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
4	20/7/25	Comments on Rev 3 Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
5	9/8/25	Hazardous Materials Section 4.1 and Appendix A Updated	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
6	11/8/25	MOD26 Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
7	7/10/25	Comments on Rev 6 Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
8	21/2/26	MOD 34 and Second Carbon Dioxide Plant Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone
9	4/3/26	Comments on Rev 8 Included	Dean Shewring	John Studdert, Simone Arnold	Kane Livingstone

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EXECUTIVE SUMMARY

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.

As part of the site's Conditions of Consent, a site Final Hazard Analysis is required. Shoalhaven Starches requested that Pinnacle Risk Management prepare this report.

There is colour coding used in this report.

Black text is original text.

Blue text has been modified for a proposed MOD.

Red text shows the updated information for the current proposed MOD.

The red text within this Hazard Analysis constitutes the Preliminary Hazard Analysis for the proposed MOD34 modifications, i.e. the removal of the existing temporary time limit imposed by Mod 28 for the emergency grain storage bunker and the construction of a grain storage shed upon the existing grain storage bunker to the rear of the Waste Water Treatment Plant.

The risks associated with the plants and equipment at the Shoalhaven Starches Bomaderry site have been assessed and compared against the Department of Planning (DoP) risk criteria in this report. Based on the assessments in this report, all the DoP risk criteria are satisfied.

Societal risk, area cumulative risk, environmental risk and propagation risk is also concluded to be acceptable given the existing controls and results of the consequence modelling.

The primary reason for the low risk levels from the site's plants and equipment is that significant levels of radiant heat from potential fires, overpressures from dust explosion vents and hydrogen sulphide releases from the biogas system are mostly contained on-site.

There are no recommendations for the proposed MOD34 grain storage shed.

GLOSSARY

ADG	Australian Dangerous Goods (code)
AEGL	Acute Emergency Guideline Levels
ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
AS	Australian Standard
ASME	American Society of Mechanical Engineers
ATEX	Explosive Atmospheres (European Directive)
BGE	Beverage Grade Ethanol
BLEVE	Boiling Liquid Expanding Vapour Explosion
BPCS	Basic Process Control System
BST	Baker Strehlow Tang
BVF	Bulk Volume Fermenter
CATOX	Catalytic Oxidation
CCPS	Centre for Chemical Process Safety
CIP	Clean-in-Place
CO_2	Carbon Dioxide
D	Diameter
DDG	Dried Distillers Grain
DDGS	Dried Distillers Grain Solids
DG	Dangerous Good
DME	Dimethyl Ether
DoP	Department of Planning
DP	Differential Pressure
EN	European Standard
ENA	Extra Neutral Alcohol
EPA	Environmental Protection Authority
FHA	Final Hazard Analysis
FRAS	Fire Resistant Anti-Static
GD	Gluten Dryer
GPRF	Gas Pressure Reduction Facility
HA	Hazard Analysis
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HCl	Hydrochloric Acid
HDPE	High Density Polyethylene

HEART	Human Error Assessment and Reduction Technique
HIPAP	Hazardous Industry Planning Advisory Paper
HRSG	Heat Recovery Steam Generators
HSE	Health and Safety Executive (UK)
IBC	Intermediate Bulk Container
IECEx	International Electrotechnical Commission for Explosive Atmospheres
IPL	Independent Protection Layer
L	Length
LEL	Lower Explosive Limit
LOPA	Layer of Protection Analysis
LPG	Liquefied Petroleum Gases
MBR	Membrane Bioreactor
MCC	Motor Control Centre
MEC	Minimum Explosive Concentration
MIE	Minimum Ignition Energy
MVR	Mechanical Vapour Recompression
NFPA	National Fire Protection Association
NOx	Nitrogen Oxides
PFD	Probability of Failure on Demand
PG	Packing Group
PLC	Programmable Logic Controller
PM	Preventative Maintenance
PMPY	Per Million Per Year
PPE	Personal Protective Equipment
PPMV	Parts Per Million by Volume
PRM	Pinnacle Risk Management
PRV	Pressure Relief Valve
PSA	Pressure Swing Absorption
QRA	Quantitative Risk Analysis
RD	Rind Dryer
RO	Reverse Osmosis
SD	Starch Dryer
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SIL	Safety Integrity Level
SO	Sulphur Oxidation
SOx	Sulphur Oxides
STEL	Short Term Exposure Limit

TNO	Dutch Based Research Organisation
TNT	Trinitrotoluene
UF	Ultra Filtration
UN	United Nations
WWTP	Waste Water Treatment Plant

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.

This report is the site's Hazard Analysis. It contains assessment of all significant process safety hazardous events, i.e. fires, explosions and toxic emissions, that have the potential for off-site impact.

The red text within this Hazard Analysis constitutes the Preliminary Hazard Analysis for the proposed MOD34 modifications, i.e. the removal of the existing temporary time limit imposed by Mod 28 for the emergency grain storage bunker and the construction of a grain storage shed upon the existing grain storage bunker to the rear of the Waste Water Treatment Plant.

The report is also updated to contain the alterations and additions to the Supagas Carbon Dioxide Facility, in particular, the second Carbon Dioxide Plant (approved under Mod 30) as well as the relocation of phosphorous oxychloride storage area (which forms part of Mod 26).

The phosphorus oxychloride storage bund is proposed to be relocated from its current approved location to a position within the vicinity of the approved chemical storage area to the west of Abernethys Creek. The new location is approximately 80 m to the south, i.e. further away from Bolong Road.

The new phosphorus oxychloride storage will either be a bespoke self-bunded Dangerous Goods cabinet or purpose-built concrete 'bunker'. A 200 L drum will be stored in this secondary containment area and transferred under nitrogen pressure to the nearby starch reaction tanks. This new location is sited next to the recently constructed starch reactions tanks, i.e. minimises the transfer pipe length, and therefore improves operational and safety aspects. Given the limited quantity of phosphorus oxychloride then no further analysis is performed in this report for this change.

The proposed MOD34 changes will predominantly involve the removal of the existing temporary time limit imposed by Mod 28 for the emergency grain storage bunker and the construction of a shed upon the existing grain storage bunker to the rear of the Waste Water Treatment Plant. The shed will be used for storing wheat. This will provide several advantages over the approved grain bunker including:

- ➢ The shed will provide a reduced risk of moisture ingress which will extend the life of the stored grain
- ➢ The shed will reduce the potential for vermin and birds to gain access to the grain
- ➢ The shed will provide cost efficiencies as it will be cheaper to operate and maintain
- ➢ The shed will also be easier to operate when compared to the current grain bunker.

Shoalhaven Starches requested that Pinnacle Risk Management prepare this revised Hazard Analysis. This Hazard Analysis 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).

1.2 Objectives

The main aims of this Hazard Analysis are to:

- ➢ Identify the credible, potential hazardous events associated with the existing plants and 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 2)
- ➢ Evaluate the potential for propagation events
- ➢ Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events
- ➢ Where necessary, submit recommendations to Shoalhaven Starches to ensure that the processes are operated and maintained at acceptable levels of process safety and effective safety management systems are used.

In addition to the abovementioned objectives, the Department of Planning, Housing and Infrastructure require the following for the hazards and risk assessment. Comment is provided on each of these requirements, however, more detailed information is provided throughout this report.

Table 1 - Department of Planning, Housing and Infrastructure Requirements

Department of Planning, Housing and Infrastructure Requirements:	Comments:
A clear indication of class, storage and handling quantities and location of all dangerous goods and hazardous materials for the entire site	MOD34: The proposed MOD34 grain storage shed will hold up to 6,900 te of grain
A verification of the proposal and the changes made to the site under MOD 31 would comply with the relevant Australian Standards	MOD34: This Clause referred to the relevant Dangerous Goods standards for MOD31. Wheat is not a Dangerous Good. Therefore, this Clause is not applicable to MOD34
Details on the new installations and changes in existing plant, including but not limited to equipment, process, operating conditions, storage location/quantities	MOD34: See the process description changes provided in Section 3 (shown in red text)
The risk analysis must be comprehensive and consider risk of propagation and cumulative risk for the entire site. Where the risk from the existing operations do not affect the risk from the proposal, the risk profile of the existing operation should be illustrated for reference	This Hazard Analysis contains a Quantitative Risk Assessment. The proposed modifications do not have any impact on cumulative and propagation risk in the Bomaderry area as the grain storage shed is to be located in a remote location at the Waste Water Treatment Plant
Demonstration the cumulative risk would comply with Hazardous Industry Planning Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning (DoP, 2011).	There is no measurable change in the Quantitative Risk Analysis results as a result of the proposed modifications. Therefore, compliance with the HIPAP 4 risk criteria, which has already been shown in previous revisions of this report, is achieved

1.3 Scope

This Hazard Analysis assesses the credible, potential hazardous events and corresponding risks associated with the Shoalhaven Starches site and any proposed modifications with the potential for off-site impacts.

Off-site transport risk is included for any materials that exceed the transport quantities and/or frequencies listed in Applying SEPP 33 (State Environmental Planning Policy) (Ref 3).

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 Hazard Analysis has been conducted as follows:

- Initially, the existing processes and any 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. This included Shoalhaven Starches personnel reviewing and updating the process descriptions and Dangerous Goods storage quantities as shown in the Site Wide Fire Safety Study (Ref 4). Following this review, Pinnacle Risk Management (Dean Shewring) conducted a number of site reviews to verify the scope items to be included in this report

- 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 any proposed equipment and the adjacent processes

- If adverse off-site impacts could occur, assess the risk levels to check if they are within the criteria in HIPAP 4 (Ref 2).

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 main 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 main 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 m 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.

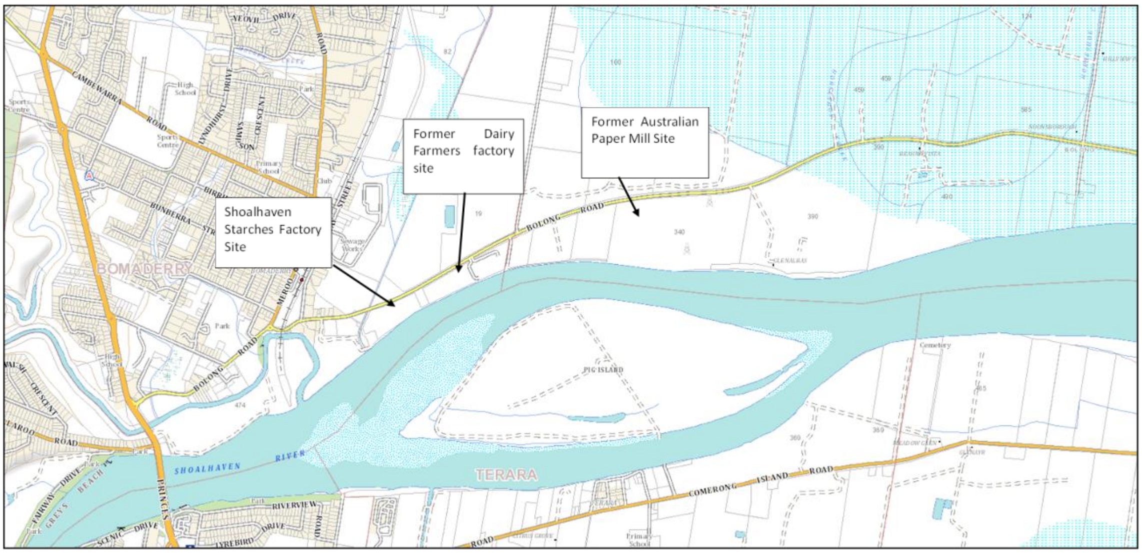
Shoalhaven Starches have a gluten and starch packing plant, the fire water tanks and pumps, natural gas supply equipment and an Environmental Farm on the north side of Bolong Road.

The Environmental Farm is approximately 1,000 hectares. 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 waste water treatment plant.

The works associated with MOD34 are located within the Environmental Farm and are limited to Lot 2 DP 833181, Lot 4 DP 610696 and Lot 1 DP 131008 Hanigans Lane and Bolong Road, Bolong.

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



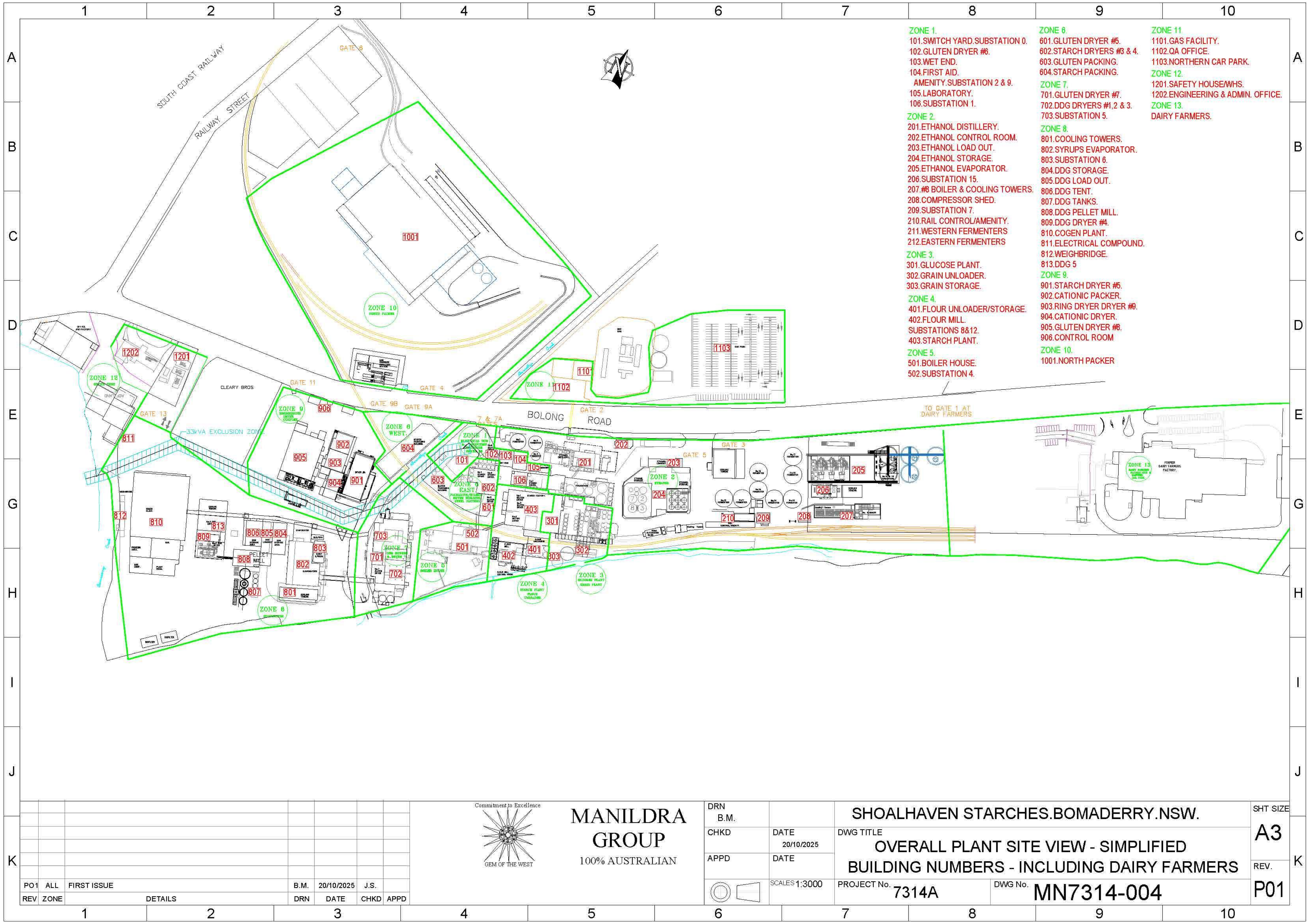
Security of the site is achieved by a number of means. This includes site personnel and security patrols by an external security company (this includes weekends and night patrols). The site operates 7 days per week (24 hours per day). Also, the site is fully fenced and non-operating gates are locked.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

There are approximately 180 people on site during Monday to Fridays 8 am to 5 pm and 100 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 site layout drawing is shown in Figure 2. The site has been divided into a number of zones for emergency response purposes. These zones are used throughout this report to assist with the understanding of the processes in each zone and the corresponding potential hazardous events.

Figure 2 - Site Layout – Shoalhaven Starches



3 FACILITIES DESCRIPTIONS

3.1 SITE OVERVIEW

The facilities within each site zone shown in Figure 2 (highlighted in green) are summarised in Table 2.

Table 2 - Site Zones Facilities Summary

Zone	Description
1	Electrical Switchyard, Substations, Laboratory and Amenities Buildings Gluten Dryer Number 6
2	Ethanol: Fermentation Distilleries (x3) Storage Road Tanker Loadout Ethanol Recovery Area Hand Sanitiser Building Nitrogen Generator Glucose (wet) Products Road Outloading Silos Evaporator, Isocontainer Storage, Substations and Cooling Towers Boiler 8 Substations
3	Glucose Plant / Building Grain Plant and Grain / Wheat unloading Ion Converters
4	Starch Plant / Building Gluten Dryers Numbers 1 to 4 / Starch Dryers 1 Flour Unloading Flour Mills A, B and C Substations
5	Boilers including Coal Stockpile Substation
6	Starch Packing Building Gluten Packing Building Starch Dryer Building – Starch Dryers Numbers 3 and 4 Gluten Dryer Number 5 Substation Glucose Dryer and Packer (Gemspray) Bulk Loading (1 te bulkabags and trucks) Container Storage Area Air Compressor Room
7	DDG (Dried Distillers Grain) Dryers Numbers 1, 2 and 3 Gluten Dryer Number 7 DDG Cooling

Zone	Description
8	Evaporators Pellet Plant DDG Storage Shed and Out Load Cooling Towers Temporary Container Area Silos (mill feed and DDG pellets) DDG Dryers Number 4 and 5 Cogeneration Plant Substation and Electrical Compound Nitric Acid Tank
9	Starch Dryer Number 5 Specialties Product Building Housing the Cationic Starch Process and Packaging, and Ring Dryer 9 Gluten Dryer 8
10	North Packing Plant
11	Natural Gas Heating, Pressure Reduction and Filtration Offices Fire Water Storage Tanks and Pumps Adjacent to Zone 11 is the BOC Carbon Dioxide Plant Proposed fans' building for the beverage grade ethanol distillery heat recovery modifications
12	Safety / Work Health Safety Offices Engineering and Administration Offices
13	Former Dairy Farmers Factory and Site including the proposed grain silos Maintenance Department Supagas Carbon Dioxide Facility
WWTP	Waste Water Treatment Plant (to the northeast of the main site) MOD26 and MOD34 Modifications

The facilities within each zone are further detailed in the following sections.

3.2 Zone 1: Gluten Dryer Number 6 and GD6 Wet End

The main processing facility in Zone 1 is Gluten Dryer Number 6.

On the site, there are six starch dryers (SD 1 to 5, and a ring dryer for starch, i.e. RD9), one glucose dryer (Gemspray) and eight gluten dryers (GD 1 to 8). Whilst there are individual differences between each dryer, they are similarly designed. The following general description for GD 6 is representative for all ring dryers on the site and is therefore not repeated for the remaining dryers in the other zones.

A water and gluten mixture is pumped from the Starch Plant to GD Number 6. The liquid gluten is dewatered, e.g. via Contra Shears (rotating screens) and a Vetter Screw Press. In other dryer designs, dewatering can be achieved via centrifuges.

The wet gluten is then fed to the dryer via a disintegrator or hammer mill where the particle size is reduced. The gluten is then dried via co-current hot air flow within the dryer piping.

The dryer air is drawn through filters to remove foreign objects. It is heated by steam (10 barg) and then a gas fired burner (to approximately 185°C).

After the air passes through a hot air box (used to collect large objects such as product clumps), the air and gluten combine and flow up through the dryer. The moisture in the gluten is evaporated and this stream enters a baghouse filter where the product gluten is removed.

The air stream from the baghouse filter passes through an induced draught fan and is discharged via a stack to atmosphere.

The gluten from the dryer baghouse filter is conveyed (e.g. screw conveyors and a blowline) to the milling stage.

The ground product is stored in bins. The ground product is then conveyed to the packaging area. The product is either stored in a buffer bin or sent to truck loadout.

The packaged product gluten is filled into bags, e.g. 25 kg bags or 1 te bulkabags, at dedicated bag filling stations.

The bags are stored in 20 foot containers until being loaded onto trucks or trains for delivery to the market.

Zone 1 also contains a laboratory and office.

The main hazards associated with the dryers are dust explosions and releases of natural gas with subsequent ignition.

3.3 ZONE 2: ETHANOL

Fermentation

The waste products from the starch, gluten and syrup production processes are combined to feed the fermentation and distillation stage of ethanol production.

The carbohydrates in the slurry feed to the fermentation area are converted to ethanol.

The fermentation process consists of the following steps:

- Enzyme (alpha amylase) is added to the aqueous slurry to achieve an initial conversion
- The slurry is heated to 83°C to break down the starch into dextrin (a soluble gummy substance obtained by hydrolysis of starch)
- Converted dextrin is evaporated to raise the solids to approximately 25%
- Yeast is added to convert glucose to ethanol at a temperature of 33°C with the evolution of carbon dioxide.

The fermentation process results in an approximate 12% solution of ethanol in water. The flash point of a 12% (vol) ethanol-water solution is 48 C, i.e. it is not a flammable liquid at typical operating conditions (approximately 30 C).

The original nine fermentation tanks are located in the "Fermentation Area" immediately to the south of the original distillery (see Figure 2). Fermentation tanks 10 to 16 were installed later in the area to the east of the original fermentation tanks. Fermenter 17 was installed in June 2021.

Fermenters 18 and 19 were installed in 2023 to the east of fermenters 10 to 17, i.e. at the approved Isocontainer storage area (which is to be relocated). Fermenters 18 and 19 are identical in design and operation to the previous fermenters. They both contain 2.8 ML of liquid. These fermenters are made of stainless steel and have agitators, recirculation pumps, transfer pumps, scavenger pumps and clean-in-place systems.

Carbon dioxide is produced within the fermenters. It is vented to atmosphere at the fermenters and/or sent to the BOC purification plant on the north side of Bolong Road and the Supagas plant to the east of the Shoalhaven Starches site.

Original Distillery

The ethanol-water solution (beer) from fermentation is fed to the distillery. The ethanol distillery comprises:

- Primary distillation which is operated at atmospheric and a temperature of 100^{o}C in Stages 3 and 6
- Rectification columns operating at a pressure of 3.5 bar and a temperature of 150°C in Stages 3 and 6
- Molecular sieves for the final purification of ethanol, i.e. by removing water. In this process, ethanol purity is increased from 95 to 99.5%, i.e. from industrial to fuel grade
- A beer column, side stripper, reboiler, rectifier and further heat exchangers.

In the molecular sieves, the 95% ethanol is first heated and evaporated using steam as the heat source. It then passes through the on-line molecular sieve which absorbs the water from the ethanol vapour. In the final part, the dehydrated ethanol vapour is condensed, cooled and pumped back to storage.

Two molecular sieves work in parallel with one on-line and the other are being regenerated. An automatic valve change-over system cycles the two sieves. A vacuum pump is used to extract the absorbed water from the molecular sieves.

The control room is located along Bolong Road. The ventilation system is designed to prevent the ingress of any ethanol vapour into the control room.

The original ethanol distillery produces:

- Fuel grade ethanol (99.5%)
- Industrial grade ethanol (95% and 99.9%) for use in producing pharmaceuticals, printer's ink and methylated spirits.

The maximum approved output from the ethanol distillery is 300 ML per annum (approximately 820 m^3/day or 650 te/day).

The waste solids and water from the ethanol distillery (from the beer columns) are processed through the DDG (Dried Distillers Grain) / Stillage Recovery Process Plant.

The waste water from the ethanol distillery is further treated before being recirculated into the plant and/or sent to the Manildra Environmental Farm Waste Water Treatment Plant.

Proposed Modifications to the Original Distillery

Manufacturing fuel-grade ethanol has a significantly lower emissions intensity compared to beverage-grade which has stricter purity requirements and a lower tolerance for water content, requiring additional energy-intensive steps and processes such as distillation and filtration.

The fundamental process for making fuel-grade ethanol is the same as beverage-grade ethanol with steam providing the thermal energy required to drive the process. However, the fuel-grade ethanol is manufactured in its distillation stack which is configured and operates differently than the beverage distillery.

Consequently, any efficiency improvements made to the beverage-grade distillery do not directly impact the performance or efficiency of the fuel-grade distillery. Similarly, the proposed beverage-grade project (discussed below) cannot be directly replicated in the fuel-grade distillery due to high costs, and technology and complexity constraints.

As a result, decarbonising the fuel-grade manufacturing process involves smaller more manageable upgrades and improvements.

It is proposed to modify parts of the fuel ethanol distillery to optimise the steam usage. The modifications will include:

- Reconfiguration of the existing T680 rectifier overheads stream which flow to a new heat recovery reboiler E2662. The low pressure steam recovered from this reboiler would drive the existing heat exchangers
- Commissioning of the existing low grade rectifier T660
- Recommissioning of the existing fusel oil recovery section.

The total steam saving for this proposal is 6 tph.

This proposal is based on the current operating conditions that are likely to continue. The total feed rate to the fuel section would be limited to 200 m^3/hr. This flowrate has not been exceeded in current operations.

The existing columns T501, C4201 and C4202 are to be placed on standby.

There will be no major changes to the other areas of the fuel grade ethanol plant, i.e.:

- Beer Feed to Fuel Plant
- T660 Low Grade Ethanol Rectifier
- Reboiler E824, Preheater E4103 and Rectifier T540.

Further details of the major changes are as follows.

Rectifier T680 and Reboiler E2662:

The operation pressure and temperature of T680 remains unchanged. The overheads from T680 are to be switched from E814 on T501 to E2662, i.e. a new heat recovery reboiler. This type of exchanger is similar to a conventional plate exchanger but the cassettes are welded.

Water will be recirculated on one side of the cassette pack and the overhead vapours from T680 heat and boil the water from the other side.

The evaporated water from the unit will pass to a separator drum D909 that is similar to the existing D908.

The reboiler E2662 will generate low pressure (LP) steam to the new LP header operating at 86 kPa(g) and 118 deg C.

The new LP header flow is to be split to supply E4103 (beer preheater), E824 (reboiler) and a small balance flow to a trim heater.

Fusel Oil Recovery:

This section mostly remains unchanged. The existing drum D463 is to be repurposed as a feed drum for T660 only. A new fusel oil feed drum, D812, is to be installed. The feed to this drum will be only fusel oils from T660.

In the event that T660 is not operational, fusel oils can be taken beneficially from T680 and if capacity permits, from T540.

BGA1 Supply:

In the proposed configuration, BGA1 would be supplied by T680.

At the design conditions, there is an adequate supply at 8,500 kg/hr. However, depending on the industrial grade requirements, some top-up from T540 may be required.

With the removal of low fusel oils from the system (mainly iso-amyl alcohol), the quality of the product from both T680 and T540 will improve significantly.

If the demand for fuel grade and industrial grade increases such that a beer feed of 200 m^3/hr cannot meet the demand then the plant reverts to the current configuration.

As the proposed changes involve taking three columns off-line, operating pressures and temperatures remaining unchanged and the plant is wholly within a bunded area then there are no new process safety events that could impact off-site people and/or the environment. Therefore, no further detailed analysis of these modifications is performed in this report.

First Beverage Grade Distillery

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.

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 as 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 original 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%
- 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 original 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 original decantor or to the original 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 original 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)
- 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
- 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.

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.

Second Beverage Grade Distillery

There are three stages within the existing industrial grade ethanol distillery (corresponding to the order of installation). These processes were installed prior to the installation of the first beverage grade distillery in 2017. Stage 1 was demolished and the second beverage grade distillery was installed at the same location, i.e. immediately to the south of the Control Room.

The existing Stage 1 industrial grade facility was similar to the second beverage grade facility, i.e. it involves the same feed (beer at 7 to 12% ethanol) and unit operations such as distillation columns (both vacuum and pressurised), vessels, heat exchangers and pumps.

The second beverage grade ethanol distillery is designed to make up to 100 ML of beverage grade ethanol per annum at 96.5 vol% ethanol.

There was no increase in overall ethanol production above the then approved 300 ML per year and no increase in waste-water generation as a result of the installation of the second beverage grade plant (as the existing Stage 1 ethanol process was demolished).

The production of beverage grade ethanol from beer at 7% to 12 % by volume alcohol coming from the wheat starch slurry fermentation is performed in a distillation / rectification process that includes the following steps:

- Stripping, degassing and concentration to produce raw alcohol at 93 to 95% volume (performed in the combined column D510/D511/D520)
- Purification by the hydroselection column (D530)
- Rectification by the rectification column (D540)
- Refining by the refining column (D550)
- Heads and Tails concentration in the Heads and Tails concentration column (D560). The D560 column also processes the Heads and Tails produced by the existing (first) beverage grade distillery.

The production of beverage grade ethanol (96.5 vol%) from beer is performed in a rectification process including the following steps.

First Step: Degassing, Stripping and Concentration.

The beer at 7% - 12 % volume and 70°C from the fermentation unit feeds the first process.

The purpose of the combined degassing (D511), stripping (D510) and concentration (D520) column is:

- To eliminate the beer gas (e.g. air, carbon dioxide and sulphur dioxide) in the degassing column D511

- To strip the alcohol in the beer from 7% to 12% volume to 0.03% volume in the stripping column D510
- To concentrate the alcohol from the stripping column to about 93 to 95 % volume in the concentration column D520.

All three sections of this combined column are operated at vacuum conditions.

The spent wash or thin stillage from the bottom of D510 is sent to the site's stillage plant.

The alcoholic vapours at 93 to 95% vol coming from the top of the concentration column D520 are condensed in a plate condenser and a seal condenser. All the condensates are collected in the vessel R525 and then sent as reflux to the concentration column D520. A small portion of heads (light impurities like esters and aldehydes) from the reflux line is sent to the impurities extraction vessel R543. Other impurities, e.g. isoamylalcohol, n-butanol and iso-butanol, are also removed from selected trays in D520 and sent to R543.

The concentrated liquid alcohol at 93 to 95 %vol is extracted a few trays below the top of D520 and sent to the hydroselection column (D530).

If required to get a good quality product and to reduce the risks of copper corrosion, the pH may be adjusted to maintain it between 7.5 and 8.5. This pH adjustment is performed by injection of caustic soda (3 to 5 wt%) below the low oils extraction point on the concentration column D520.

When required, the relevant equipment is cleaned (Clean-In-Place). This requires a complete plant shutdown.

Second Step: Purification Performed in the Hydroselection Column D530.

The hydroselection column D530 operates similarly to the hydroselection column in the existing (first) beverage grade distillery.

The ethanol from D520 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 vessel R543. The hydroselection column bottoms steam contains approximately 10 to 12% ethanol by volume and importantly, the majority of impurities have been removed. This stream is pumped to the rectification column D540.

The hydroselection column operates at vacuum conditions.

Third Step: Rectification Performed in the Rectification Column D540.

The rectification column D540 operates similarly to the rectification process in the existing (first) beverage grade distillery with the exception that the first beverage grade distillery has two columns operating in parallel.

Purified ethanol at 10 to 12% from the hydroselection column feeds the rectification column, i.e. D540. The main functions of the rectification column are:

- To strip the 10 to 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 and also used internally within the process
- To concentrate the ethanol to obtain a concentration of at least 96.5 vol%
- To eliminate all of the residual heavy impurities.

Some Heads (impurities such as aldehydes and acetaldehydes) are concentrated at the top of the rectification column. Therefore, a small bleed stream of Heads is sent to vessel R543. The beverage grade ethanol stream is taken from lower trays to avoid being off-specification in Heads.

Along the column D540, extraction streams are made to extract low oils (e.g. isoamylalcohol or fusel oils), high oils (e.g. n-butanol, isobutanol and n-propanol) and very high oils. All of these extractions are sent to the impurities extraction collector vessel R543 prior feeding of the low-grade alcohol column D560.

D540 operates at 2.3 bara pressure.

Fourth Step: Refining Performed in the Refining Column D550.

The refining column D550 operates similarly to the refining column in the existing (first) beverage grade distillery, i.e. vacuum operation.

The ethanol from the rectification column D540 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
- 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.

Fifth Step: Heads and Tails Concentration in the Heads and Tails Column D560.

The vessel R543 receives all the streams containing the impurities from the various unit operations in the plant. R543 feeds the Heads and Tails column D560.

The purpose of the Heads and Tails concentration column D560 (which operates like a rectification column) is:

- To strip the alcohol in the feed (about 60% to 70 % vol) to an alcohol content in the spent feints below 0.03% (spent feints is the bottom stream from D560 which is sent to the Manildra waste water treatment plant)
- To concentrate the alcohol to obtain at the top of the column a concentration of at least 95% by volume (this stream is recycled to the hydroselection column)
- To eliminate all the impurities and send them to the storage, i.e.
    - Heads (e.g. aldehydes, acetaldehydes and esters)
    - The low oils (e.g. isoamylalcohol called "fusel oils" mainly)
    - The high oils (e.g. n-butanol, isobutanol and n-propanol).

The ethanol containing the impurities is sold as a low-grade product.

D560 operates at 2.3 bara pressure.

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

The main material of construction for the equipment items is stainless steel.

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.

The second beverage grade ethanol plant is provided with cooling towers comprising standard cells (x4) with total capacity of 6,390 m^3/hour (of cooling water). The cooling towers are fiberglass casing, stainless steel structure with a plastic fill.

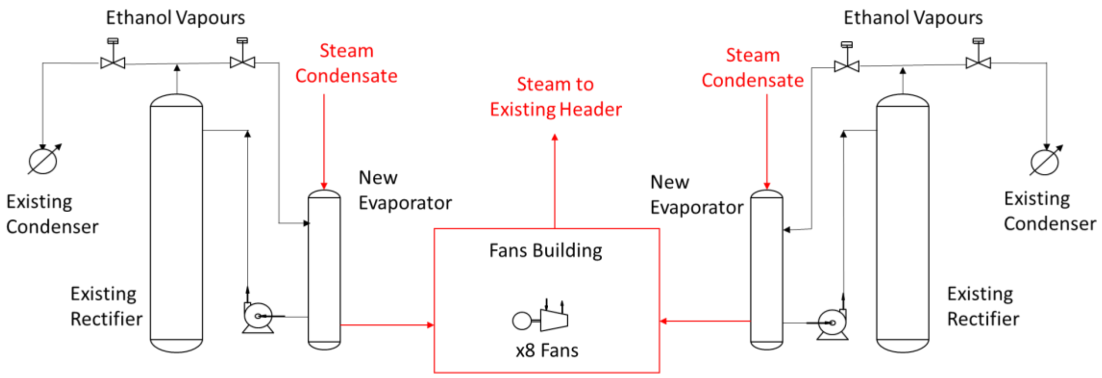
Dosing chemicals are stored in 1,000 litre IBCs (intermediate bulk containers) next to the cooling towers. They are stored in a bunded area and segregated as per the Dangerous Goods storage codes, e.g. acids stored separately from the alkalis.

Proposed Modifications to First and Second Beverage Grade Distilleries

Distillation can be energy intensive. Shoalhaven Starches beverage-grade distillation processes require 55 tph of steam which is produced by the gas-powered Cogen Plant.

It is proposed to capture and transform waste heat into usable energy to drive the ethanol, starch and gluten manufacturing processes. A process flow diagram for the proposed modifications to one of the beverage grade ethanol plants is shown in Figure 3.

Figure 3 – Process Flow Diagram for One Beverage Grade Ethanol Plant



Shoalhaven Starches operates two beverage grade distillation plants. Each of these plants has two ethanol rectifier columns. Energy is supplied at the start of the process by live steam.

The ethanol vapour overheads streams (54 to 58 C) from the four rectifiers currently flow to water cooled condensers. Therefore, the energy in these overhead vapours is lost to the cooling towers.

It is proposed to install piping and actuated valving to divert the overheads from these four rectifiers to four evaporators. The energy from condensing the four overheads streams in the shellside of these evaporators will be used to generate steam in the tubeside. The condensed ethanol vapour will be returned to the respective rectifier as reflux, i.e. as per the current designs.

Essentially, the four rectifiers can either be operated as they are currently designed or the energy in the four overheads streams can be utilised to generate steam. The existing rectifiers' condensers and the proposed energy recovery evaporators will not be operated at the same time.

Cooling water will continue to flow through the existing water cooled condensers for the following reasons:

- Biological chemical treatment of the cooling water side of the exchanger is maintained to prevent the growth of legionella
- To provide a vent condenser for anything not condensed in the evaporators and a pathway to the existing vacuum system/scrubber
- To enable rapid return to the current operational configuration should the heat recovery system trip.

The evaporators will be designed as falling film heat exchangers as part of the proposed Mechanical Vapour Recompression (MVR) process. The feed to the tubeside of the evaporators will be steam condensate (water) from an existing condensate collection tank. The condensate is circulated around each of the evaporators through the tubeside. The heat from the condensing ethanol overheads streams will vaporise some of the condensate to generate steam.

There will be a bleed stream from the condensate recirculation flow to avoid an accumulation of impurities within the tubeside of the evaporators.

The combined steam from the two Beverage Grade Ethanol 1 evaporators are drawn into eight fans in series. There will be an identical process, i.e. eight fans in series, for Beverage Grade Ethanol 2. All sixteen fans will be variable speed drive.

The steam temperature will be controlled with desuperheaters on the inlet to each fan. The desuperheaters will use steam condensate (water) to provide the cooling. Fan surge control will be provided which involves recycling outlet steam back to the suction of the first fan.

The steam pressure (372 kPa(abs)) at the outlet of the fan train is sufficient to allow the steam to enter the existing Shoalhaven Starches low pressure steam header for use within the Beverage Grade Ethanol Plants 1 and 2. This will therefore reduce the steam import to these plants, i.e. from the existing Shoalhaven Starches Cogen Plant and boilers. Correspondingly, there will be a reduction in natural gas usage and a decrease in carbon dioxide emissions.

The energy savings are therefore derived by avoiding use of cooling water to condense the overhead streams from the four rectifiers (the total cooling water requirement for the two plants is approximately 3,500 m^3/hr) but use this condensation energy to generate steam that provides heat to other equipment items.

The pressure and therefore temperature of the four rectifiers' overheads streams will not change. To allow the exchange of heat in the evaporators, the steam-side pressure will be controlled to a partial vacuum using vacuum pumps. The operating pressure on the tubeside of the evaporators and therefore the suction to the first fan will be approximately 8 to 9 kPa(abs). The generated steam temperature (at this pressure) will be 45 to 47 C.

There will be an extension of the Beverage Grade Ethanol 1 bund area to accommodate the proposed equipment. The ethanol streams (vapour and liquid) remain in this area.

The generated steam will be piped via a pipebridge over Bolong Road to the fans' building. The compressed steam will then be piped back over Bolong Road (via the same pipebridge) to be connected into the existing low pressure steam header. That is, there will be no flammable, explosive or toxic process chemicals crossing Bolong Road or within the fans' building.

All product contact surfaces (both ethanol and water vapour) will be stainless steel. All low pressure steam lines will be mild steel pipe steam with the exception of the steam lines over Bolong Road. These are to be stainless steel to mitigate the risk of under-lagging corrosion and hence a steam release within the gantry and over Bolong Road.

The operation will be controlled via the site-wide control system.

Additional controls include fixed flammable gas detectors in the extended bund area, high level and pressure trips, and temperature and vibration sensors for the fans. The water deluge system is to be extended to cover the new ethanol-handling equipment.

Given the proposed modifications, there is the extended Beverage Grade Ethanol 1 bunded area that can have a larger pool fire (than previously modelled) if a loss of containment of ethanol occurs and is ignited. The overheads piping has already been included in the quantitative risk analysis in this report (either the ethanol overheads flow to the existing condensers or to the four new evaporators but not both at the same time). Therefore, this increased pool fire size has been included in this hazard analysis (see Appendix H for details).

Tanks – Ethanol Storage Area

Product ethanol from the distilleries (i.e. the original distillery, and the first and second beverage grade distilleries) is stored in atmospheric, fixed roof tanks as detailed in Table 3.

Table 3 - Ethanol Storage Tanks

Tank	Tank Diameter (m)	Tank Shell Height (m)	Gross Capacity (m^3)
Tank 1	6.6	6.7	229
Tank 2	8.2	10.6	560
Tank 3	8.2	10.6	560
Tank 4	4.3	8.2	119
Tank 5	3.4	10.9	99
Tank 6	3.7	9.2	99
Tank 7	7.6	9.2	417
Tank 8	7.46	18	777
Total			**2,860**

All tanks are bunded as per the requirements of AS1940. Any spill in the ethanol storage tanks 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 pump to the underground recovery tank to alert the operators of spills in the bund.

There is also a contained drum storage depot (50 m^3) for DG (Dangerous Good) Class 3 flammable liquids stored in drums and 1,000 L containers.

Tanks – Ethanol Day Tanks

As part of the first beverage grade distillery project (2018), one new tank was installed in the ethanol storage area (Tank 8) and four new smaller storage tanks in the former recovery tank area (i.e. the eastern tank bunded area now known as the Ethanol Day Tanks). The tanks are constructed from stainless steel and are fixed roof.

The four smaller tanks that are installed in the Ethanol Day Tanks area are 240 m^3 each. They are 4.5 m diameter and 14.7 m high.

The four smaller tanks operate as day tanks, i.e. any off-specification ethanol product from the beverage grade distilleries is diverted to these tanks or other processes rather than flow to the larger storage tanks which contain the on-specification product ethanol for the customers.

As part of the hand sanitiser project (2020), two additional day tanks were approved for the Ethanol Day Tanks area. These are identical in design to the abovementioned four day tanks. Therefore (in 2020), there were six approved day tanks in the Ethanol Day Tanks bunded area.

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

The Ethanol Day Tanks overfill protection includes a level transmitter and high level trip.

As part of the second beverage grade distillery project, an additional three tanks in the Ethanol Day Tanks bund were installed. These three tanks are identical in size to the existing tanks, i.e. 240 m^3 each, 4.5 m diameter and 14.7 m high.

The additional three tanks replicate the functionality of the existing tanks being, they provide buffer storage for product to enable the quarantining of production for quality testing prior to release for transfer into the bulk Extra Neutral Alcohol (ENA) storage tank or to road tanker for despatch. Product that fails quality testing is downgraded and transferred to the industrial grade product storage tanks for despatch or further processing.

A valve manifold and pumping station was installed in a compound adjacent to the Ethanol Day Tanks bund to route product into and out of the Day Tanks. Three pumps are used to either transfer product to either bulk storage or to the road tanker loadout arms.

Therefore, there are nine identical, approved tanks for the Ethanol Day Tanks bund.

Road Tanker Loadout

Ethanol is pumped from storage to the road tanker loadout bay. B-Doubles, single road tankers, Isocontainers, 1 m^3 Pallecons and 205 L drums are filled with ethanol.

Road tanker loading is by done by the tanker driver with supervisory control by a Manildra operator. Only a single tanker is loaded at a time.

The loading bay has two drain points to allow any spillage to flow to the underground recovery tank. The road tankers and Isocontainers are bottom loaded to avoid splash filling and static formation.

There are two road tanker loading arms for fuel grade ethanol and another two for industrial grade ethanol. These include dry-break couplings. All four loading arms are on the same side of the road tankers, i.e. the northern side of the road tanker loadout facility.

A load pipe is used for the Isotanks (no hose).

For drums and IBCs, a 50 mm hose (with a fitting) is connected to one of the loading arms.

The product beverage grade ethanol is pumped into road tankers or Isotanks at the road tanker transfer area for delivery to the customers. Two dedicated parallel loading arms are installed for the beverage grade ethanol. Road tanker overfill is protected by a Scully system.

Overfill protection for the Isotanks is:

- When an Isotank arrives at site, it is inspected by the Ethanol Plant operators. This is both an external and internal inspection. The internal inspection is performed by the operator checking via an open hatch. Any Isotank with residual liquid, as determined by the visual inspection, is rejected (i.e. not filled). Note that the Isotanks are cleaned prior to arrival on site

- Each Isotank capacity is entered into the loadout system (in litres) by the operator and cross-checked by the driver. The quantity is transferred by a batching flow meter. There is a limit within the control system that helps prevent overfilling, e.g. the maximum limit is 26,000 litres. The loadout meter is calibrated every 6-12 months to ensure accuracy. A sample is taken from the top of every Isotank and a driver is then able to determine if the Isotank has been under or over filled

- Every load is monitored by the driver with a deadman's vigilance button, i.e. the driver needs to press the button every three minutes. If this is not done then an emergency stop will be activated.

There is a foam deluge system in case of an ethanol fire. This system can be activated by either a fire detector or by Break Glass Alarm.

There are six 5,000 L storage tanks on the south side of the road tanker loadout bay wall that store denaturants. These are dosed into the ethanol during road tanker filling. All denaturants are flammable liquids, e.g. petrol, propanol and ethyl acetate. These tanks are bunded. There are six pumps that are used to dose the denaturants into the ethanol.

Glucose (wet) Products Road Outloading Silos

Glucose products, i.e. liquid syrups, are also loaded into road tankers south of the ethanol storage area near the rail line in this Zone. These products are non-hazardous. To the east of the glucose loadout area, yeast is stored within a small building.

The former DME (dimethyl ether) plant and storage have been demolished.

Hand Sanitiser Process

This process is mothballed and is currently being removed from the site (as of early 2024) and therefore no further analysis is warranted.

Boiler 8

Boiler 8 steam production is 45 tonnes per hour. The supply pressure and temperature are 10 barg and 184°C, respectively. The boiler is a 30 MW gas-fired D type (i.e. vertical steam drum) water tube boiler.

The boiler operates 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 is a typical design involving a steam drum and a mud drum.

Water is treated in filters, water softeners and stored in a feedwater tank. It is then pumped to a deaerator where dissolved oxygen is removed using steam. The feedwater is then pumped into the boiler to maintain level. The boiler design includes provision for blowdown (both manual blowdown from the mud drum and continuous blowdown from the steam drum) to prevent high conductivity in the boiler water. The blowdown water and other waste water streams are treated at the Manildra waste water treatment plant.

Natural gas and biogas are the fuel sources for the furnace. Natural gas is piped throughout the site. Biogas is available from the Manildra waste water treatment plant and is also piped throughout the site. The fuel gas train to the boiler is compliant with the relevant standards, e.g. AS3814, Industrial and Commercial Gas-Fired Appliances.

The natural gas supply pressure is 210 kPa and is reduced at the boiler valve train.

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

The boiler is installed in a covered area (open walls).

Boiler high pressure is protected by the control system and relief valves. Boiler low and high level, and potential furnace explosions are protected via a boiler management system. This includes an air purge prior to ignition of the burners. The control system is compliant with AS2593, Boilers - Safety Management and Supervision Systems, and the Australian Gas Association codes.

The boiler and associated piping and vessels are constructed from carbon steel. All pipework is 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 is installed to mitigate the risk of injury.

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

MVR (Mechanical Vapour Recompression) Evaporators

There are three MVR evaporators installed on the eastern side of Zone 2.

The evaporation process for 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.

Nitrogen Generator

There is a PSA (Pressure Swing Absorption) process installed along the Bolong Road boundary and opposite the ethanol road tanker gantry. This PSA produces approximately 800 kPag nitrogen. There are six 5 m high, 1 m diameter (approximately) nitrogen storage pressure vessels. The nitrogen is used to pad the Ethanol Day Tanks as well as for purging purposes. As nitrogen is not a fire, explosion or toxic hazard, then no further analysis of this process area is performed in this study.

For Zone 2, the main hazards are associated with losses of containment of ethanol with subsequent ignition. This is predominantly pool fires although jet fires, flash fires, BLEVEs (boiling liquid expanding vapour explosions) and explosions (if the ethanol vapours are confined) are possible.

For Boiler 8, the main hazards are associated with losses of containment of natural gas or biogas with subsequent ignition. Internal boiler explosions can also occur due to an accumulation of unburnt flammable gas or boiler failure releasing pressurised water and steam.

3.4 ZONE 3: GLUCOSE PLANT

The Glucose Plant processes only liquid streams, i.e. the feeds and products are wet (water solutions). The feed to the Glucose Plant is liquid starch.

There are two main products, i.e.:

- Clear glucose syrup
- Brewer's syrup (a light brown colour).

Alpha amylase enzyme is added to the liquid starch feed tank. The liquid starch then goes through a jet cooker where direct steam injection is used to 'cook' the starch. The cooked starch then passes through a retention column so the alpha amylase can break down the starch further. After being flashed in the flash chamber, the cooked starch is cooled and pumped into the saccharification tanks. This stage of the process, saccharification, is the process of breaking a complex carbohydrate (such as starch) into simple sugars.

Enzymes are added to de-branch the cooked starch. The process is left for the enzyme to work (typically between 24-48 hours). Glucose is formed which is a monosaccharide (single chain carbohydrate). It is filtered, condensed via an evaporation process and then stored in tanks. Liquid glucose typically contains up to 32% water.

There are also three grain silos in the south-west corner of Zone 3. These are included in the Zone 4 HAZID (hazard identification).

Chemical storage in Zone 3 includes:

- Sodium hydroxide
- Hydrochloric acid.

The main fire and explosion hazards in Zone 3 are associated with the grain silos (dust explosions as well as smouldering grain fires). Liquid glucose is not flammable, however, it will burn in a fire following evaporation of the water. Water sprays are generally adequate for any fires involving glucose (sugar).

3.5 ZONE 4: STARCH PLANT AND FLOUR MILL

Flour to the Starch Plant is from two sources:

- Wheat is delivered to site by train, unloaded, stored and milled to produce the flour
- Flour is delivered to site by train, unloaded, stored and fed directly to the Starch Plant.

The two main products from the Starch Plant are starch and gluten. These are packaged and sold to the market.

Flour Mills:

The mill produces a range of wheat flours and millmix (bran). The first flour mill (Mill A) has a designed capacity to produce 6,825 tonnes of industrial grade flour per week. In 2018, a second flour mill (Mill B) was installed with a designed capacity of 4,641 tonnes per week. Mill C was installed in 2020 and has a designed capacity of 4,641 tonnes per week of flour.

Delivery of flour to the site is from the Manildra Group flour mills at Manildra, Gunnedah and Narrandera.

The flour mill process is summarised as follows:

- Wheat is delivered to the site in rail hopper cars; nominally of 60 tonne capacity. Each train delivers approximately 3,200 – 3,500 tonnes of wheat

- Wheat delivered to the site by train is discharged through a grid below the rail hopper car outlet using the grain intake system and is transported via a bucket elevator and drag chain conveyors system into one of five silos. The existing storage capacities are: Silo 101 is 2,200 te, and silos 102 (1,250 te), 103 (1,250 te), 104 (1,250 te) and 105 (1,000 te). The wheat intake system is a separate system to the flour unloading system from trains (the two unloading systems are approximately 50 m apart)

- Wheat is transferred from the raw wheat silos via drag chain conveyors, weighed and then passed through the following cleaning operations:

    - Sieves for the removal of impurities larger and smaller than wheat

    - Gravity separators for the removal of heavy impurities such as stones and glass

    - Magnetic separators for the removal of ferromagnetic impurities

- The moisture content of the wheat received at the site is typically in the range of 8% to 10% which is too dry for milling to get a good quality flour and to get a good separation between flour and bran. Water is therefore added to the wheat in a carefully controlled manner to increase the moisture content of the grain to around 14%

- The damp wheat is then stored in conditioning or tempering bins (900 m^3 for Mill A and 1,900 m^3 for Mills B and C) where it is allowed to remain for a period of time (normally up to 12 - 24 hours) to allow the added moisture to be fully absorbed into the grain

- When the grain is at the optimum milling condition, it is taken from the conditioning bins and passed through final scouring, weighing and separation stages (including magnetic separation) before being fed to the mills. Milling is carried out on roller mills which mill the grain into progressively finer fractions

- Each milling process is followed by coarse sieving to separate large flakes of bran and chunks of endosperm which are then passed to the next milling cycle. The finer starchy material is passed over a series of progressively finer sieves to remove any flour and to grade the remaining particles into various sizes for further grinding

- Flour from the various grinding operations is collected and blended together before passing through final treatment and weighing operations to the bulk storage bins. Therefore, flour can be stored in the flour bins from two sources, i.e. from the mills or from train unloading

- For the flour train unloading, flour drops into the in-take pit from the wagons. The flour is then conveyed (including four bucket elevators) to typically four of the eight flour bins. The bins hold up to 300 te each. The other four bins are used for the product flour from the mills. The bins are made from steel and have reinforcing rings equi-spaced up the bins' walls. The flour bins have high level trips. There is aspiration on the elevators and bins

- Flour is taken from these bins for use in the Starch Plant

- The coarse particles left at the end of the size reduction system in the mills, known as pollard, and the bran from the end of the break system is combined into a second single product (to be processed to DDG – Dried Distillers Grain) for sale as animal feed

- All air extracted from the mill is passed through baghouse filters prior to being discharged to the atmosphere

- Pneumatic conveying is used extensively to transport the flour throughout the mill and factory.

Starch Plant:

Wheat flour is typically composed of moisture (12%), protein (gluten) (12%), fat (1%) and carbohydrates (starch) (75%). The Starch Plant separates the starch and gluten in the flour.

The flour is transferred from storage to the Starch Plant or “wet end” where the following occurs:

- Starch and gluten are separated in a water mixing and screening process

- All the gluten is dried, transferred to the packing department to be packaged and sold to the market

- The waste from the process is transferred to the ethanol plant for fermentation and distillation to produce ethanol

- Some of the starch is dried (Starch Dryer Number 1)
- The remaining starch is sent to processes in other Zones in liquid form
- The dried and liquid starch is sold and used for food, cardboard, paper and other industrial purposes
- Wastage from the liquid starch process is also used in the ethanol production process (i.e. fermentation).

Starch is also used in the production of syrups at the facility, i.e. the Glucose Plant in Zone 3. The syrup products include glucose and brewer's syrup. These are used in foods and beverages such as chocolates, confectionery, beer, soft drinks and fruit juices.

The wastage from the starch, gluten and syrup production processes are fed to fermentation and then the distillation stage for ethanol production.

Gluten Dryers Numbers 1, 2, 3 and 4 are also located in Zone 4. A generic description of dryers is provided in Section 3.2.

The main hazards in Zone 4 are associated with grain and dust, i.e. dust explosions as well as smouldering fires, and losses of containment of natural gas to the dryers with subsequent ignition.

3.6 ZONE 5: BOILERS

There are eight boilers on site:

- Numbers 1, 3, 4 and 7 are fired by natural gas and biogas from the Waste Water Treatment Plant (WWTP) located at the farm
- Numbers 5 and 6 are fired by coal but are planned to be converted to gas in the near future
- Number 2 has been mothballed
- Number 8 (in Zone 2).

There is a relatively small coal stockpile in Zone 5.

The overall processes for the boilers are summarised as follows.

Coal Boilers 5 and 6:

Trucks initially deliver the coal directly to the small coal stockpile to the south side of the boilers in Zone 5 or to the Manildra Farm if this area is full.

Black coal is used at the Shoalhaven Starches site. The coal size is 10 to 25 mm and contains approximately 15% ash. It is reclaimed from the boiler area coal stockpile using a frontend loader. The frontend loader feeds the coal into a hopper and denseveyor (pneumatic transfer machine). Compressed air is used to transfer the coal to the boiler.

The coal boilers have feed hoppers which are level controlled. The coal is gravity fed onto a grate for delivery into each boiler. A door at the coal inlet to each boiler can be closed (manually) to stop the coal and hence the source of heat, e.g. in the event of an emergency.

The coal passes through a guillotine door that maintains the desired bed depth. After about 1 m of travel, the coal is ignited by the heat from the existing coal that is burning. The heat from the burning coal raises the required steam for use throughout the site, e.g. heat for reboilers in the ethanol distillery.

These boilers are ignited manually during start-up.

The flue gas containing fly ash passes through a multi-cyclone, economiser (for preheating the boiler feed water) and air heater (for the forced draft, combustion air to the furnace) before passing through baghouse filters, an induced draft fan and then the stack.

The baghouse filters contain 5 m long socks that collect the fly ash. The socks are pulsed with air to remove the fly ash (which falls to the bottom of the baghouse). This fly ash, along with the fly ash collected by the multi-cyclones, economiser and air heater, and ridlings ash from the grate, are conveyed (screw conveyors and a denseveyor) to a receiving hopper located above a pug mill (produces a paste by forcibly combining fly ash with water). This paste is then dropped directly into the ash bin. Ash from this bin is removed from site by truck and disposed of as per the EPA's approval to the Manildra farm.

Combustion gas is vented to atmosphere via a 40 m high exhaust stack.

Natural Gas / Biogas Boilers:

These boilers are gas fired boilers as per AS3814, the Australian Standard for Industrial and Commercial Gas-Fired Appliances. The boilers can be run on natural gas only, or a natural gas and biogas mixture. The control systems are designed to be high integrity to lower the risk of boiler explosions, e.g. due to passing flammable gas into a boiler's furnace when shutdown with subsequent ignition.

The natural gas pressure throughout the site and hence to the boilers is 210 kPag.

The biogas is a low-pressure system (55 kPag maximum pressure). It is produced within the WWTP by digestion of the waste water from the factory. Should the biogas not be required at the boilers then it can be combusted at the WWTP flare.

The main hazards in Zone 5 are associated with coal smouldering fires and losses of containment of natural gas or biogas with subsequent ignition. Internal boiler explosions can also occur due to an accumulation of unburnt flammable gas or boiler failure releasing pressurised water and steam.

3.7 Zone 6: Packaging, Starch Dryers 3 and 4, Gluten Dryer 5 and Gemspray

The dry finished products, i.e. starch and gluten, are stored and then transferred to the packaging area.

Packaging takes place in two locations, i.e. within the:

- Packaging building
- Another building known as the Interim Packing Plant (on-site known as the steel shed starch packer).

The starch and gluten are transferred to dedicated packaging machines in the packaging building and Interim Packing Plant where paper bags (e.g. 25 kg) and 1 te bulkabags are filled. These machines control the filling rates and quantities. The bags are sealed, e.g. glued or hand tucked. The smaller filled bags are placed on pallets and shrink-wrapping applied.

The 1 te bulkabags and pallets are transferred by fork lift truck into standard 20 foot containers for shipment to the market. This is via truck or rail (train loading takes place within this zone, adjacent to the air compressor building).

Starch and gluten can also be transferred directly to bulk trucks (top filling; single or B-Doubles) at a dedicated loadout facility.

A fork lift truck battery charging station is located at the west end of the bulk loadout area and at the south end of the Interim Packing Plant.

Starch Dryers Numbers 3 and 4, Gluten Dryer Number 5 and a Glucose (Gemspray) Dryer are also located in Zone 6. A generic description of dryers is provided in Section 3.2.

The main hazards in Zone 6 are associated with dust, i.e. dust explosions, and losses of containment of LPG (liquefied petroleum gas) and natural gas to the dryers with subsequent ignition.

3.8 Zone 7: DDG Dryers 1, 2 and 3, Stillage Plant and Gluten Dryer Number 7

The Stillage and DDG Plants consists of the following processes that reside in Zones 7 and 8:

Zone 7:

- Decanters (water removal stage)
- Distillers Dried Grain (DDG) dryers 1, 2 and 3.

Zone 8:

- Evaporators
- DDG dryers 4 and 5
- Cooling towers
- Pellet Plant and silos (mill feed and DDG pellets)
- DDG storage and load-out building
- Cogeneration Plant.

Zone 7 Details:

The decanters separate out the unfermented suspended solids (DDG) in stillage, i.e. the waste liquid left over from the distillation of ethanol.

Feed to the decanters contains up to 4% solids. This stream is fed into parallel decanters. The decanters centrifuge the suspended solids and then separate the feed into two streams: a stream containing about 25% solids and a stream containing 4% solids.

The 25% solids stream from the decanters plus syrup from the evaporators (in Zone 8) containing about 40% solids are mixed and conveyed by screw feeders into the DDG dryers for removing moisture. The dried DDG product is fed to the Pellet Plant or DDG storage and load-out building.

The major components of the three DDG dryers are:

- Tube bundle dryer
- Wet scrubber
- Condenser
- Screw conveyors
- Double shaft mixer

- High speed mixer
- Cooling towers.

The dryers rotate at slow speed. A series of baffles on the barrel side progressively moves the semi-dry material from one end of the barrel to the other end where it drops into a chute and is transported by pneumatic conveyors to the Pellet Plant or DDG storage and load-out building.

Heat from the steam tubes within the dryers removes the moisture. The condensed steam is recovered and returned to the condensate system.

Air recirculation is achieved by a fan via a wet scrubber and vertical condenser where the moisture is condensed. The air then returns to the dryer barrel through the fan and a heater. The dryer barrel is open vented on the other end of the barrel and operates at close to the atmospheric pressure. The drying air recirculates in the loop except that a small portion is removed and piped to the boilers' furnaces to destroy any small portion of odorous material that may be present. The portion of drying air removed from the loop is made up by the open vent in the barrel.

The moisture removed from the wet dryer air stream is reused within the process.

A bag filter is placed above the dryer barrel in the air recirculation loop to remove fine dust.

The sludge from the bottom of the wet scrubber is sent to the evaporators (Zone 8).

The DDG from the driers is approximately 90 C. If it is not cooled then there is a risk of fires in the DDG storage area, i.e. from self-heating. Therefore, the DDG is cooled by air prior to being conveyed to storage.

Gluten Dryer Number 7 is also located in Zone 7. A generic description of dryers is provided in Section 3.2.

To the south of the DDG dryers there are also tanks for storing and treating cooling water from the glucose process (no sugars). The pH is corrected prior to discharge.

The main hazards in Zone 7 are associated with the DDG (smouldering fires, i.e. glowing with smoke), dust explosions in Gluten Dryer Number 7 and losses of containment of natural gas to the dryer with subsequent ignition.

3.9 ZONE 8: EVAPORATORS, DDG DRYER NUMBERS 4 AND 5, PELLET PLANT, SILOS, DDG STORAGE AND OUT LOAD, AND COGENERATION PLANT

Evaporators:

The bottoms stream from the beer columns (stillage) in the distillery are pumped to the decanters (Zone 7) and then the 4% solid stream is fed to the evaporators within the stillage recovery area. Large fans provide heat to the evaporators via vapour recompression which then evaporates water from this stream.

The major components of the evaporators include the:

- Evaporator columns
- Separators
- Storage tanks
- Finisher and separator.

The evaporators are designed to further reduce the water content of stillage (after it passes through the decanters). The light phase (4% solids) removed by the decanters plus recycled material provides the feed to the evaporators (approximately 4% combined stream composition). The evaporators increase the solids content in the feed in two stages:

- The first stage increases the solids content from 4% to about 25%
- The second stage (finisher stage) increases the solids content further to about 40%. The two stages are identical in operation.

Each evaporator, which is a vertical cylinder about 4.5 m diameter and 20 m high, includes 2,000 tubes in the bundle. The shell side is warmed by compressed water vapour. Feed drops in the tubes and the heat progressively evaporates the water in the feed.

The bottom part of the evaporator has three weirs which collect the liquid with a higher level of solids but allow the water vapour to pass out. The area across the evaporator is divided into three parts and each part performs identically. Liquid collected in each weir is pumped back into the top of the evaporator into the next part.

The water vapour – air stream taken out from the bottom of the evaporator passes through a separator to remove droplets of condensed water and then it is compressed by a high-speed centrifugal fan to slightly above atmospheric pressure (30 kPag). The compressed water vapour - air returns to the shell side of the evaporator to provide the heat of evaporation.

The suspended and soluble Dried Distiller Grain (DDG) solids from the evaporators are sent to the DDG dryers or combined with bran from the flour mill and processed into DDG pellets.

The liquid from the evaporators is processed to produce water and 'solubles' or syrup. The recovered condensate is sent to the site's WWTP.

There are two storage areas for the dried DDG in Zone 8:

- Two buildings (each equipped with fusible bulb sprinklers)
- A covered (fabric) storage area.

DDG is transferred from the dryers in Zone 7 by pneumatic conveying and received into three hoppers (one for each DDG dryer). Each hopper has a bag filter. Solid DDG is stockpiled within the above-mentioned two storage areas. Two screw feeders transfer the DDG to two bucket elevators for loading into trucks in a shed outside the main storage building wall.

DDG Dryers 4 and 5:

DDG Dryer Number 4 and its associated equipment are located in Zone 8 and include the following:

- The DDG Dryer 4 and its associated equipment are installed within a building (approximately 21.8 m x 16 m floor plan)
- A switchroom on the north side of DDG Dryer 4
- A 2 x 2 m control station adjacent to the switchroom
- A cooling tower adjacent to DDG Dryer 4
- A pneumatic conveying system for the millfeed from the silo located at Gluten Dryer 7
- A pump system for syrup feed from the feed tank located on the evaporator slab
- Conveyors to transfer the DDG product to the Pellet Plant
- A pumping system for transferring process condensate to the WWTP
- Service connections and pipe gantries, i.e.:
    - Steam supply from the boilerhouse
    - Steam condensate return to the boilerhouse
    - Compressed air supply
    - Clean-in-Place chemical (CIP), i.e. caustic soda
- Air leakage and fan extraction of fugitive emissions connection to the site biofilter.

DDG No. 5 dryer is essentially a copy of the DDG4 plant. The following are the process unit operations:

- DDG Dryer No. 5 and associated equipment
- Cooling tower
- A conveying system for millfeed to the dryer
- Mechanical transfer equipment for DDG product to the Pellet Plant
- Equipment for dumping the dryer contents into a skip bin
- A piping system to transfer process condensate to the waste water treatment plant (WWTP)
- Air leakage and fan extraction of fugitive emissions connection to the site's biofilter
- Service connections and pipe gantries include:
  - Steam supply from the boilerhouse
  - Condensate return to the boilerhouse
  - Compressed air
  - Clean-in-Place (CIP) equipment.

The process description for DDG Dryer 4 is detailed below. The general process description applies equally to DDG Dryer 5. The differences are detailed following the DDG Dryer 4 description.

DDG Dryer 4 processes millfeed (wheat bran) and syrup to produce Dried Distillers Grains with Solubles (DDGS) product for the Pelletising Plant.

Millfeed from the flour mills is pneumatically conveyed and stored in a silo located to the south of Gluten Dryer 7. The discharge of this silo allows millfeed to continue feeding (via a common blowline) DDG Dryers 1, 2 and 3. A second blowline is installed to transport millfeed to a cyclone separator and dust collector, located above the DDG Dryer No 4. From the cyclone separator the millfeed is supplied under gravity to a conveying screw where it is mixed with a portion of the dried DDG product in a double shaft mixer.

The other feed ingredient, syrup, is pumped from the dryer feed tank (located at the evaporators) to the double shaft mixer where it is mixed with the millfeed before entering the high-speed mixer for more thorough mixing.

The mixture is then fed to the tube bundle dryer through the feed screw conveyor. In the tube bundle dryer, the mixture of millfeed and syrup is dried using saturated steam before being discharged through a chute into the discharge screw.

Part of the dried product leaves the discharge screw conveyor and is transported, e.g. drag chain conveyor, to the Pellet Plant. A portion of dried product is recycled back to the double shaft mixer through the dosing screw and the conveying screw.

Wet vapour (from evaporating the millfeed and syrup mixture) flows from the dryer into a wet scrubber and then into a condenser. Particulates are removed from the air / vapour stream in the scrubber. The sludge collected at the bottom of the scrubber is intermittently pumped to the decanter feed tank, located at the south-eastern corner of the DDG dyer building.

The vapour from the outlet of the condenser is partially bled to the downstream biofilter. The remaining vapour is reheated in the heat exchanger (by saturated steam) before returning to the tube bundle dryer. The condensate collected in the base of the condenser is sent to the process condensate tank via a condensate pump.

Potential fugitive DDG odour releases from the dryer air intake and mixers are captured and controlled by hoods with fan extraction connected to the site's biofilters.

Utilities for the DDG Dryer 4 include:

- Saturated steam (10 barg) is supplied to the tube bundle dryer from the boilerhouse via a steam station and then through the rotary seal on the tube bundle dryer. The steam condensate is sent to the condensate tank before being returned to the boilerhouse for reuse

- Cooling water is supplied to and from the condenser from a cooling tower located adjacent to DDG Dryer 4

- Process water is required from the site's supply for mechanical cleaning

- Raw water is required in the scrubber, for hosing down purposes and for cooling tower top-up

- Potable water for safety shower and eyewash units

- Compressed air is supplied from the general plant air system and distributed to various equipment and control valves associated with DDG Dryer No 4.

As DDG is prone to self-heating at high temperatures, a steam fire extinguishing system is installed inside the dryer housing. This will be activated automatically (via high temperature detection) or manually. When activated, steam will flow into the dryer housing and hence it eliminates the oxygen and generates an inert atmosphere. Therefore, a fire will be extinguished. This is the same design as the other three dryers.

The main hazards for DDG Dryer 4 are identical to the other three dryers, i.e. DDG smouldering fires, i.e. glowing with smoke, and dust explosions.

The differences between the DDG Dryers 1, 2, 3 and 4, and DDG Dryer 5 are summarised as follows.

Mill Feed System:

The millmix feed (i.e. the DDG) for DDG5 is sourced from two locations:

- Mills B/C blowline A11
- Blowline D11.

The millmix from blowline A11 passes through a baghouse filter and then transferred via a blowline to a silo (New Bran Silo). The blowline includes an air blower complete with instrumented protection (e.g. high pressure trip) and a discharge pressure relief valve. This blowline is approximately 200 m long and designed for 18 tph of millmix flow.

The transferred millmix enters the New Bran Silo which has a capacity of 40 te. The air from the feed blowline is filtered via a baghouse filter prior to passing to atmosphere. This silo can also receive feed from the Pellet Plant via drag chain conveyors (this is a manually controlled operation).

Millmix flowrate from the New Bran Silo and the associated baghouse filter is controlled prior to entering two identical blowlines; one for DDG4 and the other for DDG5. Millmix from blowline D11 can also be fed into these blowlines. The two blowlines convey the millmix into identical baghouse filters for drying in DDG4 and DDG5.

These operations are at ambient temperatures and close to ambient pressures.

DDG Cooling:

The dried DDG from the DDG Dryer 5 is relatively hot, i.e. at least 90C. This can cause heat damage to downstream equipment. Therefore, the dried DDG is cooled before transferring to the Pellet Plant.

The dried DDG is conveyed via a vertical drag chain conveyor to the Geelen Cooler (as per the existing DDG4 design). The Geelen Cooler uses air to cool the product DGG in a counter-current flow design. The DDG is batched from an upper level in the cooler to the lower level using louvres. Once cooled, the DGG leaves via the bottom of the cooler (again using louvres). The cooled DDG is then conveyed (drag chain conveyor and bucket elevator) and feed into the transfer system to the Pellet Plant.

Exhaust air from the cooler is filtered (using a baghouse filter) and then discharge to atmosphere.

Proposed Modifications to DDG Dryers 4 and 5

This element of the Project will reduce emissions by 12,702 te/year CO2 when it is completed in February 2026 by reducing the amount of steam required by 10 tph.

The Project will install a heat recovery system into the DDG dryers 4 and 5 which will transfer heat from the hot dryer discharge gasses to process water (via a heat exchanger).

This heated process water will provide some of the air heating requirements to selected, existing gluten and starch dryers.

This proposed Project has a similar "back end" to what has been implemented for the current dryers SD5, GD6 and GD7. That is, the preheating of the incoming dryer air stream by hot water that is generated in the DDG area.

A more detailed process description is as follows.

The DDG heat recovery system will be designed to recover waste heat from DDG dryers DDG5 and DDG4 using a recirculated, pumped hot process water circuit. Recovered waste heat in the process water will then be used to preheat air by circulating the hot water through air heating coils in the GD8, Cationic Starch and RD9 dyer units with future extension of waste heat recovery to SD3 and SD4 an option.

Recovery of Waste Heat from DDG5:

Waste heat in the hot humid vapour (92 C) flowing from the existing DDG5 wet scrubber to the existing condenser is to be recovered via a plate heat exchanger. The heat will be transferred to a recirculated process water stream. The DDG5 vapours are to be drawn through the recovery heat exchanger using a booster fan (3 kPag discharge pressure) which returns the cooled vapour to the DDG5 condenser inlet.

Liquid condensed in recovery heat exchanger is to be separated in the fan inlet separator with the condensed liquid sent to the DDG5 waste tank by condensate pumps where it will be combined with other liquid streams and pumped to waste.

Flash steam from the DDG5 steam condensate tank will also be directed to the recovery heat exchanger for additional heat recovery.

Hot water will be recirculated through the recovery heat exchanger by hot water recirculation pumps. Hot water will also be supplied to DDG4 heat recovery and provision has been made to supply hot water to a future DDG dryer unit DDG6.

Recovery of Waste Heat from DDG4:

The DDG4 heat recovery system will operate in an identical manner to the DDG5 system with waste heat recovered from the DDG4 wet scrubber outlet stream and condensate tank flash steam outlets. DDG4 will not have hot water recirculation pumps as the DDG5 hot water recirculation pumps will be used for both dryers.

Supply of Waste Heat to the GD8 Air Heater:

Hot water heated by the DDG5 and DDG4 recovery heat exchangers is to be supplied to GD8 through piping. Hot water is to be supplied to the GD8 air heating coil and returned to DDG5 and DDG4 for heat recovery.

A hot water bypass line at GD8 enables hot water to be recirculated through the hot water circuit if the GD8 air heater is isolated / not available for heat recovery.

Supply of Waste Heat to Cationic and RD9 (Ring Dryer) Air Heaters:

Hot water is supplied to Cationic Starch and RD9 air heaters in a similar fashion as GD8 via supply and return branch lines connected to the GD8 supply.

Hot Water Expansion Pot:

A hot water expansion pot is to be located at an elevated location on the south side of GD8. The expansion pot is to be connected to the hot water return line and provides expansion volume for the recirculated hot water system due to system temperature changes (e.g. from ambient to normal operation, heat recovery load changes during operation and from operation to shutdown).

Cogen Blowdown Cooling:

A Cogen Plant blowdown cooler is to be provided to cool the Cogen blowdown and recover waste heat prior to the blowdown being sent to the waste tank. Recirculated hot water is to be supplied to a heat exchanger to cool the hot blowdown stream.

Blowdown cooling also assists to reduce the temperature of the combined waste water sent to the Shoalhaven Starches WWTP for treatment.

CIP System:

DDG vapours contain small quantities of volatile organic compounds which condense when vapours are cooled and tend to form waxy deposits on surfaces. Over time, these deposits build-up and form fouling deposits which require cleaning / removal.

The DDG5 and DDG4 heat recovery systems are to be new with no similar systems operating on site and consequently the degree and speed of potential fouling is not yet known. Because the recovery heat exchangers will operate at a relatively high temperature (around 80°C) compared to the DDG condensers which operate at about 40°C, it is possible that fouling may be slower and less severe in the recovery heat exchangers than currently seen in the condensers.

To enable the recovery heat exchangers to be easily cleaned so that efficient heat recovery can be maintained, a dedicated CIP system is to be provided to periodically clean the vapour sides of the DDG5 and DDG4 recovery heat exchangers. The CIP tank and supply pump are located near to the DDG4 heat recovery system.

CIP of the vapour sides of the recovery heat exchangers will consist of several stages: initial hot flush, hot caustic wash and final rinse.

The CIP tank is to be located in a contained area. The tank is to be fabricated using 304L stainless steel with a nominal capacity of 8 m^3. Any spills can be neutralised and/or sent to the Shoalhaven Starches WWTP for treatment.

All pressure vessels associated with the heat recovery modifications are to be compliant with recognised standards, e.g. ASME (American Society of Mechanical Engineers) Section VIII.

The existing fire sprinkler layout designs are to be revised inside DDG4 and 5 as there will be new platforms being installed to access shut off valves.

All materials in contact with the process materials will be stainless steel.

The heat recovery processes will be controlled via the existing site-wide control system.

Given that this proposed modification involves a wet air stream and water then there are no new fire, explosion or toxicity hazards with the potential for off-site impact. As stated above, the CIP tank and equipment is to be within a contained area with any spills neutralised and/or disposed of via the Shoalhaven Starches WWTP. Correspondingly, no further hazard analysis of this modification is performed in this report.

Pellet Plant:

The Pellet Plant takes waste solids from the main processes on site, adds raw materials for product quality purposes, and produces pellets that are used as livestock feed.

The feeds to the Pellet Plant are as follows:

- Syrup. This is a dark brown soluble liquid fraction that remains after grains have been fermented in the process of producing ethanol in combination with yeasts and enzymes
- Millfeed pellets. This is primarily wheat husks in pellet form. The pellet size is approximately 5 to 6 mm (cylinder shape)
- Barley. This is grain barley, i.e. direct from the fields
- Limestone. This is in solid form and grit sized (approximately 1.1 mm maximum particle size)
- Calcium propionate. This material is used for mould control. It is in solid form

- Premix. If used, they are additives to the pellets. They would be in powder form.

The syrup and millfeed pellets are mixed in the upstream DDG dryers. The product from the dryers is DDGS (dried distillers grain solids). The remaining above-mentioned materials are added to the DDGS to produce the desired pellet composition. The combined stream is mixed and then pelletised to produce the required product.

The process is characteristic of a materials storage and handling process. With the exception of the syrup, all the feeds and product pellets are in solid form. These are stored in silos and bins.

Millfeed pellets are brought in via rail and stored in large 1,300 te silos located to the east of the site. They are finely ground and transported to the DDGS plant (a distance of approximately 200 m). Additionally, the flour mills produce loose millfeed which is also transported to the DDGS plant as well.

All the ground millfeed is mixed with the syrup and dried in dryers. Subsequently, they are transported to the Pellet Plant. On entering the Pellet Plant, the DDGS is stored in smaller bins for feeding the batch mixer via drag chain conveyors and bucket elevators.

The barley is brought in via trucks and tipped into an intake pit and stored in a 1,300 te silo at the Pellet Plant. The barley is transported via drag chain conveyors and bucket elevators to a grinding stage. From the bucket elevator, the barley passes through a cleaner, feeder, a screw conveyor and slide gates to the barley grinding bins. Slide gates and screw conveyors under the barley grinding bins control the flow through the hoppers to a roller grinding mill.

The barley is milled to approximately 2 mm particle size. A destoner and magnetic separator (for tramp metal) are installed prior to the mill to prevent these types of foreign objects from entering and hence being a source of ignition.

After milling, the barley passes through a vibratory sieve. The oversize is returned for further milling. The ground product is then stored in the feed dosing bins for feeding the batch mixer.

All dry raw materials are then fed to the batch mixer from the dosing bins via screw conveyors. The batch mixer is a paddle type mixer. The mixed product is then transported via bucket elevators to the presses feed bins.

From these bins, the mixed products are pressed through a die to form the product 5 to 6 mm pellets. Steam is used for heating the presses.

The pellets are then cooled by air in the product coolers to approximately 45^{o}C and then conveyed by drag chain conveyors and bucket elevators through sifters to the product silos or DDG storage shed. Product pellets can be stored within these silos or fed directly to the loadout area where product is loaded to containers or trucks. There is a container inverter within this area for filling the 20 foot containers (lifts the 20 foot containers vertically so they can be filled from the top end). The product pellets are delivered to the market via trucks and trains (the pellets are in shipping containers for the latter).

The DDG storage shed contains an automatic sprinkler system. The loadout bay has an automatic sprinkler system. Located on top of the storage shed are dust collectors for the loadout operations and shed. These have explosion venting protection and built-in fire sprinkler systems.

Other equipment and processes within Zone 8 are:

- Container storage and preparation. This includes storage of full containers of packed starch and gluten, loose DDG and DDG pellets as well as an area where plastic liners are placed inside containers prior to filling
- Cooling tower (fibreglass construction)
- Transformers
- Diesel storage tank
- Biofilters for odour control
- Sodium hypochlorite storage.

The main hazards in Zone 8 are smouldering fires involving grain, DDG and pellets.

Cogeneration Plant Description:

The Cogeneration (Cogen) Plant at the Shoalhaven Starches facility is a continuous process based on two natural gas fired turbines; each coupled to a generator capable of generating up to 27MW of power each at 11kV. The power is connected to the site's main substation for distribution through the electrical distribution network.

The exhaust gases from the turbines are ducted into two heat recovery steam generators (HRSG) which capture the waste heat from the exhaust in conjunction with co-firing of natural gas to produce up to 110 te/hr of saturated steam per HRSG at 1,100 kPag.

Each HRSG has a stack for emission of the combined exhaust gases from the turbine and HRSG.

Natural Gas Supply:

Natural gas is supplied to the Cogeneration Plant at 4,000 kPag for combustion in the turbines. The gas is further reduced to 500 kPag for supply to the co-firing of the HRSGs. Under maximum output conditions, natural gas consumption is 12,293 kg/hr for the turbines and 5,455 kg/hr for the HRSGs.

Steam Supply:

Steam is supplied from the Cogeneration Plant at 1,100 kPag and is transported via a pipebridge to the site boiler house for distribution through the steam network. The Cogeneration Plant has a total steam capacity of 210 te/hr.

Steam is also supplied to the Cogeneration Plant via the same headers. This allows for faster HRSG start-up time by pre-heating the deaerators. The heating steam flow rate is 10 te/hr.

Condensate:

Condensate is returned from the various process plants via the Boilerhouse and the pipebridge at 100 C. This condensate provides 70% of the water requirements for the operation of the HRSGs.

Condensate is transferred from the site collection system into a 220 kL storage tank at 150 m^3/hr.

From the storage tank, the condensate is then transferred into the HRSG deaerators at a maximum flowrate of 150 m^3/hr.

Make-up Water:

Make-up water is generated at the Boilerhouse Reverse Osmosis Plant and supplied to the Cogeneration Plant via a pipebridge. It provides the remaining 30% of the HRSG water feed.

Make-up water is transferred from the Boilerhouse Reverse Osmosis Plant into a 220 kL storage tank at 120m^3/hr.

From the storage tank, the make-up water is then transferred into the HRSG deaerators at a maximum flowrate of 150 m^3/hr. These supply lines are dosed with sodium hydroxide (caustic soda) in order to ensure the supply water pH is above 8. The make-up water temperature is ambient.

The make-up water is preheated prior to supply to the deaerators through economisers in the HRSG exhaust.

Cooling Water System:

The Cogeneration Plant has a cooling water system to provide cooling to the following:

- Gas turbine lubrication oil system
- Generator lubrication oil system
- Steam sampling system.

There are two cooling towers outside the building which cool water to approximately ambient temperature. There are four cooling water pumps (two duty, two standby) which pump cooling water to the above three users within the Cogeneration Plant at combined flow rate of 85 m^3/hr. The system operates with a supply temperature of 20 C and a return temperature of 45 C.

Chemical Supply – HRSG Boiler:

There are four chemicals added to the HRSG boiler to maintain operation and prevent corrosion of the boiler and steam system. These are stored in IBC cabinets and dosed at very low flow rates (<5L/hr) directly into the HRSG deaerator and boiler.

Electricity Supply:

Power is supplied from the Cogeneration Plant at 11kV and is reticulated via cabling on the pipebridge to the main substation for distribution through the existing electricity network. The Cogeneration Plant has a total capacity of 54MW.

Electricity Supply – Synchronization:

The generators are connected in parallel with the external electricity supply network. To prevent a catastrophic failure of the electrical infrastructure, the generators must be "in phase" with the network prior to connection in a process known as synchronization. The generator control system adjusts the throttle of the turbine to correct the frequency and phase of the generator and adjusts the excitation voltage of the generator to correct the voltage output, such that these values correspond with the external supply. Prior to the closing of a critical circuit breaker, a "check sync" protection relay on the circuit breaker compares the frequency and phase across the circuit breaker to allow closing of the circuit breaker.

Electricity Supply – Reverse Power Control:

To prevent the export of power from the Shoalhaven Starches Cogeneration Plant, a control scheme is provided to reduce the output of the turbines if reverse power is detected.

Automatic Control:

Automatic control of the Cogeneration Plant is via a vendor supplied control system comprising Woodward Micronet+ controllers and RX3i sequencers. Turbine combustion control is achieved by modulation of an electronically controlled fuel metering valve that adjusts the fuel supply to the turbine. The fuel is mixed with the air flowing through the turbine before ignition in the combustor section. The Micronet+ controller monitors the combustion process for abnormal conditions and initiates pre-determined control actions including trip of the turbine.

Modes of Operation:

Both Cogeneration Plants can operate independently.

Each Cogeneration Plant is started by starting the gas turbine. Air and natural gas are fed into the gas turbine combustion chamber while the turbine is force-rotated using a hydraulic start motor. As the turbine rotates and combustion occurs, the turbine will begin to rotate independently and the hydraulic start motor is disabled. The gas turbine then continues to rotate and the generator is enabled converting the rotation of the gas turbine into electricity.

The exhaust gas from the turbine is then directed into the bypass stack by a swing gate “diverter” and exhaust flow into the HRSG is prevented by a guillotine valve.

Prior to the HRSG starting, air is forced through the HRSG combustion chamber to remove any remaining gases. The guillotine valve and diverter are then opened to the HRSG combustion chamber allowing hot gases to flow through. Gas is then fed into the HRSG burners and they are ignited. The HRSG can then operate and generate steam from the heat of the exhaust gases. If additional steam output is required, additional natural gas can be fed to the HRSG burners to be combusted.

The bulk chemical storage for the Cogeneration Plant is summarised in the following table. None of these chemicals are flammable or combustible.

Table 4 – Cogen Plant Bulk Chemicals

Material	Location	DG Rating	Storage Amount
Nitrogen	Western end of building (inside)	Class 2.2	336 kg (8 x 42 kg)
Carbon Dioxide	Inside the building at the gas turbines	Class 2.2	363 kg (8 x 45.4 kg)
Sodium Bisulfate	External process area (bunded)	Class 8	1,000 L self-bunded IBC
Caustic/Sodium Hydroxide 10%	External process area (bunded)	Class 8	1,000 L self-bunded IBC
Corrosion Inhibitor (amine)	Inside building	Class 8	2 x 1,000 L self-bunded IBC
Defoamer	Inside building	None	2 x 1,000 L self-bunded IBC
Deposit Inhibitor	Inside building	Class 8	2 x 1,000 L self-bunded IBC

Nitric Acid Tank:

The stillage evaporators use nitric acid and caustic (sodium hydroxide) for CIP (clean-in-place). Additional nitric acid storage is required. This is to be located in Zone 8.

Nitric acid at 68 wt% will be delivered to site via a road tanker and it will be parked adjacent to the nitric acid bulk storage facility. The frequency of deliveries is expected to be two times per month. The delivery and storage facility are to be bunded, therefore, any spills / stormwater will be captured and disposed of manually with sump pumps.

The new nitric acid tank will be 20 m^3 and constructed from 316 stainless steel. It will be an atmospheric pressure and temperature storage tank. The tank's vent will be connected to a scrubber to prevent local acidic vapour emissions. The scrubber will continually recirculate with raw water until a set conductivity value / nitric acid concentration is reached, then is disposed of via the WWTP.

The nitric acid system is to be designed, operated and maintained to AS3780. The nitric acid is pumped to the stillage CIP tank on demand for CIP purposes. Following CIP, waste nitric acid is disposed of via the WWTP.

The main hazards in Zone 8 are associated with the Cogeneration Plant, i.e. due to releases of natural gas igniting, confined explosions involving natural gas and oil fires.

3.10 Zone 9: Starch Dryer Number 5, Specialties Products Building (including Ring Dryer 9) and Gluten Dryer 8

Starch Dryer Number 5, the cationic starch process, Ring Dryer 9 (the latter two being within the Specialties Products Building) and Gluten Dryer 8 are located in Zone 9. A generic description of dryers is provided in Section 3.2.

Cationic Starch Process:

Some of the product starch from Starch Dryer 5 (SD5) is transferred to the Specialty Products Building. This starch is converted to cationic starch to meet market demands.

The SD5 product starch is transferred to the process via a hopper and conveyor to Silo 20. If required, starch can be returned from Silo 20 to SD5 or sent to the process' packing operation. Otherwise, it is converted to cationic starch in the process as follows.

Starch from Silo 20 is transferred via hoppers, a conveyor and a weigher to a mixer. Other raw materials added to the mixer include the cationic reagent, caustic soda or hydrochloric acid (depending on the modified starch grade) and water. If required, a flow agent is added to the mixed product at the outlet of the mixer.

The mixed product is then heated using 10 barg steam and conveyed into one of four reactor silos. Once the reaction within the silo is complete, the mixed product is then transferred via a conveyor, hopper and weigher to a second mixer where the pH is adjusted as required. The pH corrected product is then feed into a dryer.

The dryer design is similar to the other dryers at the site. A generic description of dryers is provided in Section 3.2. Air is drawn through the dryer using an induced-draught fan. The air is filtered and then heated using hot water, hot condensate, steam and combusted natural gas. The natural gas burner is compliant with the relevant standards, e.g. AS3814.

The hot air and the reacted starch are mixed and carried through the dryer where the water content of the starch decreases. The product modified starch is removed from the air stream using a cyclone and a bag filter. The exhaust gas from the induced-draught fan is vented to atmosphere.

The dried modified starch is stored in a hopper and then transferred via a conveyor to a grinder. The ground modified starch is then stored in a silo and subsequently processed in a sifter. The oversized material (only small quantities are expected) is processed on site. The sifted modified starch is then conveyed, via a magnetic separator, to a chute for filling 1 te bulkabags.

Dust control from various equipment items, e.g. the sifters, is achieved via an aspiration system including an induced-draught fan, a bag filter and ducting. The starch collected in the bag filter is sent to the final product silos.

The caustic soda, hydrochloric acid and cationic reagent are stored within dedicated atmospheric tanks. A hazardous materials transfer bay and storage bunds are constructed for storage of these products. These raw materials are pumped and flow controlled into the process. The tanks are located in separate bunded areas. All rainwater and potential spills are disposed of via the existing Manildra waste water treatment plant as per the current site practice for all plant areas.

Fumes within the building are minimised via an induced-draught fan that draws air containing mists such as hydrochloric acid through a scrubber. The waste water from the scrubber is also pumped to the waste water treatment plant.

GD8 Wet End:

Flour is transferred from the existing flour storage systems to a silo in the GD8 building. The flour is transferred via a 300 m long blowline. The silo is fitted with a top-mounted bag filter as per standard designs.

The flour, water and possibly enzymes are mixed within a dough mixer. The wet dough is then transferred to a tricanter. This machine separates the wet feed into wet starch, wet gluten and waste/pentosans (polysaccharides) which are sent to the ethanol plant for processing.

From this point in the process there are two identical processing trains. This allows maintenance and cleaning to be performed on one process train whilst the other remains in operation.

The wet gluten from the tricanter is screened (multiple screens are used, i.e. Contrashears, Bent Screens and centrifugal sieves). The screened wet gluten flows to the GD8 dry end whilst the waste liquid from the screening stage is also sent to the ethanol plant for processing.

The wet starch is also separated from water using screens and cyclones. The collected water is recycled within the process. The wet starch is processed via the existing starch plant and equipment on site.

The wet process streams are routinely cleaned using Clean-In-Place (CIP) processes as well as water washing. This involves dilute caustic soda (3 to 5%).

GD8 Dryer:

The wet gluten flows to the wet gluten hopper and then a screw press. Free moisture drains from the screen sides and base of the hopper. A conical screw squeezes and extrudes the gluten before discharging into the gluten feed hopper.

De-watered gluten is then pumped (via a progressive cavity positive displacement type pump) at constant rate into the disintegrator through a fishtail feeder, which extrudes a thin sheet of material over the full disintegrator width and feeds it into a re-circulating stream of hot air and dry powder. The wet material is dispersed and coated with dry powder before being dried and transported around the ring duct by the drying air.

The dryer air is drawn through filters to remove foreign objects. It is heated by hot condensate, steam (10 barg) and then a gas fired burner (to approximately 185°C).

At the dryer manifold, an adjustable blade allows a predetermined fraction of circulating material to be selectively removed from the system, whilst oversize and semi-dried material is returned to the disintegrator. The disintegrator is a fixed beater impact mill, which breaks down agglomerates and disperses the circulating mass into the drying airstream. This combination of manifold and disintegrator gives screen-less grinding and even moisture distribution to the product.

Gluten is then separated from the exhaust air stream in a reverse jet baghouse filter, complete with a pre-separator section, which ensures that material is quickly removed from the hot airstream when it is dry (to minimise thermal degradation).

Dried material is discharged through a system of screw conveyors and rotary valves, allowing control of the recycle of coarse material from the pre-separator and fine material from the baghouse filter, or a combination of the two, with the remainder being discharged as final product to the milling system.

An induced draught fan at the baghouse filter outlet draws process air and gluten through the drying system and maintains circulation within the ring duct. The air flows to atmosphere via a stack.

Product gluten from the dust collector is fed to the milling system via a bin and variable speed screw discharge (designed to eliminate surges and maintain a constant feed rate). The product gluten is passed over a magnet to remove ferrous material and transferred to the classifier mill by an induced draught pneumatic conveyor (using filtered ambient air).

The aspirated grinding mill incorporates an internal classifying wheel with independent drive. Through varying the speed of this wheel, oversize particles are deflected back into the mill for further grinding. Milled product is then transported to the final collection within a second pneumatic conveyor.

Finished product gluten is separated from the mill exhaust by a dedicated reverse jet baghouse filter and discharged by a rotary valve.

The ground product is then conveyed via a blowline to the existing packaging area. The product is either stored in a buffer bin or sent to truck loadout.

The product gluten is transferred to the packaging plant for export to the market.

Any spills and material captured inside the plant (e.g. washdown and emptying of equipment for maintenance) are collected via a sump system and pumped to the Manildra Waste Water Treatment Plant.

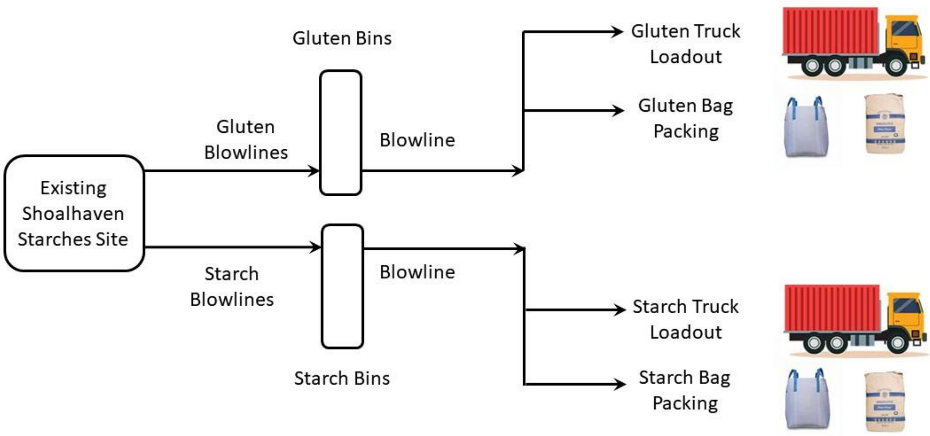
The main hazards in Zone 9 are associated with dust explosions in Starch Dryer Number 5, the cationic starch process, Dryer 9 and GD8, and losses of containment of natural gas to the dryers with subsequent ignition.

3.11 ZONES 10 AND 11: NORTH PACKING PLANT AND THE NATURAL GAS PRESSURE REDUCTION FACILITY

North Packing Plant:

The north Packing Plant and its associated container loading facilities are built on an undeveloped property owned by the Manildra Group of Companies on the northern side of Bolong Road. The process is shown in the following block flow schematic.

Figure 4 – Packing Plant Process Schematic



The facility includes:

- Transfer blowlines (x5) from the existing site on the southern side of Bolong Road
- Pipes under Bolong Road
- The packing plant facilities for filling bags and trucks
- A warehouse for bag storage
- A rail extension for loading containers onto trains (250 m long).

The building has dimensions of approximately 108 metres by 60 metres, and a height of approximately 34 metres above ground level.

There are also 11 product storage silos (300 and 150 tonnes) located to the east of the Packing Plant building.

In addition to the above, there is a container / truck loading facility between the Packing Plant and the silos. Three railway spur lines are also included to service this container loading area. The containers are stored to the south of the Packing Plant building.

The dried product is pneumatically conveyed from the existing site to the silos via an underground pipe crossing for Bolong Road and once on the North Packing site, travel a short distance above ground and then under the container yard to the silos / building. The silos provide feed to the Packing Plant and container loading facility.

The packaged product is filled into 1 tonne or 25 kg bags at dedicated bag filling stations (including feed bins). The 1 tonne bag filling stations are designed for approximately 40 tonnes per hour filling rate. The bags are then loaded into containers for distribution to the market.

The Packing Plant is built to avoid dust emissions as product is not blown into bags but rather mechanically packed.

The packing building is designed to meet good practice for food safety and housekeeping / cleanliness. The steel work has been designed to prevent ledges for product to settle on (i.e. reducing the risk of dust explosions).

The bags are stored in a warehouse (concrete and steel construction). Starch and gluten can be delivered to the market via road or rail, e.g. using bulk trucks, or bags in containers or on trucks. At this point on the rail system the train is moving at walking pace, i.e. process safety incidents involving the train are unlikely. The Packing Plant is designed for 2,400 ton per day of product. All equipment in contact with the product is constructed from 304L or equivalent stainless steel. All equipment handling potentially explosive dust is designed to ATEX and/or NFPA (US National Fire Protection Association) standards. This includes rotary valves for seals, explosion vents, equipment earthing and hazardous area zoning with the electrics and instruments to suit the requirements.

MOD26: Shoalhaven Starches currently have approval for the construction of 20 finished product silos to be situated within the Northern Packing Plant site presently under construction on the northern side of Bolong Road (MOD21).

Shoalhaven Starches now propose, on an interim short-term basis, to construct up to 19 finished product silos (starch and gluten) on the main factory site instead of in conjunction with the Northern Packing Plant site.

The rationale for these works is the current silo configuration and pneumatic transfer system at the factory site will require four product transfers to transfer product to the Northern Packing Plant site. Each pneumatic transfer is powered by electricity and results in moisture loss in the product.

Relocating the finished proposed product silos and associated transfer system to the factory site, as proposed under this Modification Proposal, will require only two transfers to the Northern Packing Plant site. This will result in electricity savings (estimated in the order of 4,200 MWh savings per annum.) and less moisture loss in the finished product.

The product will transfer from the proposed factory silos directly into the Northern Packing Plant Feed Bins located within the Northern Packing Plant building. It is anticipated that the current approved silos within the Northern Packing Plant site will be constructed as a longer-term project when Shoalhaven Starches explore increased production from their overall operations in the future.

The relocated finished product silos will be housed within a building that will have a footprint of 29.4 metres by 17 metres, and an overall height above ground level of 44.56 metres. Fourteen of the silos will be 2.2 m diameter whilst the other five will be 5 m diameter.

The Finished Product Silo building will be connected to the existing factory across the internal rail spur line by two pipe bridges.

The above proposed silo designs already exist at the Shoalhaven Starches site for some of the existing plants and the typical controls are shown in Appendix B. The corresponding risks, i.e. dust explosions, are generally acceptable. The design details for these silos, e.g. the silos' design pressure and explosion vents, are not currently available. Therefore, the modelling of potential dust explosions is to be performed once these design details are known (see the recommendations in this report).

Gas Pressure Reduction Facility (GPRF):

The GPRF reduces natural gas pressure from up to 15,000 kPa to two operating pressures, i.e.:

- 4,000 kPa for supply to the Cogeneration Plant
- 210 kPa as required by other Shoalhaven Starches operations. This is the standard natural gas supply pressure to the users throughout the site.

The natural gas supply pipeline contains the following main features:

- Flow measurement at the tie-in point to the Eastern Gas Pipeline
- The pipeline is primarily underground, i.e. approximately 5 km. This section of the pipe includes pig traps for routine maintenance
- At the Manildra site, the gas is filtered, monitored for flow and then heated in a water-bath heater. This is to avoid generating low temperatures when the gas pressure is reduced
- The gas pressure is then reduced to approximately 4,000 kPa, i.e. this is the main Gas Pressure Reduction Facility. This includes redundant pressure regulators and an actuated emergency isolation valve. There is a pressure safety valve downstream in case the valves pass when closed
- The gas is then split into two streams:

- One stream flows at 4,000 kPa to the Cogeneration Plant
- The other stream has its pressure reduced to 210 kPa in a similar pressure reduction facility to that described above. This pipe supplies natural gas to the boilers and dryers.

The design maximum gas flow is 45 TJ/day. The diameter of the underground pipe is 300 mm.

The main hazards in Zones 10 and 11 are associated with dust explosions at the North Packing Plant, and losses of containment of natural gas from the supply pipeline or GPRF with subsequent ignition.

3.12 Zone 13: The Former Dairy Farmers Factory

Manildra has bought the adjacent land and facilities that were previously used by Dairy Farmers. Spare equipment is stored at this location. Also, some finished product, i.e. packed starch and gluten, in 50 kg and 1 te bulkabags are stored in some of the buildings. The packaged products are moved via fork lift trucks and flat-top trucks.

Argyle Meats (a meat processing facility; not an abattoir) was also located in this zone. The meat processing plant is no longer operational. Manildra also own this land. This is now the maintenance facility.

MOD26 Proposed Modifications

Shoalhaven Starches propose the following modifications at the Bomaderry site:

- Installation of three wheat silos to the west of the former Dairy Farmers factory building
- Construct a train and truck unloading facility to the south of the former Dairy Farmers factory building. Wheat that is brought to the site will be loaded into this facility and then delivered to the three silos by conveyors
- Installation of services and grain conveyor gantry. The stored grain will be transferred from the bottom of the silos over the rail line and then transferred by conveyor along the southern boundary of the site to be used in the existing Shoalhaven Starches factory operations located further to the west, i.e. the flour mills.

The following provides a description of these changes.

It is proposed to construct a train and truck unloading facility to the west of the former Dairy Farmers factory building. Wheat that is brought to the site will be unloaded into this facility, e.g. by opening doors on the industry-standard train wagons. The wheat will then be transferred to the storage silos by conveyors.

The unloading facility will have the capacity to unload 1,500 tonnes per hour enabling Shoalhaven Starches to unload a train in approximately three hours.

The transfer system from the underground intake pit to the silos will involve drag chain conveyors (in the underground pit with a chain speed of 0.75 m/s), belt conveyors and a bucket elevator (belt speed of 3.7 m/s and 36 m high). The conveyors will include underspeed protection. The belts will be made from FRAS (fire resistant anti-static) material to lower the risk of a belt fire. The belt conveyors will be motor driven (typical motor size of 37 kW). The bucket elevator materials of construction will include urethane, HDPE (high density polyethylene) and/or ceramics to lower the risk of ignition due to static sparks from metal-to-metal contact.

The proposal includes an additional three wheat silos to the west of the former Dairy Farmers factory building. These silos will each have an overall height above ground level of 32 metres, diameter 23.683 metres and a volume of 11,577.3 m^3. This corresponds to a wheat capacity of 9,000 te. This storage quantity provides a one-week buffer for transport issues that could delay wheat being brought to the site.

The silos will be externally stiffened (i.e. three external stiffeners per side wall sheet), constructed from galvanised steel and have 30 degrees sloping rooves. The silos will be fitted with dust collectors as per the existing wheat silos at the site. The dust collectors' socks will be routinely pulsed with compressed air to avoid material build-up and potentially sock failure. There will be internal sweep augers to ensure that wheat is emptied uniformly from each silo.

The stored grain will then be transferred from the bottom of the silos to the existing flour mills at the site via a series of belt conveyors and a bucket elevator (belt speed of 2.7 m/s and 10 m high). The belt conveyors will travel over the rail line and then along the southern boundary of the site to the existing flour mills. The outloading capacity to the existing plant will be 300 te per hour. The bucket elevator will be fitted with explosion vents.

The outloading conveyor belts will also be made from FRAS material and be motor driven (typical motor size of up to 30 kW).

The new conveyors will transfer the wheat to the base of an existing bucket elevator at the site for transfer to the flour mills.

The second last belt conveyor will be fitted with a belt weigher to allow the operators to control the quantity of wheat being transferred.

If any grain is spilt then it will be collected manually or by a front-end loader and returned to the system via the rail intake hopper.

The above proposed equipment items already exist at the Shoalhaven Starches site for some of the existing plants and the typical controls are shown in Appendix B. The corresponding risks, i.e. dust explosions, are generally acceptable. The design details for these equipment items, e.g. the silos' design pressure, are not currently available. Therefore, the modelling of potential dust explosions is to be performed once these design details are known (see the recommendations in this report).

3.13 WASTE WATER TREATMENT PLANT

All waste water from the Shoalhaven Starches processing areas flow to the waste water treatment plant (WWTP) which is located on the Shoalhaven Starches farm on the north side of Bolong Road.

The waste water contains organic material that is removed by biological processes.

Anaerobic digestion (or fermentation in the absence of oxygen) of organic matter is carried out by a special, mixed group of anaerobic microorganisms (bacteria). During anaerobic treatment, these microorganisms utilise the organic matter contained in the waste waters as a source of food and energy. As a result, the microorganisms essentially convert organic matter to biogas containing methane (65%). This biogas is used as an energy source for the Shoalhaven Starches operations. The existing waste water treatment plant produces in the order of 1,700 GJ/day of biogas which is supplied to power (in part) the existing gas fired boilers at the factory site. Excess biogas can be combusted in a flare at the WWTP.

The waste water initially enters a BVF (bulk volume fermenter). Digestion takes place within this area and hence biogas (containing methane) is produced. The biogas is collected under a cover and then drawn from the BVF by blowers. The fans that supply the biogas to the boilers operate in a range of 30-120 kPag.

The waste water flows from the BVF to the MBRs (membrane bioreactors) for further purification. Excess water from the BVF that cannot be treated through the MBR goes into the Sulphur Oxidation (SO) pond and then to the irrigation system . MBR permeate is pumped through a reverse osmosis (RO) unit with the purified water being returned to site and the surplus treated water is mixed with excess BVF water and sent to the irrigation system.

The dosing and auxiliary chemicals include sodium hypochlorite, aqueous ammonia (23 wt%), magnesium hydroxide, ferric chloride, sodium hydroxide (caustic), citric acid, sodium bisulphite, sulphuric acid and anti-scalant. LPG is also stored and used for operation of the biogas flare.

The main hazards at the existing WWTP are associated with losses of containment of biogas and LPG with subsequent ignition.

Proposed WWTP Modifications

The existing waste water treatment process treats an average of 10 ML/day of which 6.5 ML/day is treated to a standard that allows it to be recovered for re-use in the factory processes.

Wastewater flows have increased recently in proportion to flour processing at the site. Additional WWTP capacity is therefore required to accommodate these increased wastewater flows.

The existing biogas fans that supply the biogas to the boilers operate up to 120 kPag. It is envisaged that under the proposed modifications to the WWTP biogas production will increase from the current 3,500 m^3/hr to 5,000 m^3/hr. This increase in biogas production would be equivalent to a reduction in 10% of the site's natural gas usage.

The proposed additional MBR and RO systems, as well as the BVF (Bulk Volume Fermenter), are duplicates of the existing systems. All these new systems will run in parallel to the existing and have interconnections in between each operation.

The proposed WWTP modifications will involve the following components:

- One in-ground treated effluent storage pond with a capacity of 150 ML adjacent and to the east of the existing SO Basin and BVF Reactor (Anaerobic Digestor). This additional treated wastewater storage is required to compensate for the loss of storage as a result of the conversion of Ponds 1, 2 and 3 that is detailed below

- Convert the existing Wet Weather Storage Ponds No. 1, 2 and 3, situated to the north of the approved SO Basin, into another Anaerobic Digestor with a volume of approximately 80 ML. This pond will also be covered with a gas tight floating cover and utilise the same anaerobic digestor process that is presently used on the site, i.e. it will operate as a Bulk Volume Fermenter (BVF). Infrastructure within the pond and under the pond cover will facilitate the action of anaerobic micro-organisms responsible for the digestion of the soluble and suspended organic matter. Metabolism of organic matter will generate the biogas

- Install an above ground enclosed steel 400 kL Equalisation Tank to the south-west of the converted Pond 3 anaerobic digester. The role of the Equalisation Tank will be to equalize the raw wastewater flow to Pond 3. There is no biogas in the Equalisation Tank

- It is proposed to construct a building for biogas collection fans from the new Pond 3 digester immediately adjacent and to the south-west of the Equalisation Tank

  Biogas scrubber units including flares will be installed. The scrubber will remove hydrogen sulphide (H_2S) from the biogas which will reduce acid corrosion in the boilers and improve air quality (reduction in sulphur dioxide emissions). The chillers cool the biogas and remove moisture from the biogas. The hydrogen sulphide typically ranges from 5,000 to 9,000 ppm, with an average of less than 6,000 ppm. The biological scrubber will be designed to handle peaks up to 9,000 ppm.

The biogas is to be extracted by blowers / fans from the digester cover and forced through an arrangement of closed tanks for chemical and biological removal of hydrogen sulphide as a slurry. It is envisaged to equip the system with vacuum and overpressure protection devices; no venting is required or expected in normal operation. The hydrogen sulphide slurry will be collected in buffer tanks and disposed off-site. For final polishing and to address potential hydrogen sulphide concentration peaks, the biogas is to be forced through activated carbon filters

- Interconnecting pipework, pumps and blowers

- A new wastewater collection tank (70 KL) at the factory site and a new pipe to the Wastewater Treatment Plant to service the western area of the factory site

- Substation and maintenance shed to service the new plant and equipment at the Manildra Farm

- Additional MBR and RO plant and associated building. The RO unit will have clean-in-place chemicals as per the existing RO unit.

The WWTP upgrades will result in an increase in WWTP capacity from 10 ML/day to approximately 14 ML/ day and increase the amount of treated water returned to the factory for re-use from 6.5 ML/day to approximately 12 ML/day. The amount of water that will be sent to irrigation is estimated to be approximately 2 ML/day. At present approximately 3 ML/day of treated water is spray irrigated. The proposed work will therefore result in a reduction in the volume of treated water that will be required to be spray irrigated.

The biogas volume under the existing digestor cover is 496 m^3. The new digestor will have 483 m^3 of biogas under its cover. There are no new chemicals or an increase in stored volumes required for the WWTP expansion project.

Given the proposed changes, the main fire and explosion hazards at the WWTP are associated with losses of containment of biogas with subsequent ignition. Toxic impact is also possible due to a release of biogas that contains up to 9,000 ppm of hydrogen sulphide (i.e. before the scrubber). These events are assessed in this report.

Proposed MOD34 Changes

It is proposed to remove of the existing temporary time limit imposed by Mod 28 for the emergency grain storage bunker and the construction of a grain storage shed upon the existing grain storage bunker to the rear of the Waste Water Treatment Plant. This location is north of the existing Wet Weather Storage Pond No. 6 located on the Shoalhaven Starches Environmental Farm (the Waste Water Treatment Plant) on the northern side of Bolong Road at Bomaderry.

The proposed grain storage shed location is shown in Figure 5. The details of the shed are shown in Figure 6 and are summarised as follows:

- 24 metres width
- 60 metres length
- 9.5 metres height.

It is anticipated that the shed will have a storage capacity of 6,900 te of grain at any one time. The shed floor will be concrete. The walls and roof are to be constructed from steel.

Semi-trailers will be loaded with grain in western NSW and deliver the grain directly to the grain storage shed.

Driveway and vehicle access to the proposed grain storage shed will remain the same as that which is associated with the existing temporary grain storage bunker approved under Mod 28. Grain will be transferred into the grain storage shed via a mobile auger as is the case with the existing temporary grain storage bunker. The mobile auger capacity will be approximately 380 te/hr. The grain will then free-fall into the shed and be stored in stockpiles.

During rail disruptions, grain will be loaded (using a loader) from the grain storage shed into semi-trailers and then delivered to the Shoalhaven Starches factory site. As rail deliveries will be disrupted, the semi- trailers will deliver the grain to the existing rail grain delivery bins situated beneath the rail line to enable the Shoalhaven Starches factory production processes to continue.

Given that grain and grain dust can be present within the shed then the main potential hazardous events are fires and dust explosions.

Figure 5 – MOD34 Proposed Grain Storage Shed Location

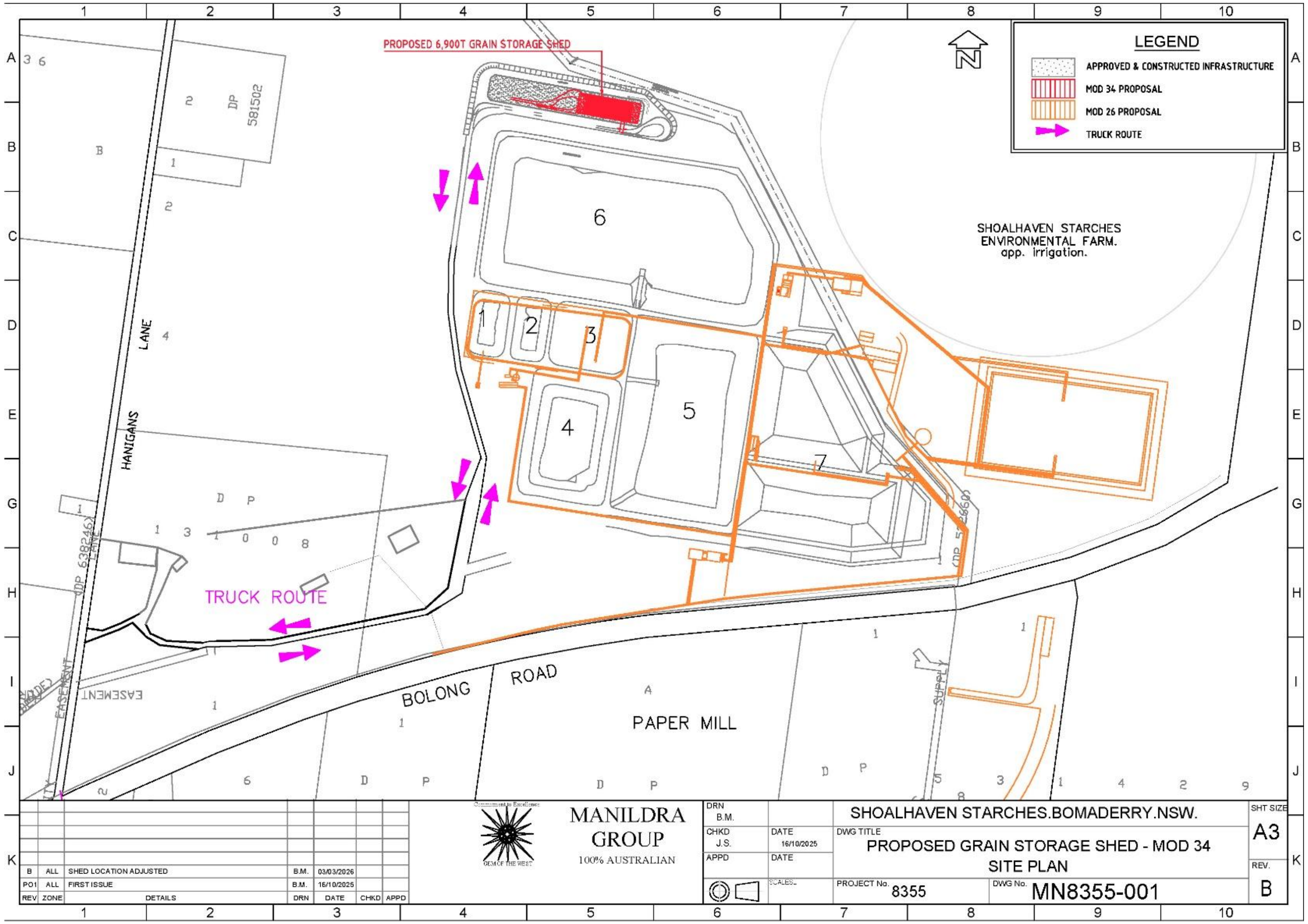
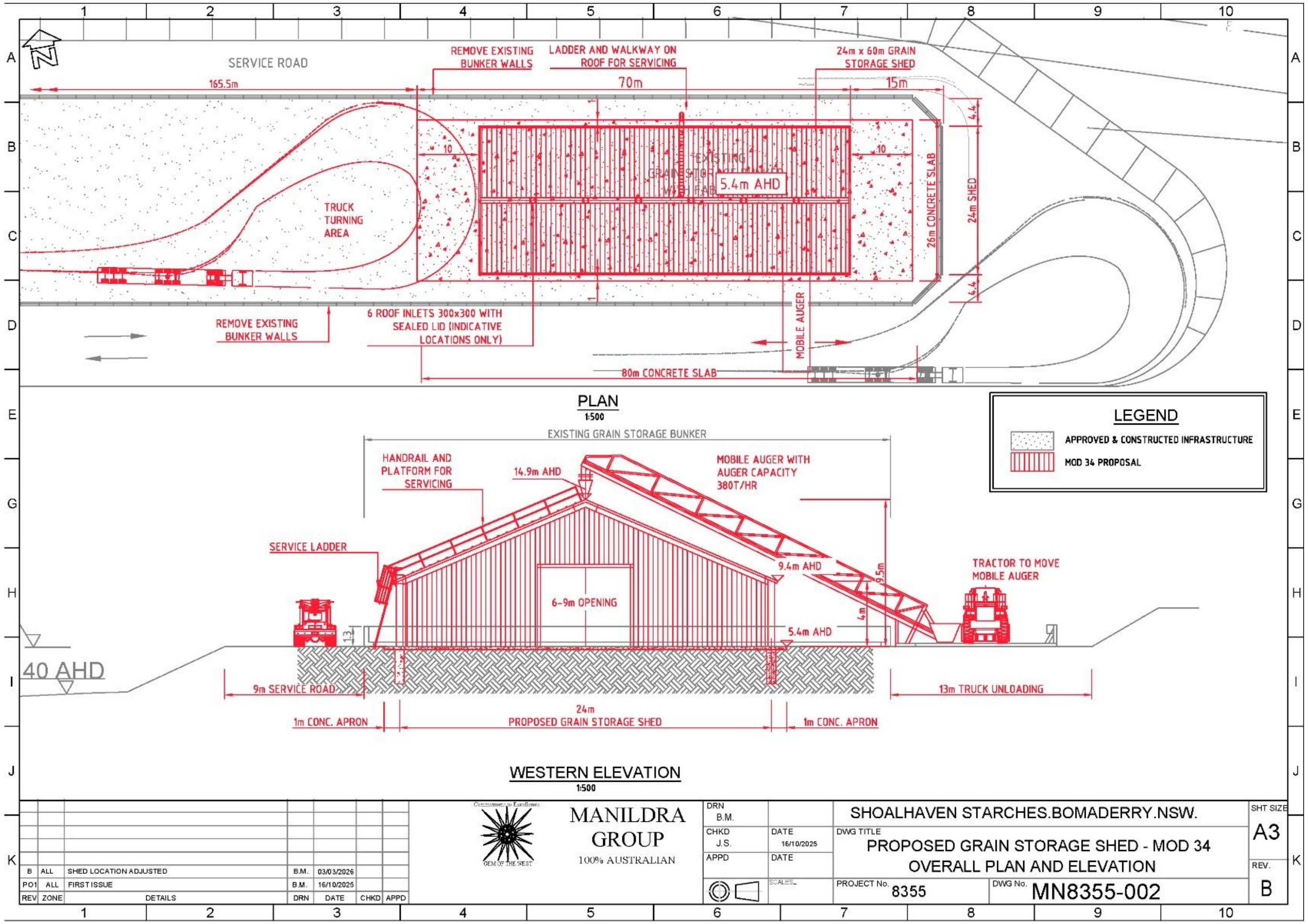


Figure 6 – Grain Storage Shed Plan and Elevation



3.14 CARBON DIOXIDE PLANTS

2017 Plant:

Supagas own and operate a 50 TPD carbon dioxide plant on the Bomaderry site. The plant location is shown in Figure 7.

The plant is located on the Shoalhaven Starches site, i.e. adjacent to the Manildra Maintenance Department building. The site is located at 220 Bolong Road, Bomaderry.

Supagas take carbon dioxide with a purity of approximately 92 % from the Shoalhaven Starches fermentation system and process this gas into food grade carbon dioxide (>99.99% purity) suitable for food and hospitality markets around Australia.

The plant has an initial maximum capacity of 50 tonne per day, i.e. Stage 1. The plant capacity will be increased to 100 tonne per day in the future.

The plant feed stream has the following approximate composition:

- Carbon dioxide 91.7 vol%;
- Oxygen 1.2 vol%;
- Nitrogen 4.3 vol%;
- Water 2.45 vol%;
- Total sulphur 10 ppmv;
- Hydrocarbons 3,120 ppmv; and
- NOx 50 ppmv.

Figure 7 – Carbon Dioxide Plant Location

Source: Google Maps

The following equipment is installed at the site to enable the carbon dioxide to be purified and liquefied.

- ***Cold Water Scrubber***. This dehumidifies the warm, moist carbon dioxide exiting the Shoalhaven Starches fermentation process and primarily removes water and alcohol from the feed stream. The scrubber waste stream is captured and reused by Shoalhaven Starches. The cold water scrubber is located on the Shoalhaven Starches site. The resulting carbon dioxide feed stream is piped (underground) to the Supagas plant. This pipe is approximately 690 m long and 200 mm nominal diameter.

- ***Carbon Dioxide Compressor***. The carbon dioxide compressor takes the carbon dioxide from the cold water scrubber and raises the pressure to approximately 1,950 kPag.

- ***Sulphide Removal Unit***. Carbon dioxide is fed into the beds that contain an active ingredient which removes any organic sulphides. This active ingredient is removed when spent and sent for disposal at an authorised facility.

- ***CATOX System***. The carbon dioxide is fed through a CATOX system (catalytic oxidation reactor) where the remaining hydrocarbons are oxidised into moisture and carbon dioxide. This system runs at approximately 330 degrees C. The reaction process occurs with oxygen in a catalyst filled vessel.

- ***Carbon Dioxide Driers***. The carbon dioxide is further dried to a point where its moisture content is reduced to less than 20 parts per million. This occurs within one of two driers containing molecular sieves, i.e. one drier is on-line whilst the other drier is being regenerated.

- ***Carbon Dioxide Liquefier***. The dried, gaseous carbon dioxide at approximately 1,800 kPag is liquefied in a distillation column and condenser. An ammonia refrigeration system is used to condense the carbon dioxide (total ammonia capacity of approximately 700 kg).

- ***Carbon Dioxide NOx Removal Vessel***. Liquid carbon dioxide flows through a bed of molecular sieve. The molecular sieves adsorb any NOx (nitrogen oxides). The molecular sieves are replaced as required and disposed of in accordance with statutory requirements.

- ***Carbon Dioxide Tanks***. The carbon dioxide is then stored in either a 100 tonne tank, a 200 tonne tank or one of two 150 kL (165 tonne) tanks. Each of the 150 kL tanks is 17.2 m high and 3.8 m diameter. These storage tanks are designed similarly to the 200 tonne tank, i.e. there will be an inner and outer tank with the outer tank being designed to contain the carbon dioxide if the inner tank fails. The 100 tonne tank is an insulated horizontal tank.

The carbon dioxide is transferred (as required) from the tanks into road tankers and then distributed to the market. There are two types of road transport:

- A B-double capable of carrying a 30 tonne payload
- A single tanker that has a capacity of 20 tonnes.

Stage 1 (i.e. the 50 tonne per day plant) involves a maximum of 2 truck movements per day and stage 2 (i.e. the 100 tonne per day plant) will involve a maximum of 5 truck movements per day.

If the oxygen content in the carbon dioxide feed stream falls below 0.3 vol% then the CATOX system will not work effectively and the carbon dioxide purity will be off-specification. Therefore, there is backup high pressure oxygen on site. This is used for the CATOX if the oxygen is insufficient in the feedstock.

Wastes from the plant include:

- Waste water (blowdown) from the cooling towers which is sent to the Shoalhaven Starches waste water treatment plant. This comes from the sump of the cooling tower and is undertaken to prevent total dissolved solids from building up that are naturally present in the water
- The sulphide beds and NOx removal beds contain absorbents that when spent are sent as trade waste and replaced with new absorbent
- The cold water scrubber removes any residual alcohol and this is captured and reused by Shoalhaven Starches.

The hazardous process fluids involved with the proposed process are:

- Carbon dioxide
- Oxygen
- Ammonia.

The main potential hazardous events associated with the carbon dioxide plant are therefore asphyxiation (carbon dioxide), enhanced oxygen fires (these are historically local, short-duration events) and toxicity from potential ammonia releases. Whilst ammonia is also flammable (the flammable range is 16 to 25%), the ammonia (approximately 700 kg) is within a refrigeration system which is located in the open, i.e. no confinement and hence ignition risk.

As the Supagas carbon dioxide plant is located approximately 0.5 km east of the Shoalhaven Starches facility and the hazards have been separately assessed (Refs 5 and 6)

2026 Plant:

The proposed alterations and additions to the 2017 carbon dioxide plant (MOD30) involve similar plant and equipment. MOD30 has now been approved. A process description for the second carbon dioxide plant is as follows.

1. ***Low Pressure Gas Supply***

Raw carbon dioxide gas is supplied at 0.1 barg and 30°C. It flows through a knockout drum (suction filter) to remove liquids and droplets before being compressed in the carbon dioxide booster.

The gas is then cooled in two heat exchangers (using cooling water and then ammonia) and further liquids are removed via another knock out drum.

2. ***Carbon Dioxide Compressor***

The carbon dioxide is then compressed to a pressure of up to 22 barg in a two-stage screw compressor.

The feed carbon dioxide stream is compressed up to 4.45 barg in the 1st stage. This compressed stream is combined with a gas balance line from the storage tanks / liquefaction area and a gas line from a carbon dioxide separator in order to recover boil-off gas.

At the outlet of the 2nd stage, the carbon dioxide enters into a carbon dioxide oil separator in which lubricating oil is separated by gravity and coalescing elements.

Lubricating oil is then cooled in the carbon dioxide / oil cooler heat exchanger (shell and tube) and then pumped by means of the carbon dioxide oil pump to the lubricating circuits of the screw compressor.

The high-pressure carbon dioxide exiting the carbon dioxide oil separator flows back to the cooling skid in which, after passing through the carbon dioxide oil coalescer, the residual content of oil in the carbon dioxide stream is reduced to a minimum.

3. ***CATOX***

The hot compressed gas is processed in a guard bed to pre-remove the sulphur components and then in a CATOX unit to oxidize the hydrocarbons compounds, i.e. to form water and carbon dioxide.

The carbon dioxide gas must be preheated to activate the reaction (the temperature of the preheating depends on the type of the components inside the gas, usually the temperature is around 300/400°C).

The gas stream oxygen content is not enough to ensure the reaction so it is necessary introduce additional oxygen to guarantee the complete combustion of the hydrocarbons.

The carbon dioxide exiting the CATOX unit passes through an economiser (to save energy for CATOX pre-cooling), an aftercooler (using cooling water) and then a high pressure precooler (using ammonia). The temperature decreases from approximately 190°C to 10°C. There are moisture separators after the aftercooler and high pressure precooler.

4. Dryer

The drying system consists of two beds that ensure continuous operation, i.e. whilst the first bed is in operation, the other is in regeneration or in standby waiting for changeover.

Bed changeover takes place primarily based on time or mass (number of hours in service or the amount of carbon dioxide processed, i.e. whichever comes first causes a changeover to the fresh bed, while other bed starts it regeneration cycle.

Regeneration is achieved by the following sequence:

- Depressurisation of the regenerating vessel
- Heating by means of an ambient air blower and heated up to approximately 200°C in the dryer regeneration heater
- Cooling using storage tanks boil-off gases and non-condensables from liquefaction
- Pressurisation of the regenerated vessel.

During the depressurisation and heating steps, the regenerating flow is vented to atmosphere while during the cooling step it is recovered to the inlet raw gas cooler line.

Downstream of the dryers there is a dust filter to avoid any particulate carryover to the liquefaction section.

There will be a dew point analyser installed at the outlet of the dryers. This instrument ensures the correct changeover between the two dryer vessels and also provide an important alarm in case of water breakthrough that can cause blockages in the downstream equipment.

5. Liquefaction

The dried carbon dioxide vapour stream passes through the tube side of the stripper column reboiler, i.e. to provide heat for the distillation process within the stripper.

After passing through the reboiler, the carbon dioxide stream flows to the carbon dioxide condenser where it is liquefied (approximately -28°C) by means of low pressure ammonia. The ammonia vaporises (operating pressure around 0.2 barg) and flows back to the suction of the ammonia compressor.

The liquid carbon dioxide stream from the carbon dioxide condenser flows by gravity down the stripper. Due to vapour rising from the reboiler, the non-condensable impurities are reduced to meet the required carbon dioxide specification for storage.

There will be a vent condenser that uses liquid carbon dioxide at low pressure to cool and condense the gas carbon dioxide recovered from carbon dioxide condenser. This condensed liquid is returned to the stripper.

Product liquid from the bottom of the stripper flows via a subcooler (in which the liquid carbon dioxide is cooled to approximately -27°C) to the NOx cold trap.

6. NOx Cold Trap

Liquid carbon dioxide exiting the liquefaction section passes through a lead-lag configuration of two vessels filled with molecular sieves before being sent to the pump skid. These vessels are the NOx cold trap where NOx (in particular, NO_2) is removed so that the final product specifications can be achieved.

The lead-lag configuration allows continuous operation. When one vessel (the first in contact with liquid carbon dioxide) is exhausted then bed regeneration (heating and cooling) can be performed. The status of each vessel can be checked by manually sampling the gas from the sampling valves after each vessel.

7. Liquid Carbon Dioxide Pumps

Liquid carbon dioxide from the NOx cold trap section is sent to the carbon dioxide pump buffer vessel. There are two liquid carbon dioxide pumps (duty / standby) that transfer the liquid carbon dioxide to the required storage tank.

The carbon dioxide pumps have minimum flow recirculation lines to keep the pumps cool and provide deadhead protection.

All liquid carbon dioxide lines will be fitted with thermal relief valves in case the liquid is isolated and heated (and hence creating thermal overpressure).

8. Ammonia Refrigeration

Gaseous ammonia from the liquefaction skid enters the ammonia compression package consisting of a single stage screw compressor.

The ammonia vapour stream is compressed to approximately 15 barg and enters an ammonia / oil separator in which lubricating oil is separated by gravity and coalescing elements.

The lubricating oil is then cooled in the ammonia / oil cooler and then pumped to the lubricating circuits of the screw compressor.

Compressed ammonia exiting the compressor is condensed in the ammonia condenser and then the liquid ammonia flows into the ammonia receiver. The ammonia then flows to various heat exchangers, e.g. the carbon dioxide condenser, for cooling and/or condensing purposes. The gaseous ammonia from these heat exchangers then return to the ammonia compressor.

9. Storage Tanks

It is proposed to install two additional vertical storage tanks as part of the project. These tanks will be 200 tonne capacity. Each tank will be 23 m high and 4.33 m diameter. These storage tanks are to be designed similarly to the existing 150 tonne tanks, i.e. there is an inner and outer tank with the outer tank being designed to contain the carbon dioxide if the inner tank fails.

There are two main vents for the proposed second carbon dioxide plant, i.e. an ammonia vent (e.g. for pressure safety valves) and a carbon dioxide vent. These are to be vented at a safe height to allow dispersion of the gases prior to potentially impacting people.

Given the extra capacity from the proposed second carbon dioxide plant then there will be approximately five truck movements per day delivering carbon dioxide to the market.

The hazards and risks associated with the entire Supagas carbon dioxide facility have been detailed and assessed (Ref 7) and found to be compliant with the NSW HIPAP 4 risk criteria. This is due to the limited off-site adverse consequential impacts and the generous separation distances to other plants and sensitive land users. No further analysis is provided in this report. The details of the assessment can be found in Ref 7.

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

The facility handles and stores the hazardous materials shown in Table 5, Table 6 and Table 7. Drawings showing the storage locations of these materials are shown in Appendix A. These locations are identified by the “Map Ref. No.”, i.e. the first column in Table 5.

In summary, the hazardous materials include:

- Dangerous Goods (DG) 2.1 flammable gases, e.g. natural gas, LPG (liquefied petroleum gas) and biogas
- DG 2.2 non-flammable and non-toxic gases, e.g. nitrogen
- DG 3 flammable liquids, e.g. ethanol, methanol, gasoline, acetic anhydride and xylene
- DG 5 oxidisers, e.g. hydrogen peroxide and peroxyacetic aid mixture (proxitane)
- DG 8 corrosive substances, e.g. sulphuric acid, sodium hydroxide (caustic soda), sodium hypochlorite, hydrochloric acid, nitric acid, cooling towers and boilers dosing chemicals, sodium chlorite, acetic anhydride, ferric chloride solution, ammonia-water solution, citric acid and phosphorus oxychloride
- Combustible materials and dusts, e.g. grains, flour, starch, gluten, glucose, coal and DDG.

The credible, significant hazardous events for the storage and processing facilities are summarised in the Hazard Identification Word Diagrams in Appendix B. The diagrams show the causes and consequences of the events, together with major preventative and protective features.

Information for the development of the potential hazardous events was obtained from:

- Previous Preliminary and Final Hazard Analyses
- Hazardous events identification studies (including HAZOP studies) performed within Manildra
- Manildra’s and Pinnacle Risk Management’s experience in the industry.

Table 5 - Hazardous Substances Storage Depots (Manifest Quantities)

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
1	Ethanol	2	Ethanol	230,000	1170	3. Flammable	II	Above-Ground Tank
2	Ethanol	2	Ethanol	560,000	1170	3. Flammable	II	Above-Ground Tank
3	Ethanol	2	Ethanol	560,000	1170	3. Flammable	II	Above-Ground Tank
4	Ethanol	2	Ethanol	118,000	1170	3. Flammable	II	Above-Ground Tank
5	Ethanol	2	Ethanol `	98,000	1170	3. Flammable	II	Above-Ground Tank
6	Ethanol	2	Ethanol	123,000	1170	3. Flammable	II	Above-Ground Tank
7	Ethanol	2	Ethanol	441,000	1170	3. Flammable	II	Above-Ground Tank
8	Ethanol	2	Ethanol	750,000	1170	3. Flammable	II	Above-Ground Tank
9	Starch	6	Sulphuric Acid 50%	5,000	2796	8. Corrosive	II	Above-Ground Tank
10	Ethanol	2	Methanol	5,000	1230	3. Flammable 6.1 Toxic	II	Above-Ground Tank
11	Ethanol	2	Methyl Isobutyl Ketone	5,000	1245	3. Flammable	II	Above-Ground Tank
12	Ethanol	2	Unleaded Petrol	5,000	1203	3. Flammable	II	Above-Ground Tank
13	Ethanol	2	Tert Butyl Alcohol	5,000	1120	3. Flammable	III	Above-Ground Tank
14	Ethanol	2	Unleaded Petrol	5,000	1203	3. Flammable	II	Above-Ground Tank
15	Ethanol	2	Unleaded Petrol	5,000	1203	3. Flammable	II	Above-Ground Tank
16	Ethanol	2	Ethanol	1,404,000	1170	3. Flammable	II	Above-Ground Tanks
17A		2	Ammonium Bromide (Biosperse XD3899)	2500	N/A	Health Hazard	II	Tank Tank (IBC)
17B		2	Sulfuric Acid 60%	1000	1830	8. Corrosive	II	Tank
17C		2	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	1000	3265	8. Corrosive	II	Tank
17E		2	Sodium Chlorite 25% (Biosperse CX7250)	1000	1908	8. Corrosive	II	Tank (IBC)
17F		2	Sodium Hypochlorite 12.5%	2000	1791	8. Corrosive	III	Tank (IBC)
17G		2	Alcohol Ethoxylate (Ausperse 47)	1000	N/A	Skin Irritant	N/A	Tank (IBC)

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
17H	Ethanol (Cooling Towers)	2	Mixed Phosphoric Acid, Zinc Sulphate, Etidonic Acid (Performax PM3607)	1000	3264	8. Corrosive	III	Tank (IBC)
17I		2	Phosphonic Acid Sodium Salt (Performax TK2272)	1000	N/A	N/A	N/A	Tank (IBC)
17J		2	Sulphuric Acid <2.5% (Biosperse CX9400A)	1000	N/A	N/A	N/A	Tank (IBC)
17K		2	Ammonium Bromide (Biosperse XD3899)	1000	N/A	Enzyme	N/A	Tank (IBC)
18A	Ethanol (Cooling Towers - BGA1)	2	Sodium Hypochlorite 12.5%	1000	1791	8. Corrosive	III	Tank (IBC)
18B		2	Sulfuric Acid 60%	1000	1830	8. Corrosive	II	Tank (IBC)
18C		2	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	300	3265	8. Corrosive	II	Tank
18D		2	Sodium Chlorite 25% (Biosperse CX7250)	1000	1908	8. Corrosive	II	Tank (IBC)
19A	Ethanol (Cooling Tower Cell 5)	2	Sodium Hypochlorite 12.5%	1000	1791	8. Corrosive	III	Tank (IBC)
19B		2	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	250	3265	8. Corrosive	II	Tank
19C		2	Mixed Dialkyl (C8-C10) Dimethyl Ammonium Chloride, Ethanol (Biosperse CN6501-AP)	250	2920	8. Corrosive 3. Flammable	II	Tank
19D		2	Sulfuric Acid 60%	250	1830	8. Corrosive	II	Tank
20A	Ethanol	2	Sodium Hypochlorite 12.5%	4000	1791	8. Corrosive	III	Tank (IBC)
20B		2	Sodium Chlorite Solution 31%	4000	1908	8. Corrosive	II	Tank (IBC)
21	Ethanol	2	Sodium Borohydride & Sodium Hydroxide Solution	3000	3320	8. Corrosive	II	Tank (IBC)
22	Glucose	3	Sodium Hydroxide Solution	52,000	1824	8. Corrosive	II	Above-Ground Tank
23	Ethanol	2	Xylene (DCI-11) N-Propyl Acetate Ethyl Acetate	6,000 6,000 6,000	Various	3. Flammable 3. Flammable 3. Flammable	II	Roofed Store IBCs
24A		2	Sulfuric Acid 60%	300	1830	8. Corrosive	II	Tank

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
24B	Glucose (cooling towers)	2	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	300	3265	8. Corrosive	II	Tank
24C		2	Mixed Dialkyl (C8-C10) Dimethyl Ammonium Chloride, Ethanol (Biosperse CN6501-AP)	300	2920	8. Corrosive 3. Flammable	II	Tank
24D		2	Sodium Hypochlorite 12.5%	1500	1791	8. Corrosive	III	Tank (IBC)
24E		2	Sodium Chlorite 25% (Biosperse CX7250)	1500	1908	8. Corrosive	II	Tank (IBC)
25	Glucose	3	Nitric Acid 50%	1000	2031	8. Corrosive	II	Tank (IBC)
26B	Starch	4	Hydrogen Peroxide, Acetic Acid, Peracetic Acid (Bioxysan 20)	2000	3098	5.1 Oxidising 8. Corrosive	II	Tank (IBC)
27A	Boiler house	5	Sodium Hydrogensulphite 50% (Bisulfites Solution)	1000	2693	8. Corrosive	III	Tank (IBC)
27B		5	Cyclohexylamine, 2-diethylaminoethanol Solution (Amines, Liquid)	1000	2735	8. Corrosive	II	Tank (IBC)
27C		5	Sodium Hydroxide 5% (Corrosive Liquid, Basic, Inorganic)	1000	3266	8. Corrosive	II OR III	Tank (IBC)
27D		5	Poly(Ethylene-Propylene) Glycol, Butoxy (Antispumin)	1,000	N/A	N/A	N/A	Tank (IBC)
28	Starch (Main Driveway)	4	Hydrochloric Acid 32%	2000	1789	8. Corrosive	II	Tank
29	Starch Dryer 5	9	Sodium Hydroxide 50%	2000	1824	8. Corrosive	II	Tank
30	DDG Dryers	7	Sodium Hydroxide 50%	5000	1824	8. Corrosive	II	Tank
31A	DDG Dryer 4 (Cooling Tower)	8	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	300	3265	8. Corrosive	II	Tank
31B		8	Mixed Dialkyl (C8-C10) Dimethyl Ammonium Chloride, Ethanol (Biosperse CN6501-AP)	300	2920	8. Corrosive 3. Flammable	II	Tank
31C		8	Sodium Hypochlorite 12.5%	300	1791	8. Corrosive	III	Tank (IBC)
32A	Laboratory	4	Hydrogen Gas	54kg (8.8 m3)	1049	2. Flammable Gas		Gas Bottle
32B		4	Oxygen gas	54 kg (8.8 m3)	1072	2. Oxidising Gas		Gas Bottle

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
35	Starch	2	Acetic Anhydride	5,000	1715	8. Corrosive & 3. Flammable	II	Above-Ground Tank + 220L drums
36	Stillage	8	Sodium Hypochlorite	36,000	1791	8. Corrosive	II	Above-Ground Tank
37	Ethanol Distillery	2	Ethanol	225,000	1170	3. Flammable	II	In-process
38	Ethanol Load-out	2	Ethanol	43,000	1170	3. Flammable	II	In-process (tanker)
39A	Cogen	8	Natural Gas Pipeline High Pressure	29000	1971	2. Flammable Gas	II	In-process (Pipeline)
39B	Boiler house	5	Natural Gas Pipeline Low Pressure	11000	1971	2. Flammable Gas	II	In-process (Pipeline)
48	DDG	7	Sodium Hydroxide	36,000	1824	8. Corrosive	II	Above-Ground Tank
49	Glucose	3	Hydrochloric Acid	32,000	1789	8. Corrosive	II	Above-Ground Tank
51	Ethanol	2	Methyl Isobutyl Ketone Methanol N-Propanol Ethanol Ethyl Acetate Isopropanol Toluene Acetone Methoxy Propanol Propyl Alcohol N Propyl Acetate Xylene (DCI-11) Petrol	50,000	1245 1230 1274 1170 1173 1219 1294 1090 3062 1274 1276 1307 1203	3. Flammable	II & III	Tank (IBC)
57	DDG	8	Nitric Acid <65%	6,000	2031	8. Corrosive	II	Tank (IBC)
58	Starch	4	Phosphorus Oxychloride	100	1810	8. Corrosive 6. Toxic	I	5Lt containers in cabinet
59A		8	Propionic Acid/ Formic Acid Solution	2,000	1848 1779	8. Corrosive & 3. Flammable	II	Tank (IBC)
59B		8	Sodium Hydrogensulphite 50% (Bisulfites Solution)	1000	2693	8. Corrosive	III	Tank (IBC)

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
59C	DDG (Cooling Towers)	8	Cyclohexylamine, 2-diethylaminoethanol Solution (Amines, Liquid)	1000	2735	8. Corrosive	II or III	Tank (IBC)
59D		8	Sodium Hypochlorite 12.5%	3000	1791	8. Corrosive	III	Tank (IBC)
59E		8	Mixed Dialkyl (C8-C10) Dimethyl Ammonium Chloride, Ethanol (Biosperse CN6501-AP)	300	2920	8. Corrosive 3. Flammable	II	Tank
59F		8	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	1300	3265	8. Corrosive	II	Dosing Tank & Tank (IBC)
59G		8	Sodium Chlorite Solution	1,000	1496	8. Corrosive	II	Tank (IBC)
59H		8	Phosphonic Acid Sodium Salt (Performax TK2272)	1000	N/A	Skin Irritant	N/A	Tank (IBC)
59I		8	Sulphuric Acid <2.5% (Biosperse CX9400A)	2000	N/A	N/A	N/A	Tank (IBC)
59J		2	Sodium Hydroxide 5% (Corrosive Liquid, Basic, Inorganic)	1000	3266	8. Corrosive	II OR III	Tank (IBC)
60	Starch	4,6	Sodium Chlorite Solution	3,000	1496	8. Corrosive	II	Above-Ground Tank
61A	Boiler 8	2	Cyclohexylamine, 2-diethylaminoethanol Solution (Amines, Liquid)	1,000	2735	8. Corrosive	II	Tank (IBC)
61B		2	Sodium Hydrogensulphite 50% (Bisulfites Solution)	1,000	2693	8. Corrosive	III	Tank (IBC)
61C		2	Sodium Hydroxide 5% (Corrosive Liquid, Basic, Inorganic)	1,000	3266	8. Corrosive	II	Tank (IBC)
62A	Cationic Starch Plant	9	Quat 188 Cationic Reagent 69% Active	50,000	N/A	N/A	I or II	Above-Ground Tank
62B		9	Sodium Hydroxide	100,000	1824	8. Corrosive	II	Above-Ground Tank
62C		9	Hydrochloric Acid	50,000	1789	8. Corrosive	II	Above-Ground Tank

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
64A	Fermentation (Cooling Towers)	2	Sodium Hypochlorite 12.5%	1,000	1791	8. Corrosive	III	Tank (IBC)
64B		2	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Operion CB1010)	1,000	2922	8. Corrosive		Tank (IBC)
64C		2	Sulphuric Acid 50%	1,000	2796	8. Corrosive	II	Tank (IBC)
64D		2	Corrosive Liquid, Basic, Inorganic	1,000	3266	8. Corrosive	II OR III	Tank (IBC)
64E		2	Corrosive Liquid, zinc chloride 10%, hydrochloric acid 10%	1,000	1760	8. Corrosive	II	Tank (IBC)
65A	CoGen	8	Sodium Hydrogensulphite 50% (Bisulfites Solution)	1,000	2693	8. Corrosive	III	Tank (IBC)
65B		8	Sodium Hydroxide Solution 10%	1,000	1824	8. Corrosive	II	Tank (IBC)
65C		8	Cyclohexylamine, 2-diethylaminoethanol Solution (Amercor 8548)	1000	2735	8. Corrosive	II	Tank (IBC)
65D		8	Sodium Hydroxide (Amertrol HT3530)	1,000	3266	8. Corrosive	II	Tank (IBC)
65E		8	Poly(Ethylene-Propylene) Glycol, Butoxy (Antispumin)	1,000	N/A	N/A	N/A	Tank (IBC)
68A	CoGen (Cooling Towers)	8	Sulphuric Acid 60%	1,000	2796	8. Corrosive	II	Corrosive Cabinet Tank (IBC)
68B		8	Sulphuric Acid <2.5% (Biosperse CX9400A)	1,000	N/A	N/A	N/A	Corrosive Cabinet Tank (IBC)
68C		8	Sodium Hydrogensulphite (Amersite 2P)	1,000	N/A	N/A	N/A	Corrosive Cabinet Tank (IBC)
68D		8	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Biosperse CN7539)	1000	3265	8. Corrosive	II	Corrosive Cabinet Tank (IBC)

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
68E	CoGen (Cooling Towers) SD5 Southern Reaction Tanks Ethanol Ethanol Starch Plant	8	Sodium Hydroxide (Amertrol HT3530)	1,000	3266	8. Corrosive	II	Corrosive Cabinet Tank (IBC)
68F		8	Cyclohexylamine, 2-diethylaminoethanol Solution (Amercor 8548)	1000	2735	8. Corrosive	II	Corrosive Cabinet Tank (IBC)
68G		8	Sodium Hydroxide Solution 25%	1,000	1824	8. Corrosive	II	Corrosive Cabinet Tank (IBC)
68H		8	Phosphonic Acid Sodium Salt (Performax TK2272)	1,000	N/A	N/A	N/A	Corrosive Cabinet Tank (IBC)
69		8	Sulphuric Acid 50%	10,000	2796	8. Corrosive	II	Above-Ground Tank
70		2	Sodium Chlorite Solution 31% (Fermasure)	10,000	1908	8. Corrosive	II	Corrosive Cabinet Tank (IBC)
72		2	Sodium Borohydride & Sodium Hydroxide Solution	3000	3320	8. Corrosive	II	Tank (IBC)
73		4	5-Chloro-2-Methyl-4-Isothiazolin-3-one (Operion CB1010)	1000	2922	8. Corrosive	II	Tank (IBC)
74	DDG	8	Corrosive Liquid, zinc chloride 10%, hydrochloric acid 10%	4,000	1760	8. Corrosive	II	Tank (IBC)

Table 6 - Hazardous Substances and Other Pollutants (Smaller Quantities)

Map Ref. No.	Plant Location	Map Zone	Substance	Estimated Storage Quantity	UN Number	DG Class / Hazard	Storage Method
C2	Laboratory	4	Benzene	200mL	1114	Flammable/ Carcinogen	200mL containers
C3	Glucose	3	Enzymes	3,000 L	N/A	Irritant / Sensitiser	Tank (IBC)
C4	Glucose	3	Sodium Metabisulphite	300 kg	N/A	Irritant / Sensitiser	Tank (IBC)
C5	Glucose	3	Pearlite	1000 kg	N/A	Irritant / Sensitiser	25kg bags
C6	Glucose / Ethanol	3	Enzymes & Yeast	1000 L	N/A	Irritant / Sensitiser	Tanks IBC
C24	Starch	4	Chlorine Dioxide Solution (0.3%)	2,500 L	N/A	Non-hazardous at < 1% solution	Above-Ground Tank
C13	Boilerhouse	5	Coal	500 T	N/A	Combustible	Stockpile

Table 7 – WWTP Hazardous Substances Storage Depots

Map Ref. No.	Plant Location	Map Zone	Substance	Maximum Storage Quantity (L)	UN Number	DG Class	PG	Storage Method
53	Farm	MN000-002	Ferric Chloride Solution	20,000	2582	8. Corrosive	III	Above-Ground Tank
54A	Farm	MN000-002	Ammonia Solution	2,000	2672	8. Corrosive	III	Above-Ground Tank
54B		MN000-002	Sodium Hydroxide Solution	2,000	1824	8. Corrosive	II	Above-Ground Tank
54C		MN000-002	Hypochlorite Solution	10,000	1791	8. Corrosive	II	Above-Ground Tank
54D		MN000-002	Citric Acid	1,000	N/A	N/A	N/A	Above-Ground Tank
54E		MN000-002	Phosphonate Salt Solution (Antiscalant)	2,000	N/A	N/A	N/A	Above-Ground Tank
56	Farm	MN000-002	L.P.G	3,200	1075	2.1. Flammable gas		Above-Ground Tank
63	Farm	MN000-002	Sulphuric Acid 50%	10,000	2796	8. Corrosive	II	Above-Ground Tank
66A	Farm	MN000-002	Sulphuric Acid 50%	5,000	2796	8. Corrosive	II	Tank (IBC)
66B		MN000-002	Ammonia Solution	2,000	2672	8. Corrosive	III	Tank (IBC)
66C		MN000-002	Phosphonate Salt Solution (Antiscalant)	1,000	N/A	N/A	N/A	Tank (IBC)
66D		MN000-002	Citric Acid	2,000	N/A	N/A	N/A	Tank (IBC)
75	Farm	MN000-002	Phosphorus Oxychloride	900	1810	8. Corrosive 6.1 Toxic	I	220L drums + 5L containers

4.2 HAZARDOUS EVENTS SUMMARY

4.2.1 Pool Fires

A summary of potential pool fires is as follows:

- A bund fire within the original ethanol distillery or the beverage grade distilleries. A bund fire can also occur in the proposed distillery heat recovery evaporators bunded area
- A bund fire within the ethanol storage or day tank areas
- An ethanol tank top fire
- An ethanol pump fire
- A fire at the ethanol road tanker loadout bay
- A bund fire at the denaturant tanks
- A fire associated with loss of containment from a drum or IBC in the storage area
- A diesel fire at the diesel storage tank (Zone 7)
- A transformer oil fire.

The significant potential pool fire events are associated with the ethanol operations and these are analysed in Section 5 of this report.

4.2.2 Jet and Flash Fires

Jet and flash fires can occur due to releases of:

- Ethanol vapour, e.g. from the molecular sieves or pressurised columns
- Natural gas
- Biogas
- LPG.

Jet fires are normally extinguished by isolation of the gas supply. This is possible for natural gas at the supply Gas Pressure Reduction Facility (GPRF) as well as on-site piping isolation valves. Biogas is a low pressure system (less than 55 kPag) and can be stopped by shutting down the blowers and burning the biogas in the flare at the WWTP.

4.2.3 Explosions

Explosions are possible due to:

- Natural gas and biogas delayed ignition within dryers, buildings, the Cogen Plant or boilers
- Ethanol vapours being confined and then ignited
- Dust ignition within equipment, e.g. dryers, dust collectors, mills and bucket elevators
- Dust ignition within buildings
- Explosion within the tanks storing flammable materials, e.g. ethanol, acetic anhydride and aqueous ammonia
- Chlorine dioxide gas above 10% vol in air is explosively unstable.

These events can cause significant damage and injuries. The important prevention measures are shown in Appendix B. The outcome of these events can be residual fires that need to be extinguished using the site's fire protection systems.

4.2.4 Miscellaneous Fires

Miscellaneous fires through the site include:

- Grain, coal and dust fires, e.g. silos, stockpiles, DDG dryers and storage
- Electrical fires.

These are local fire events.

4.2.5 Toxic Gas Releases

The main toxic gas release at the site is hydrogen sulphide from losses of containment of biogas, in particular, at the WWTP. This event has been analysed in Section 10 of this report.

5 RISK ANALYSIS

5.1 HIPAP 4 CRITERIA ANALYSIS

The assessment of risks to both the public as well as to operating personnel around the Shoalhaven Starches facility 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.

The risk criteria applying to developments in NSW are summarised in Table 8 (from Ref 2).

Table 8 - 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

Description	Risk Criteria
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 x 10^{-6} per year

The values of interest for radiant heat (e.g. Ref 2) are shown in Table 9.

Table 9 - 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

The effects of explosion overpressures are summarised in Table 10.

Table 10 – Explosion Overpressure Effects

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

OVERPRESSURE, kPa	PHYSICAL EFFECT
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

The Shoalhaven Starches site can be described as:

- Relatively large (approximately 800 m east-west)
- There are discrete areas where specific hazards exist (e.g. the distilleries)
- The distance to sensitive land users is also relatively large
- There are no credible events that involve all of the plants at the same time.

Therefore, to review compliance with the HIPAP risk criteria then the risk analysis is performed on an area and/or hazard type basis. These areas are summarised as follows:

1. Confined building explosions
2. Vented dust explosions
3. Distilleries' events
4. Gas pipeline events
5. Hydrogen sulphide releases prior to the proposed WWTP scrubbers.

These areas are risk assessed in the following sections of this Hazard Analysis. Cumulative and propagation risk assessment is included in these sections.

6 RISK ANALYSIS - CONFINED BUILDING EXPLOSIONS

6.1 CONSEQUENCE ANALYSIS

There are two main scenarios where confined dust explosions can occur at the Shoalhaven Starches site, i.e.:

1. Within buildings, i.e. there is sufficient combustible dust within the building, it is dispersed and then ignited

2. .Within process equipment, e.g. silos, baghouse filters and bucket elevators.

The main confined dust explosions of interest for the site (with respect to off-site risk) are within the larger silos and within the buildings. Other equipment, e.g. baghouse filters, have explosion vents installed (see Section 7 for details).

The majority of the buildings are steel portal frame with cladding. These typically fail at 7 to 20 kPa (depending on the cladding materials of construction) and hence high overpressures from these potential confined explosions are not expected. This is on the assumption that good design and practices (such as regular housekeeping) are used.

From a review of the potential confined dust explosions at the site, the equipment items and buildings that have possible significant dust explosion hazards with the potential to impact people and property off-site are provided in the following table.

The confined explosions within these equipment items and buildings have been modelled using the methodology in Appendix C. The results of the modelling are shown in the following table. These results are shown graphically in Appendix D. The results are also applicable to confined natural gas releases (natural gas is used for heating the air when it enters a dryer). The methodology is also applicable to natural gas and biogas confined explosions within the boilerhouse and Cogen building.

Table 11 - Confined Dust Explosions Modelling Results

Scenario	P_{Max} (kPa)	Volume (m^3)	Opening		Distance (m) to the Nominated Overpressures (1):		
	(2)	(L x W x H)	Area (m^2)	Perimeter (m)	21 kPa	14 kPa	7 kPa
Zone 1:							
Gluten Dryer 6 Building Dust Explosion (5)	22	1,830 (8) (31.5 x 5.8 x 10)	58 (9)	32	11	14	23
Zone 3:							
Wheat Silo (Silo 101) Dust Explosion (3)	9	2,610 (6) (Dia = 12.5 m)	123 (7)	39	-	11	19
Zone 4:							
Starch Plant Building (GD1 to GD4) (10 and 11)	19	7,956 (39 x 34 x 6)	204	80	13	17	25
Flour Mill A Building Dust Explosion (4)	22	1,080 (8) (24 x 9 x 5)	45 (9)	28	< 10	13	20
Flour Mills B and C Building Dust Explosion (4)	22	1,320 (8) (24 x 11 x 5)	55 (9)	32	10	14	22
Zone 5:							
Boilerhouse (12)	19	6,000 (13) (20 x 20 x 15)	300	70	19	25	42

Scenario	P_{Max} (kPa)	Volume (m^3)	Opening		Distance (m) to the Nominated Overpressures (1):		
	(2)	(L x W x H)	Area (m^2)	Perimeter (m)	21 kPa	14 kPa	7 kPa
Zone 6:							
Starch Packing Building (metal clad)	19	8,056 (53 x 19 x 8)	152	54	13	17	27
Gluten Packing Building (metal clad)	19	10,880 (68 x 20 x 8)	160	56	13	17	27
SD 3 and 4 Building (metal clad)	19	2,520 (28 x 18 x 5)	90	46	11	14	22
RD5 (GD5) Building (metal clad)	19	935 (17 x 11 x 5)	55	32	-	12	18
Zone 7:							
GD7 Building (14)	22	1,560 (26 x 10 x 6)	60	32	11	14	22
Zone 8:							
DDG Storage Building (steel clad)	19	2,600 (26 x 12.5 x 8)	100	41	11	14	25
Pellet Mill Building (steel clad)	19	2,000 (25 x 16 x 5)	80	42	10	14	20
T201 Silo (600 te) - South of the Pellet Plant (18)	9	603 (Dia = 7.5 m)	44	23.6	-	-	11

Scenario	P_{Max} (kPa)	Volume (m^3)	Opening		Distance (m) to the Nominated Overpressures (1):		
	(2)	(L x W x H)	Area (m^2)	Perimeter (m)	21 kPa	14 kPa	7 kPa
Cogeneration Plant Building (15)	22	56,600 (61 x 44.2 x 21)	928	130	35	47	75
Zone 9:							
SD5 Building (16)	22	4,536 (42 x 18 x 6)	108	48	13	16	25
Cationic Process Plant Building (17)	22	2,028 (26 x 13 x 6)	78	38	12	14	22
Ring Dryer 9 Building (17)	22	1,944 (18 x 18 x 6)	108	48	12	15	25
Cationic Packer Building (17)	22	2,592 (18 x 18 x 8)	144	52	14	19	30
GD8 Dry End Building (17)	22	5,376 (42 x 16 x 8)	128	48	14	18	30
Zone 10:							
North Packing Plant (17)	22	79,500 (8) (108 x 46 x 16)	736 (9)	124	26	38	65
Waste Water Treatment Plant							
Grain Storage Shed (19)	19	17,280 (60 x 24 x 12)	292	69	19	25	40

Notes:
1. Distances are from the building or equipment item walls.
2. As per EN14491, 2 kPa is added to the failure pressures.
3. The wheat silos and flour unloading bins are low-strength atmospheric pressure designs only, i.e. they are expected to fail at approximately 7 kPa. The wheat silos are the largest silos on the site. There are eight flour unloading bins.
4. The walls are concrete tilt panels, i.e. they are expected to break at the joints first (API 752, *Management of Hazards Associated with Location of Process Plant Permanent Buildings*, provides a failure overpressure of approximately 17 kPa). Round this up to 20 kPa failure overpressure.
5. Gluten Dryer 6 building has insulated panels for walls, i.e. insulation inside steel cladding, and Besser blocks on the lower floor. A failure overpressure of 20 kPa is used for the Besser blocks (TNO, *Methods for the Determination of Possible Damage (The Green Book*), 1992). The GD6 building is close to Bolong Road and hence the potential to impact people off-site.
6. Silos and bins are assumed to be 10% full of product, i.e. the volume equals 0.9 x the vessel volume.
7. Silo and bin cross-sectional area.
8. The full volume of one floor or storey is used in the calculations, i.e. the dust is confined to one storey only due to the solid walls and floors.
9. The area of the wall at the end of the longest flame travel is used.
10. The main Starch Building (GD1 to GD4) is a mixture of materials of construction, i.e. concrete, brick and metal clad. Take the metal cladding will fail first (a failure overpressure of 17 kPa).
11. There is a "Roof Bin" (for gluten) on the main Starch Building. This is within a "penthouse" building addition (located on the western side of the Starch Building) that is a confined dust explosion hazard. This building addition is approximately 8 m wide x 12 m long x 12 m high but 12 m above ground level. It has metal sheeting. Given the location and height then there are no off-site propagation risks.
12. The boilerhouse is mostly sheet metal although there is some polycarbonate sheeting (for lighting) and some lower level brick walls. The building has multi-levels. Given the bulk of the walls and roof are thin sheet metal then take a failure overpressure of 17 kPa.
13. The boilerhouse is modelled as approximately 20 m wide, 20 m long and 15 m high, i.e. one level.
14. The GD7 building is made from concrete. It is approximately 8 to 10 m wide with each storey approximately 5 to 6 m high. Modelled as a confined explosion within one storey.
15. The Cogeneration Building internal explosion scenario is protected with a SIL 2 rated gas detection system and double actuated block valves outside the building plus a downstream actuated bleed valve that vents the natural gas (within the piping inside the building) to above the building. The building has concrete panel walls.
16. SD5 Building is Bondor (Sandwich) panels.
17. Building is steel framed with concrete cladding.
18. The design pressure for T201 is +10.77 mBar or 0.011 Bar or 1.1 kPa. Take a rupture pressure of 7 kPa to be consistent with the wheat and flour silos.
19. The end walls of the grain storage shed are assumed to fail if a confined dust explosion occurs. The openings are conservatively ignored.

Based on the results shown in Table 11 and graphically in Appendix D, the following conclusions can be made:

- Given the information shown in Table 10, fatality (in particular, to a person in a building) is possible if the overpressures are between 14 to 21 kPa. The events that can lead to 14 kPa overpressures (or more) off-site are a confined explosions in the GD6 building or starch packing building (the 14 kPa overpressure contour extends over Bolong Road) or within the Cogeneration Plant building (the 14 kPa contour extends across the site's western boundary over Bomaderry Creek). The 7 kPa overpressure contours do not extend over sensitive uses including hospitals, schools and aged care, residential areas, commercial areas, sporting complexes and active open spaces. Correspondingly, the individual fatality risk criteria in Table 8 are satisfied. Also, as the 14 kPa overpressure contours do not extend over adjacent industrial land uses then the propagation risk criterion due to explosions is compliant with the $50x10^{-6}$ per year criterion

- On-site propagation to adjacent buildings and/or equipment is expected if a confined building explosion occurs, i.e. the majority of modelled events show the 14 kPa overpressure contour at adjacent buildings and/or equipment is exceeded. The likelihood of this propagation is estimated in the following Section of this report

- Propagation from the MOD34 proposed grain storage shed is not expected given the remote location and open adjacent area, e.g. Pond 6. The explosion overpressures also do not travel off-site, therefore, there is no off-site contribution to risk from this event.

Propagation can also occur due to projectiles. The following summarises previous confined building explosions and the distances that projectiles have travelled:

1. Slurry explosive factory (e.g. aluminium and sulphur). Debris was found up to 75 m from the explosion site (Ref: Eckhoff, Page 192).

   The mixer screw was found 12 m from its original location.

2. Washburn "A" Mill; Minneapolis, May 2, 1878 (Wikipedia).

   The Washburn "A" Mill explosion of 1878 is the most infamous flour mill explosion in history. It killed 17 people, pulverized the main building and devastated seven more. The explosion was so powerful that it broke windows as far away as St. Paul and **limestone blocks from the building were thrown into yards up to eight blocks away**. If it is assumed that a block is approximately 50 m (based on a review of the street layout from Google Maps) then eight blocks is approximately 400 m.

3. West Pharmaceutical Services January 29 , 2003 (Wikipedia)

   This explosion occurred in a four storey building.

Witnesses reported hearing "a sound like rolling thunder", as what was later determined to be a chain reaction of explosions rapidly propagated. The shock wave broke windows at distances of up to 300 m away, and propelled debris as far as 3.2 km, some of which started additional fires in wooded areas at this distance. The blast could be felt 40 km away. A student at a school over 800 m away was injured by glass fragments.

4. Port Colborne, Canada, August 9, 1919 (Wikipedia)

   The Port Colborne explosion at Port Colborne, Ontario, Canada, was a grain dust explosion in an elevator on August 9, 1919. The elevator was within a concrete structure.

   The explosion sent flames hundreds of feet in the air (e.g. at least 60 m) and debris was blown 2.4 km away.

Given the above four dust explosion events then projectiles can travel up to 3.2 km, i.e. there is the potential to impact people, businesses and/or structures off-site. The likelihood for these types of events is estimated in the following Section of this report.

6.2 LIKELIHOOD ANALYSIS

A summary of historical dust explosions is given in Eckhoff (Ref 8). More recent data (the US Occupational Safety and Health Administration) shows that the force from such an explosion can cause employee deaths, injuries and destruction of entire buildings. For example, 3 workers were killed in a 2010 titanium dust explosion in West Virginia, 14 workers were killed in a 2008 sugar dust explosion in Georgia and 6 fatalities occurred in the West Pharmaceutical explosion 2003. The U.S. Chemical Safety and Hazard Investigation Board identified 281 combustible dust incidents between 1980 and 2005 that led to the deaths of 119 workers, injured 718, and extensively damaged numerous industrial facilities.

That is, dust explosions are credible events and can cause significant impacts.

From Ref 9, the damage radius from overpressures of a dust explosion is usually limited to the building (or equipment item) in which it occurs and to a very short range outside. This is supported by the historical incidents involving dust explosions where the majority of fatalities involve on-site personnel.

The majority of dust explosion incidents detailed in Ref 8 resulted in no fatalities. For the incidents where fatalities occurred (e.g. the above US data), these were to on-site personnel. Ref 8 quotes statistics from the USA where, on average, dust explosions result in approximately 5 deaths per year. Historically, about one in six fatalities occur in the food and grain industry.

In practice (Ref 8), the assessment of dust explosion hazards is bound to be subjective because the problem is too complex for quantitative analytical methods to yield an indisputable answer. Therefore, the acceptable safeguards for any given design will vary from company to company. Ref 8 quotes work by Pinkwasser and Haberli who suggest most of the dust explosion hazards in the grain, feed and flour industry can be eliminated by soft means such as training, motivation, improving the organisation, good housekeeping and proper maintenance. All of these safeguards are in-place at Shoalhaven Starches.

The CCPS (Center for Chemical Process Safety) has developed a modified LOPA (Layers of Protection Analysis) methodology for assessing the risk of dust explosions (Ref 10).

LOPA is a simplified semi-quantitative risk analysis tool used to determine how many independent protection layers (IPLs) are needed and how much risk reduction should be applied to each layer. This is achieved by combining the effects of the independent protection layers and comparing the result to risk tolerance criteria.

An IPL is a device, system or action that is capable of preventing a scenario (i.e. not mitigation) from proceeding to its undesired consequence independent of the initiating event or the action of any other layer of protection associated with the scenario. Normally procedural controls such as housekeeping are not allowable as IPLs, however, some of these are taken into consideration in the CCPS dust hazard analysis methodology.

A description of the methodology is given in Appendix E.

For a dust explosion in one of the Shoalhaven Starches buildings, the following initiating event and probabilities are used (see Appendix E for details).

Table 12 - Building Dust Hazard CCPS Likelihood

	Value	Comments
Initiating Event: Loss of containment of dust sufficient to cause a combustible atmosphere	0.01/yr	The value for “Existence of a combustible atmosphere at a bagging station” is used for the buildings
Enabling Condition:	1	The processes are assumed to be operating close to 365 days per year
IPL 1: Area classification to lower the risk of ignition	0.1	All equipment is designed to Australian and ATEX Standards
IPL 2: Preventative maintenance (PM) to maintain bonding and grounding of the equipment	0.1	PMs are allowed in addition to the design IPL (IPL 1 above)
Conditional Modifier 1: Occupancy: There are 2 or more people present 50% of the time	0.5	Based on site experience

	Value	Comments
Conditional Modifier 2: Probability of ignition	0.1	Agricultural dusts have a minimum ignition energy of more than 10 mJ. This conditional modifier allows for sources of ignition other than static, and faulty electrics and instruments (as included above)
Total:	$5x10^{-6}$/yr	

That is, use of the CCPS methodology yields a likelihood value of approximately $5x10^{-6}$/yr for two or more on-site fatalities. For a 'Catastrophic' consequence rating (i.e. two or more on-site fatalities), the risk level is II (see the risk matrix in Appendix E).

This is a moderate level of risk. This area is the beginning of the ALARP region (i.e. as low as reasonably practicable). As the buildings and equipment are designed to the relevant Australian and International Standards (e.g. IECEx), there are controls to lower the likelihood of ignition (e.g. hazardous area compliant equipment and permits to work) and there is a continuous housekeeping programme to maintain cleanliness then there are no further practical measures recommended to economically lower the risk.

Using the data in Table 12, the likelihood of a building dust explosion is in the order of $5x10^{-6}$/yr / 0.5 = $1x10^{-5}$/yr, i.e. the 0.5 probability for two or more people being present is removed from the calculation.

The estimated building dust explosion likelihood of $1x10^{-5}$/yr is typical for industry experience, i.e. building dust explosions do occur but they are low frequency events. As this value is below the individual fatality risk criterion in Table 8 for risk to be contained within the boundary of an industrial site, i.e. $50x10^{-6}$/yr, then this criterion is satisfied. Correspondingly, the risk of propagation from overpressures and/or projectiles is also acceptably low.

Given the analysis in this Section of the report, i.e. Section 6, then the risk criteria shown in Table 8 are all satisfied for building explosions.

7 RISK ANALYSIS – EQUIPMENT DUST EXPLOSIONS

Many of the process equipment items handling combustible dusts at the site are protected by explosion vents. These are either flameless or directly vented to atmosphere. The typical vent rupture pressure is 10 kPa, and the majority of protected equipment items have relatively small volumes, therefore, propagation or adverse impacts from high overpressures (when the vents open) are not expected.

Based on the site visits and plant reviews performed by Pinnacle Risk Management, there is only one set of non-flameless explosion vents that could pose an off-site impact risk, i.e. the explosion vents for GD8 (in Zone 9). These vents are directed to the north from GD8, i.e. towards Bolong Road.

The dust explosion modelling results for this set of vents is shown in Table 13. The same modelling methodology as per the building dust explosions was used, i.e. using the correlations in EN14491.

A discussion of the modelling results is provided following Table 13.

Table 13 – GD8 Dust Explosion Vents Modelling

Scenario	P_{Max} (kPa)	Volume (m^3)	Opening		Flame Length (m)	Distance (m) to the Nominated Overpressures (1)		
			Area (m^2)	Perimeter (m)		21 kPa	14 kPa	7 kPa
Zone 9:								
Gluten Dryer 8 Baghouse Filter 11 - Dust Explosion There are 14 rupture discs. These vent to the north at approximately 16.5m aboveground level	30 (2)	405	11.9	51.5	25	< 10	13	20

Notes:
1. Distances are from the building or equipment item walls.
2. P_{Max} based on measured values.

Given the results from the explosion vent modelling for the GD8 Baghouse Filter Number 11 and that the distance from these vents to the nearest off-site area (Bolong Road) is approximately 35 m then no significant off-site effects are expected if these vents' discharge flames. There are also no structures or plant that could be impacted by flames, i.e. no risk of propagation.

Typically, the diameter of a flame from an explosion vent is approximately 0.5 to 1 times the estimated length. Given the estimated flame length in Table 13 (25 m) and the heights of the vents then the flames are not expected to reach ground level or head height, i.e. reducing the impact to people walking in these areas. This on-site propagation impact is also lessened as a deflector plate has been installed in front of these vents, i.e. the vented flames are directed upwards and therefore away from ground level.

Therefore, the GD8 explosion vents do not contribute to off-site and on-site propagation risks and the risk criteria shown in Table 8 are therefore satisfied.

8 RISK ANALYSIS – ETHANOL DISTILLERIES

There are a number of scenarios in the ethanol distilleries that can lead to off-site impact, i.e.:

- Liquid releases at the ethanol storage, day tanks and distilleries that could lead to flash fires and/or pool fires
- A release at the road tanker unloading bay that could lead to a flash fire and/or pool fire
- Vapour releases from the pressurised piping and vessels in the distilleries. These can lead to flash fires or explosions.

Given the diversity of the potential events then the risk from this area of the site (i.e. the "Ethanol Distillery") is assessed via a quantitative risk analysis (QRA).

A description of QRA is provided in Appendix F.

The meteorology used in the modelling is provided in Appendix G.

The consequence calculations and results are provided in Appendix H.

The likelihood determinations are provided in Appendix I.

The results of the QRA are shown in the following figure.

Figure 8 – QRA Individual Fatality Risk Contours

Key:

Orange Contour = 1 pmpy

Red Contour = 50 pmpy

The main conclusion from the QRA is that the individual fatality risk of 50 pmpy remains onsite, i.e. satisfying the industrial fatality risk criterion shown in Table 8.

The other individual fatality risk and injury risk criteria are satisfied given the generous separation distances, e.g. the nearest residential area is approximately 500 m from the Ethanol Distilleries. There are no significant toxicity risks from the Ethanol Distilleries. The only nearby industrial facility is the BOC Carbon Dioxide Plant on the north side of Bolong Road. This is approximately 60 m from the Ethanol Distillery. The consequential impact analyses in Appendix H show that the following events could impact this location from radiant heat:

- Isotank BLEVE (likelihood of 4.8×10^{-7} per year)
- Flash fires from 50 mm holes (vessels or piping) (F1.5 weather / wind only)
- Flash fires from large ethanol vapour releases from the Stages 2, 4, 5 and 7 vessels or piping (neutral and stable weather conditions only).

Using the likelihood data in Appendix I (including the weather / wind probabilities), the cumulative likelihood for the 50 mm holes scenarios that could impact the BOC site is 1.7×10^{-7} per year and the cumulative likelihood for the large ethanol vapour release scenarios is 3.3×10^{-7} per year.

The total likelihood for exceeding 23 kW/m^2 at the BOC site is then:

$$4.8 \times 10^{-7} + 1.7 \times 10^{-7} + 3.3 \times 10^{-7} = 1 \times 10^{-6} \text{ per year.}$$

This is less than the 50 pmpy criterion in Table 8.

Therefore, all risk criteria in Table 8 are satisfied.

9 PIPELINE RISK ANALYSIS

There are two main flammable gases being conveyed through pipelines within the site, i.e.:

- Natural gas. There is a 2.1 barg pipe network supplying natural gas to the dryers and boilers, and another 40 barg pipe supplying natural gas to the Cogeneration Plant
- Biogas from the WWTP. This is a low-pressure system, e.g. 0.55 barg, that supplies this gas to some of the boilers.

As per the UK's Pipelines Safety Regulations 1996, only pipelines conveying a hazardous fluid such as a fluid which is flammable in air and (or is to be) conveyed in the pipeline as a gas at above 7 barg or as a liquid with a boiling point below 5 C need to be assessed.

However, both the risks from the 2.1 barg and 40 barg natural gas piping systems have been previously assessed (Ref 11) and determined to be compliant with the risk criteria in Table 8. To avoid repetition, these analyses have not been reproduced in this report.

As the pressure within the biogas piping system is lower than the above two natural gas systems then the risk of biogas releases leading to jet and flash fires, and possible explosions is corresponding low and acceptable.

The biogas can contain up to a maximum hydrogen sulphide concentration of 9,000 ppm. As hydrogen sulphide is a toxic gas then releases have the potential for irritation, injury and fatal impacts.

The risk of biogas hydrogen sulphide releases has also been previously assessed (Ref 12) and determined to be compliant with the risk criteria in Table 8. As with the previous natural gas assessments, to avoid repetition, the hydrogen sulphide analysis has not been reproduced in this report.

The main reason for the compliant risk from the pipelines is that they are designed to AS4041 (the Australian Standard for Pressure Piping).

10 WWTP Biogas Hydrogen Sulphide Releases

The biogas can contain up to a maximum concentration of 9,000 ppm. As hydrogen sulphide is a toxic gas then releases have the potential for irritation, injury and fatal impacts.

Hydrogen sulphide is a toxic, flammable and corrosive gas with a 'rotten egg' odour.

Hydrogen sulphide has a flammable range in air of 4% to 44%, i.e. well above the 0.9% in the biogas.

The time-weighted average (for eight hours) for hydrogen sulphide is 10 ppm (14 mg/m^3) and the Short Term Exposure Limit (STEL) is 15 ppm (21 mg/m^3). At low concentrations of hydrogen sulphide (50 to 500 ppm) irritation of the mucous membranes and respiratory tract can occur. At higher concentrations (600 ppm) nausea, dizziness and oedema occur. The concentration identified as dangerous for periods of half to one hour is 400-700 ppm. Prolonged exposure at 250 ppm can result in pulmonary oedema (build-up of fluid in the lungs). Lethal hydrogen sulphide toxicity following inhalation of 1,000 to 2,000 ppm paralyses the respiratory system and breathing ceases. Loss of sense of smell can occur at concentrations of 150 to 200 ppm.

800 ppm is the generally accepted lethal concentration for 50% of an exposed human population for 5 minutes exposure (LC50).

Some further details on concentrations and effects are given below:

- 0.0047 ppm is the recognition threshold of human smell, the concentration at which 50% of humans can detect the characteristic odour of hydrogen sulphide
- 10-20 ppm is the borderline concentration for eye irritation
- 50-100 ppm leads to eye damage
- At 150-250 ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger
- 320-530 ppm leads to pulmonary edema with the possibility of death
- 530-1,000 ppm causes strong stimulation of the central nervous system and rapid breathing, leading to loss of breathing (i.e. death)
- Concentrations over 1,000 ppm cause immediate collapse with loss of breathing, even after inhalation of a single breath.

The following information is used to define the hydrogen sulphide levels for irritation, injury and fatality. Injury impact duration (Table 8) is defined as "a relatively short period of exposure". This is taken to be 10 minutes.

The toxicity effects of hydrogen sulphide (H_2S) are summarised in Table 14.

Table 14 - Effects of Hydrogen Sulphide

Exposure Level (ppm)	Duration (minutes)	Effects
0.75	10	AEGL 1
41		AEGL 2
76		AEGL 3

The three AEGL (Acute Emergency Guideline Levels) tiers are defined as follows:

- **AEGL - 1** is notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL - 2** is irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL - 3** is life-threatening health effects or death.

Given the above definitions, AEGL 1 (0.75 ppm) and 2 (41 ppm) are taken as the limits for irritation and injury, respectively. AEGL 3 is taken for potential fatality although this is conservative given the above information, e.g. 50-100 ppm leads to eye damage.

Assuming a worst-case release, i.e. a release between the biogas fan and the biogas scrubbers occurs (i.e. where there is positive pressure) and maximum biogas flows then the release rate of hydrogen sulphide is estimated as follows:

$$H_2S_{Flow} = 5{,}000 \text{ m}^3\text{/hr} \times 0.009 = 45 \text{ m}^3\text{/hr} = 0.013 \text{ m}^3\text{/s}$$

Note that the covered digester operates at a negative pressure (i.e. this is on the suction side of the biogas fan) so any holes in the cover will result in air ingress. If such an event occurs then detectors will divert the biogas to flare.

The density of hydrogen sulphide at atmospheric conditions is 1.36 kg/m^3. The hydrogen sulphide mass rate is:

$$Mass_{Hydrogen\ Sulphide} = 0.013 \times 1.36 = 0.018 \text{ kg/s}$$

The modelling of this release for the dominant weather / wind conditions (see Appendix G) is shown in Table 15. The modelling was performed using EFFECTS.

Table 15 – Hydrogen Sulphide Release Modelling

Atmospheric Stability / Wind Speed (m/s)	Distance (m) to:		
	AEGL-1 (0.75 ppm)	AEGL-2 (41 ppm)	AEGL-3 (76 ppm)
A2	285	35	20
B3	370	40	25
C5	420	40	25
D5	660	60	40
E3	1,400	125	80
F1.5	4,300	340	230

The nearest residential property to the WWTP is approximately 830 m away (to the east). Correspondingly, off-site injury and fatality impacts are not expected. It is possible that irritation impact could occur if a release takes place and the wind is blowing towards the receptor for the E3 and F1.5 combinations. The maximum plume width for both these weather / wind combinations is approximately 100 m (at approximately 1,000 m downwind from the release point).

The estimate of the cumulative likelihood for irritation impact is shown in Table 16. The estimated likelihood is 1.45×10^{-7} times per year. This is below the HIPAP 4 irritation criterion of 50×10^{-6} per year. Therefore, this criterion is satisfied.

The following table shows the estimated likelihood calculations for irritation impact at the closest residential area to the WWTP.

Table 16 – WWTP Biogas Hydrogen Sulphide Releases Risk Analysis

	Likelihood of Pipe Release, times/yr.km	Pipe Length, km	Weather / Wind	Total Weather / Wind Probability	Impact Direction Probability	Likelihood of Irritation Impact, times per year	Comments
Irritation Impact from Hydrogen Sulphide	2.00E-05	1	E3	0.069	0.02	2.76E-08	Wind direction is from the west, i.e. to impact the nearest residential area
	2.00E-05	1	F1.5	0.155	0.038	1.18E-07	
Total						**1.45E-07**	

11 TRANSPORT RISKS

Of the Dangerous Goods listed in Table 5 and Table 6, the following two exceed the Applying SEPP 33 (Ref 3) criteria (see the table below):

- ➢ Ethanol (Dangerous Good Class 3, Packing Group II
- ➢ Corrosives (Dangerous Good Class 8).

Table 17 – Applying SEPP 33 Transportation Screening Thresholds

	Vehicle Movements		Minimum Quantity*	
	Cumulative	Peak	Per load (tonne)	
Class	Annual	Weekly	Bulk	Packages
1	See Note	See Note	See Note	
2.1	> 500	> 30	2	5
2.3	> 100	> 6	1	2
3PGI	> 500	> 30	1	1
3PGII	> 750	> 45	3	10
3PGIII	> 1,000	> 60	10	No Limit
4.1	> 200	> 12	1	2
4.2	> 100	> 3	2	5
4.3	> 200	> 12	5	10
5	> 500	> 30	2	5
6.1	All	All	1	3
6.2	See Note	See Note	See Note	
7	See Note	See Note	See Note	
8	> 500	> 30	2	5
9	> 1,000	> 60	No Limit	

Note: Where proposals include materials of Class 1, 6.2 or 7, the Department of Planning should be contacted for advice. Classes used are those referred to in the Dangerous Goods Code and are explained in Appendix 7 (of Applying SEPP 33).

* If quantities are below this level, the potential risk is unlikely to be significant unless the number of traffic movements is high.

Ethanol transportation risk has been assessed for the Manildra ethanol and methanol storage and handling facility being built at Port Kembla (Ref 13). This transportation risk assessment only includes the ethanol transport from the Manildra Bomaderry site to the Port Kembla terminal, i.e. it does not include all the existing ethanol vehicle movements to various customers throughout Australia. The risk associated with these existing vehicle movements is controlled as detailed below.

The approximate current movements (per year) for the corrosives that are delivered to the site are:

- Sodium hydroxide (50wt%) x 333 @ 25 te per load
- Hydrochloric acid (32wt%) x 170 @ 20 kL per load
- Sodium hypochlorite (12wt%) x 145 @ 20 kL per load.

That is, the total number of Class 8 vehicle deliveries per year to the site is 333 + 170 + 145 = 648. This total is above the Applying SEPP 33 criterion of greater than 500 annual truck movements for Class 8 corrosives.

In addition to the above listed corrosives, nitric acid at 68 wt% will be delivered to site via a road tanker. The frequency of deliveries is expected to be two times per month or 24 times per year. This will yield a total of 672 Class 8 vehicle deliveries per year.

The nitric acid road tanker will be compliant with the relevant Australian Standards, the road tanker driver will be a licensed Dangerous Goods driver and the delivery company will have its own safety management system for Dangerous Goods deliveries and emergencies.

There are other Class 8 materials delivered in 1,000 L IBC's but the volumes are significantly less than the above.

Causes for road tanker accidents are summarised in Table 18 (Ref 14). These are typical for most roads throughout Australia.

Table 18 - Causes for Road Tanker Accidents

Human Error	Equipment Failures	System or Procedural Failures	External Events
• driver impairment, e.g. alcohol or drugs • speeding • driver overtired • driver exceeding safe working hours • en-route inspection • contamination • overfilling • other vehicle's driver • taking tight turns/ramps too quickly (overturns) • unsecured loads	• non-dedicated trailer • rail road crossing guard failure • leaking valve • leaking fitting • brake failure • relief device failure • tyre failure • soft shoulder • overpressure • material defect • steering failure • sloshing • high centre of gravity • corrosion • bad weld • excessive grade • poor intersection design • road chamber/width • suspension system • tyre fire caused by friction, brakes overheating or exploding tyres give sparks due to metal in the rubber) • fuel tank fire (diesel)	• driver incentives to work longer hours • driver training • carrier selection • container specification • route selection • emergency response training • speed enforcement • driver rest periods • maintenance • inspection • time of the day restrictions	• vandalism/sabotage • rain • fog/visibility • wind • flood/washout • fire at rest area/parking areas • earthquake • existing accident • animals on road

The significant consequential impacts of a road tanker accident are as follows:

- Injury and possible fatality to the driver and others involved in the accident
- Injury, and property and environmental impact if a loss of containment of ethanol occurs and is ignited, i.e. due to radiant heat impact from a pool or flash fire
- Environmental impact if a loss of containment occurs and the corrosives or ethanol flows into an environmentally sensitive area.

For potential ethanol pool fires, Ref 13 shows that the distance to 4.7 kW/m^2 is approximately 11 m from the edge of the fire, i.e. if there is development close to the road where an accident occurs and a release ignites then adverse radiant heat impact to people and/or property is possible.

The main Dangerous Goods transportation safeguards are as follows and further detailed below:

- Road tankers compliant with the Australian Standards. This includes routine preventative maintenance
- Licenced drivers
- All roads that are used are approved by the NSW government

- Routes are chosen based on operational factors such as the least distance to travel
- Ethanol and corrosives are transported in compliance with the Australian Dangerous Goods Code which includes the mandatory the requirements for emergency response to incidents.

Emergency Response:

The core objectives of the existing Manildra Transport Emergency Response Plan (TERP) are to:

- Minimise adverse effects on employees and the general public, damage to property, or harm to the environment during an emergency
- Facilitate a rapid and effective response, and recovery from an incident
- Provide assistance to emergency services
- Communicate vital information to relevant personnel, both internal and external to the Manildra Group.

This TERP is produced in accordance with Regulation 14.5 of the Road Transport Reform (Dangerous Goods) Regulations 1997, and the Australian Dangerous Goods (ADG) code.

Ethanol Driver Selection:

All ethanol drivers undergo rigorous assessments before and during employment which consists of driving assessments, and loading and unloading assessments. To maintain employment within the Manildra Group, drivers are responsible to maintain currency of the necessary class of Heavy Vehicle licence and any other necessary qualifications, e.g. Dangerous Goods Licence and Safe Load Program (SLP) Loading Pass.

Placarding:

The vehicles carrying ethanol are designed for the sole purpose of transporting Class 3 Dangerous Goods. Vehicle placarding is positioned as per the ADG Code requirements in the form of Emergency Information Panels (EIP's). Placarding is also required for the vehicles carrying corrosives as per the ADG Code.

Given the above safeguarding and the multiple number of locations where the existing corrosives are sourced from, and ethanol is delivered to, then no further assessment via a Draft Route Selection study is recommended.

12 RISK ASSESSMENT SUMMARY

12.1 PROPAGATION RISK

Based on the assessment in this report, on-site propagation is possible, in particular, for the following events:

- Building dust explosions (this includes overpressures and projectiles)
- Fires, e.g. silo fires leading to structural collapse or an explosion
- Fires and explosions in the Ethanol Distilleries
- Flammable gas pipeline failures and subsequent ignition.

Should a building dust explosion occur then it is expected that the building will be severely damaged and the propagation impacts may include further damage to structures and equipment and other process safety events such as further dust explosions, gas explosions, fires and/or releases of harmful materials and energy. These events can impact people, the environment, property and the business.

From Section 6, the estimated building dust explosion likelihood of $1x10^{-5}$/yr is typical for industry experience, i.e. building dust explosions do occur but they are low frequency events. This value is below the individual fatality risk criterion for risk to be contained within the boundary of an industrial site, i.e. $50x10^{-6}$/yr. Correspondingly, the risk of propagation from overpressures and/or projectiles is also low.

Fires and explosions in the Ethanol Distilleries can lead to propagation both within the Ethanol Distilleries as well as to adjacent plants and structures. A review of the base event likelihoods in Appendix I shows that some events are relatively high, e.g. bund fires for the ethanol bulk storage tanks and denaturant tanks ($1x10^{-3}$ per year), other events have moderate likelihoods (e.g. fires at the ethanol road tanker loadout – $1x10^{-4}$ per year) and most explosions, and jet and flash fires events have relatively low likelihoods (e.g. approximately $1x10^{-6}$ per year and lower). The latter are typical industry values and pose a low risk of propagation provided the installed plant is adequately maintained and operated.

Plant spacing lowers the risk of bund fires for the ethanol bulk storage tanks and denaturant tanks propagating to nearby equipment and structures, i.e. the distances to the 23 kW/m^2 radiant heat level are 23 m and 11 m, respectively, from the centre of the bunds. A similar finding is applied to the ethanol road tanker loadout bay, i.e. there is both adequate spacing to the nearby plants, and the adjacent denaturant tanks are protected by a brick wall and an automatic deluge system.

A fire event in any one of the three distilleries can be extinguished by the installed deluge system. This fire protection is designed to lower the risk of propagation as well as limit the damage within the distillery that had the release.

Propagation is also possible due to a release of natural gas or biogas with subsequent ignition. The main reason for the compliant risk from the pipelines and therefore a low propagation risk is that they are designed to AS4041 (the Australian Standard for Pressure Piping). Should such an event occur, e.g. a release and jet fire, then it is possible to isolate all natural gas and biogas lines to prevent propagation as well.

12.2 CUMULATIVE AREA RISK

Based on the building dust explosion modelling (at a likelihood of $1x10^{-5}$ per year with the adverse impacts remaining close to the buildings), the majority of significant consequential impacts remain on the Shoalhaven Starches site (it is noted, however, that some events do cross Bolong Road) and the results of the QRA for the Ethanol Distilleries (see Figure 8) then the site's operations do not significantly increase the risk in the Bomaderry area.

12.3 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.

The site is surrounded by the Shoalhaven River to the south (approximately 400 m wide), the Manildra farm to the north, Manildra properties and farm land to the east, and commercial, industrial and residential land use to the west.

As shown in this study of the Shoalhaven Starches site, the risk of off-site fatality is below the HIPAP 4 risk criteria.

As the nearest houses are approximately 500 m from the Ethanol Distilleries (which is located towards the eastern end of the site) and 300 m from the Cogeneration Plant building (at the western end of the site), and the 1 pmpy contour does not extend beyond Manildra property, then societal risk applying to populated areas is therefore satisfied.

12.4 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. chemical tank transfers and material losses of containment, that can potentially impact the environment.

The potential environmental impact events and their controls are detailed in Appendix B. These include the following:

- Ethanol releases from the Ethanol Distilleries. This includes contaminated fire water
- Large loss of containment of beer from the fermentation tanks
- Waste water releases, e.g. from the piping systems and possibly the WWTP ponds
- Leachate leaks from the biofilters
- Chemical spills (e.g. for the cooling towers and RO systems)
- Raw materials or products spills, e.g. wheat and coal
- Atmospheric emissions, e.g. chemical vapour release, abnormal stack operations or a failed baghouse filter.

Spills of dosing chemicals and ethanol from the process equipment, tanks and adjacent piping are designed to be contained in the bunds and sumps. The bunded areas are sized to contain the entire contents of the largest tank so that a total loss of contents does not spill over the bund. 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, i.e. the WWTP. Any major on-site spills can be contained and managed at the treatment plant.

There are pipes that across Abernethys Creek. These pipes are fully welded to lower the risk of leaks and environmental impact.

The biofilters at the western end of the site could leak leachate onto the ground and potentially into the Shoalhaven River. The integrity of the biofilters containment is routinely checked by local inspections.

There can be vapour emissions, e.g. biogas containing hydrogen sulphide (up to 9,000 ppm), dust from equipment failures, vapours from dosing chemicals, abnormal stack emissions and carbon dioxide from the fermenters.

Hydrogen sulphide releases have been analysed (Section 10) and found to not pose unacceptable off-site risks. The other chemical vapours that can be emitted, e.g. chlorine dioxide, are limited by volume.

The boiler flue gas streams are analysed and vented via stacks. The carbon dioxide is preferentially sent to the BOC and Supagas carbon dioxide plants for purification, liquefaction and transport to the market. Any other carbon dioxide releases are vented at height to avoid ground level impacts, e.g. people suffering headaches.

Given the analysis in this report, the potential vapour releases are not expected to have a significant impact to the environment as they are limited by volume, duration, concentration and/or equipment maintenance.

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.

13 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.

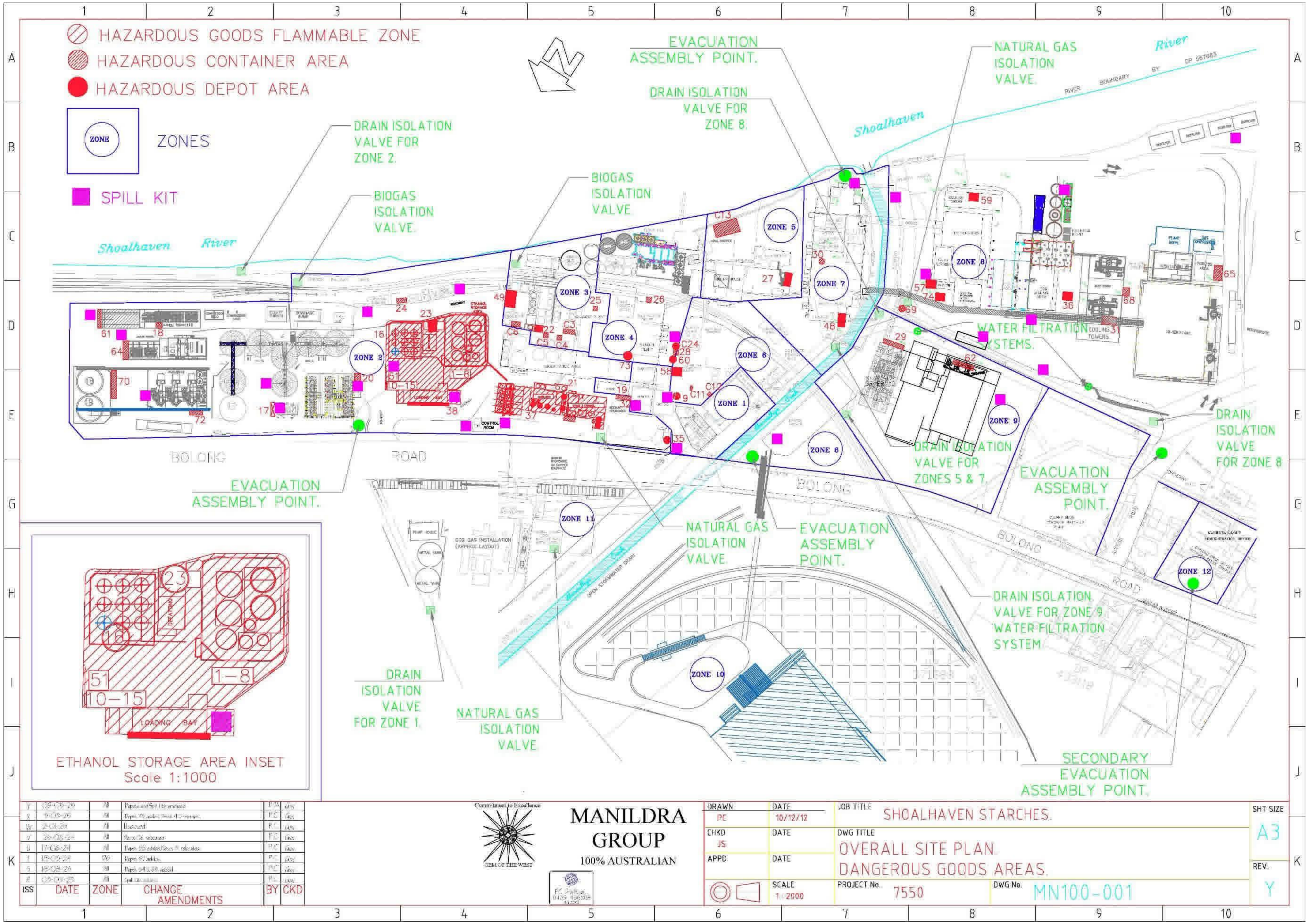
Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year	Yes
Fatality risk to residential and hotels	1×10^{-6} per year	Yes
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year	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

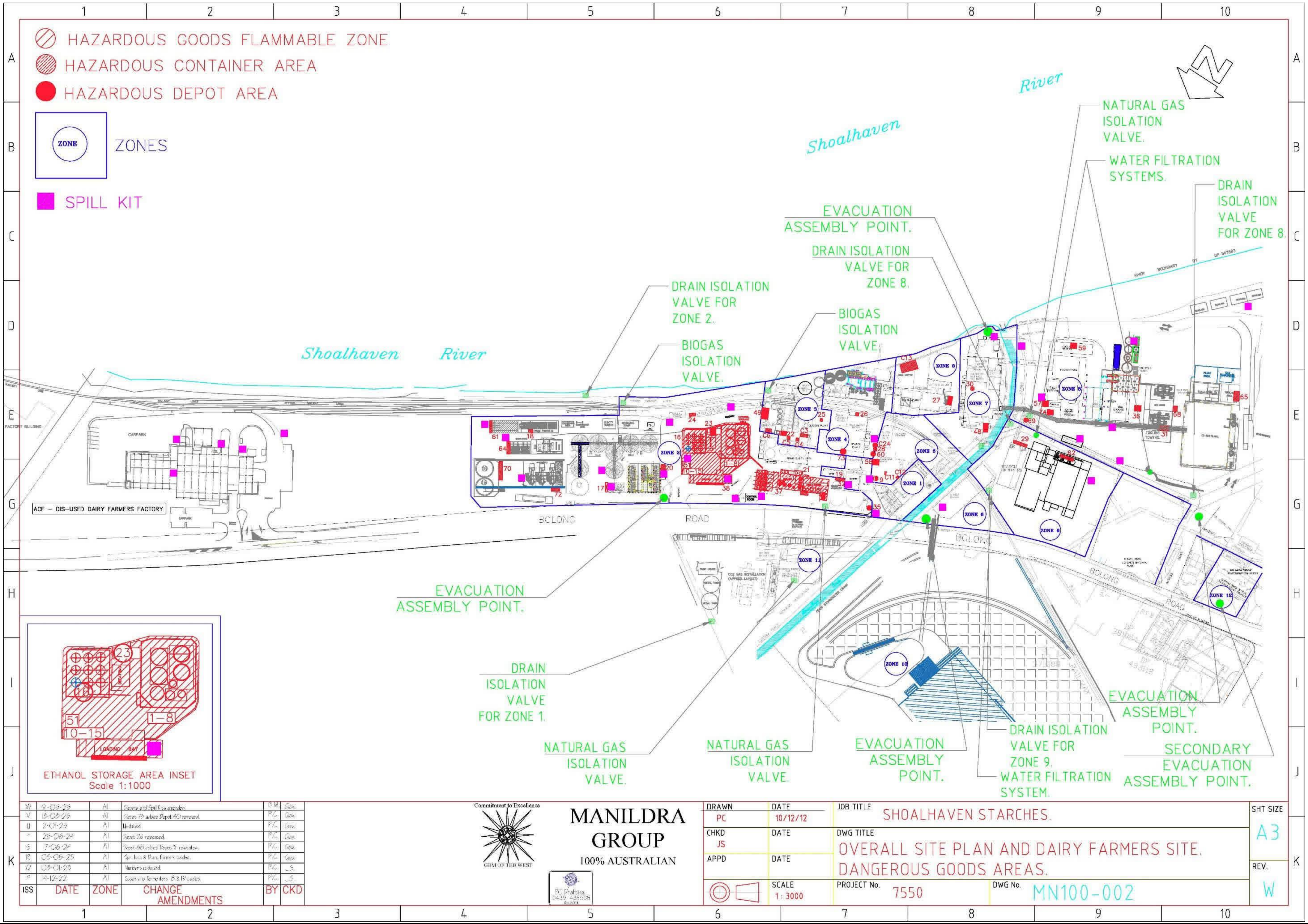
Societal risk, area cumulative risk and environmental risk is also concluded to be acceptable. The primary reason for the low risk levels from the modifications is that significant levels of radiant heat from potential fires, overpressures from dust explosion vents and hydrogen sulphide releases from the biogas system are mostly contained on-site.

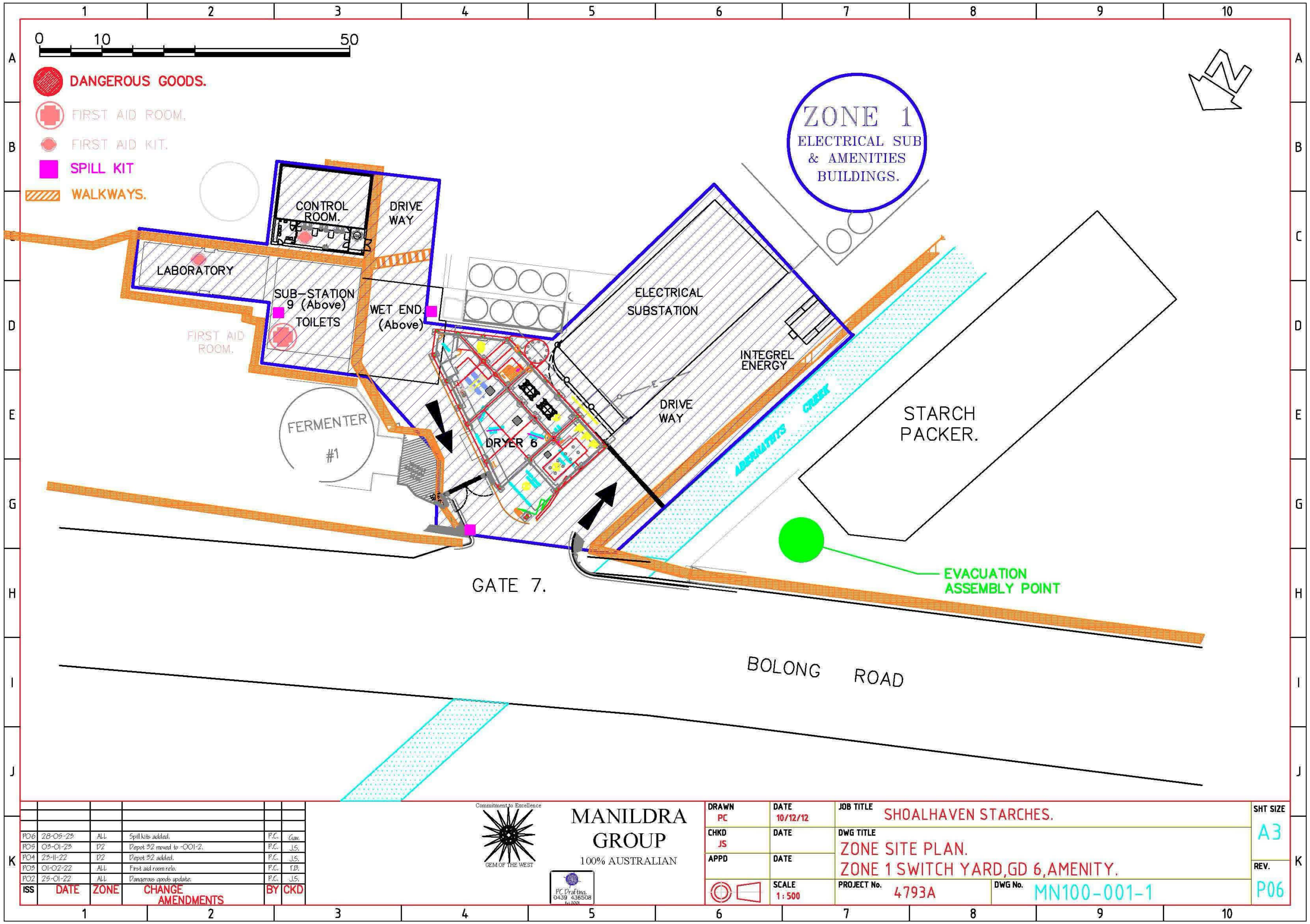
There are no recommendations for the proposed MOD34 grain storage shed.

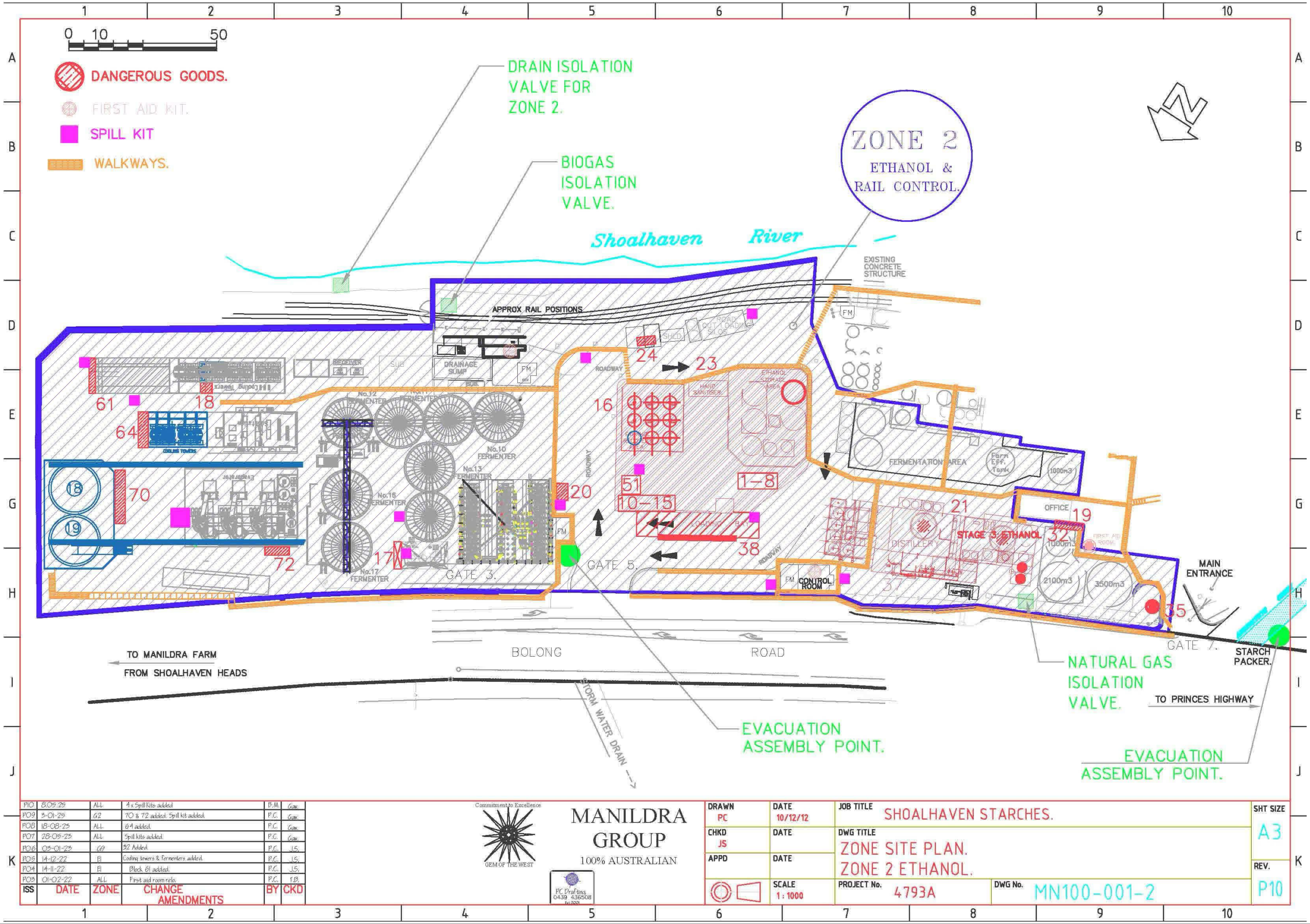
14 APPENDIX A – HAZARD MATERIALS STORAGE LOCATIONS

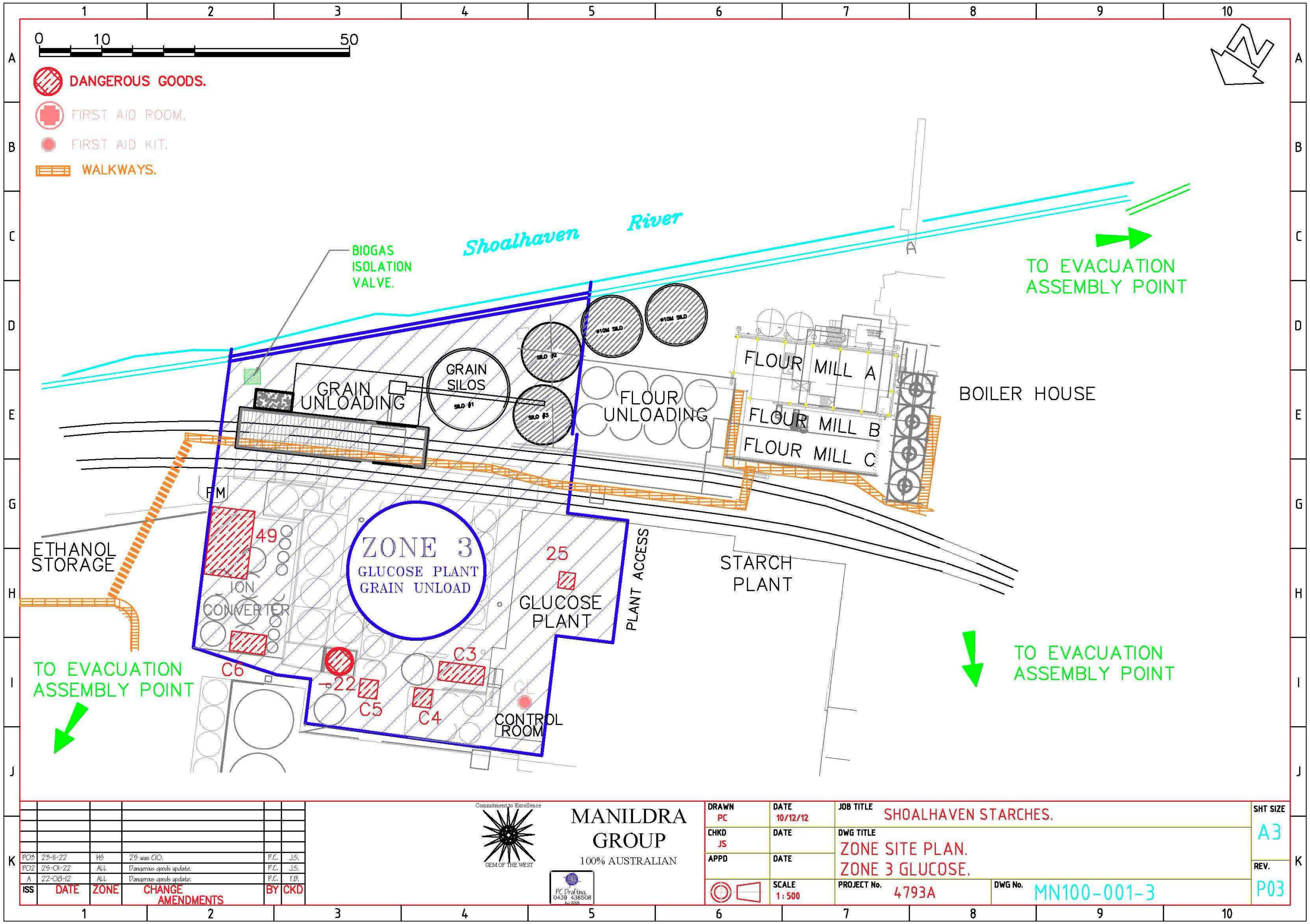
Appendix A – Hazardous Materials Storage Locations

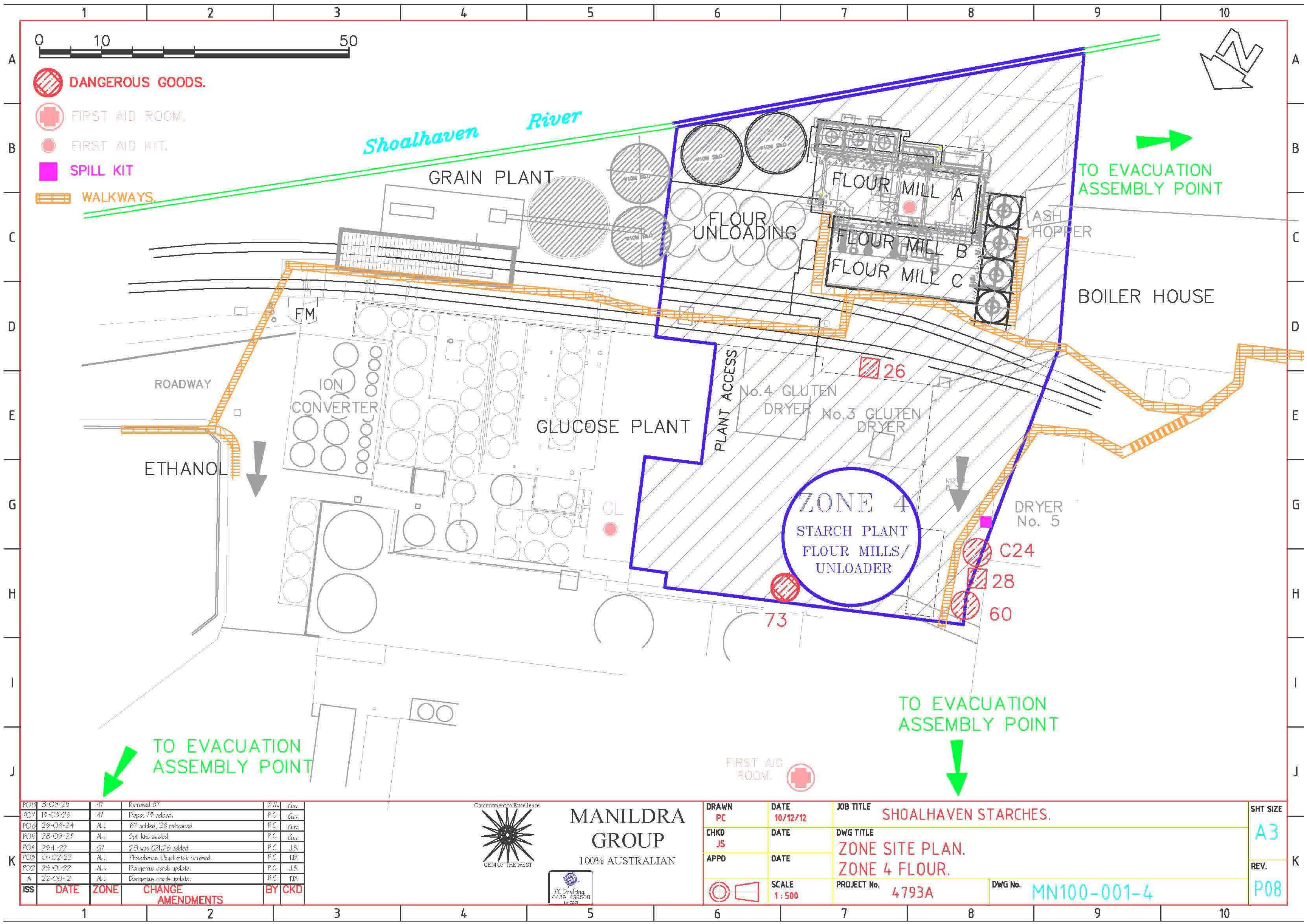


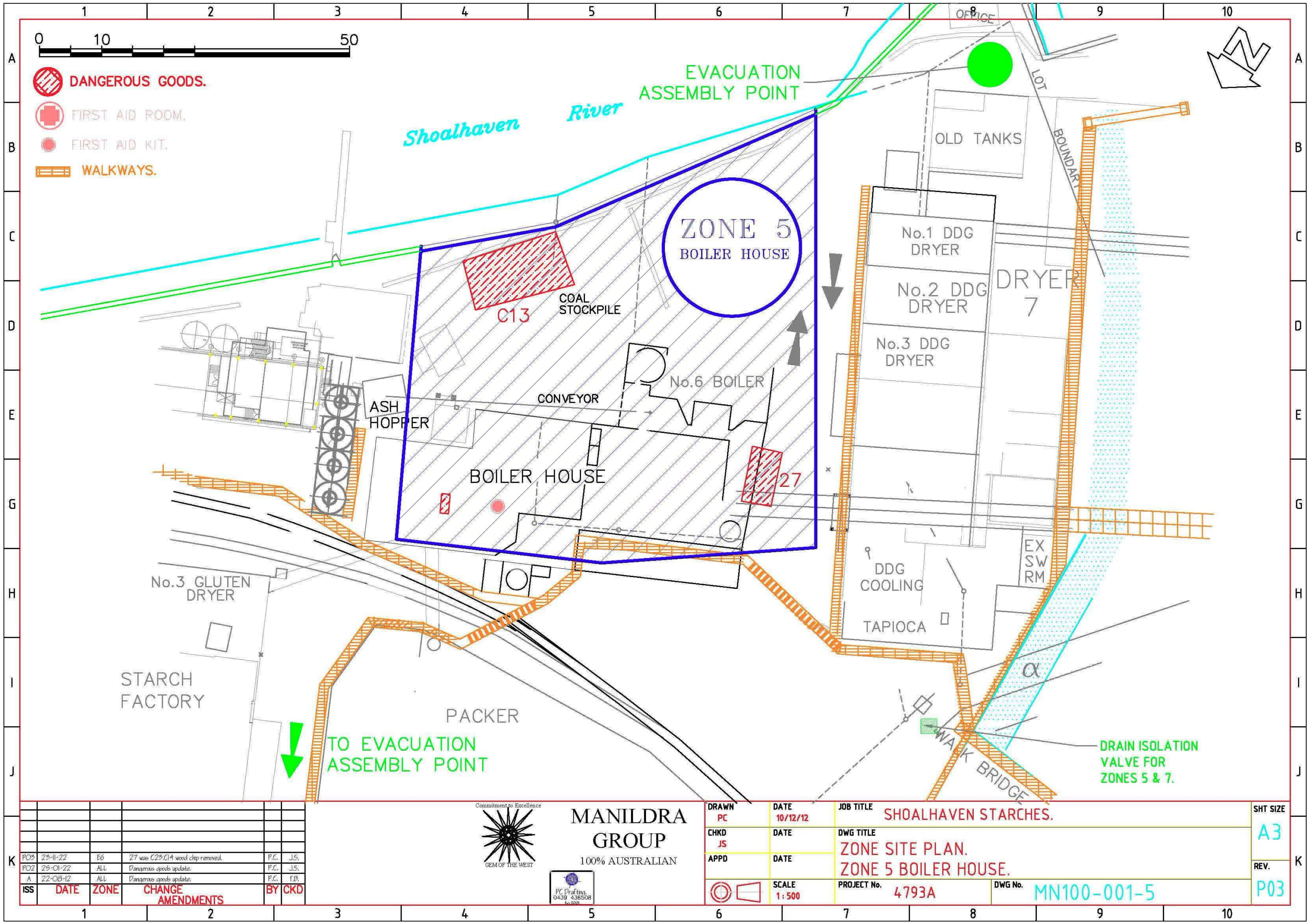

HAZARDOUS GOODS FLAMMABLE ZONE
HAZARDOUS CONTAINER AREA
HAZARDOUS DEPOT AREA
ZONES
SPILL KIT
Shoalhaven River
NATURAL GAS ISOLATION VALVE.
WATER FILTRATION SYSTEMS.
DRAIN ISOLATION VALVE FOR ZONE 8.
EVACUATION ASSEMBLY POINT.
DRAIN ISOLATION VALVE FOR ZONE 2.
BIOGAS ISOLATION VALVE.
EVACUATION ASSEMBLY POINT.
DRAIN ISOLATION VALVE FOR ZONE 1.
NATURAL GAS ISOLATION VALVE.
DRAIN ISOLATION VALVE FOR ZONE 9.
WATER FILTRATION SYSTEM.
SECONDARY EVACUATION ASSEMBLY POINT.
ACF – DIS-USED DAIRY FARMERS FACTORY
BOLONG ROAD
ETHANOL STORAGE AREA INSET
Scale 1:1000
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE OVERALL SITE PLAN AND DAIRY FARMERS SITE. DANGEROUS GOODS AREAS.
SCALE 1:3000
PROJECT No. 7550
DWG No. MN100-002
SHT SIZE A3
REV. W
ISS DATE ZONE CHANGE AMENDMENTS BY CKD


0 10 50
DANGEROUS GOODS.
FIRST AID ROOM.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
ZONE 1
ELECTRICAL SUB & AMENITIES BUILDINGS.
CONTROL ROOM.
DRIVE WAY
LABORATORY
SUB-STATION 9 (Above)
TOILETS
WET END. (Above)
FIRST AID ROOM.
FERMENTER #1
DRYER 6
ELECTRICAL SUBSTATION
INTEGREL ENERGY
DRIVE WAY
STARCH PACKER.
ABERNATHYS CREEK
EVACUATION ASSEMBLY POINT
GATE 7.
BOLONG ROAD
P06 28-05-23 ALL Spill kits added. P.C. Gav.
P05 03-01-23 D2 Depot 32 moved to -001-2. P.C. J.S.
P04 23-11-22 D2 Depot 32 added. P.C. J.S.
P03 01-02-22 ALL First aid room relo. P.C. T.B.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
Commitment to Excellence
GEM OF THE WEST
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC DATE 10/12/12
CHKD JS DATE
APPD DATE
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 1 SWITCH YARD, GD 6, AMENITY.
PROJECT No. 4793A
DWG No. MN100-001-1
SHT SIZE A3
REV. P06

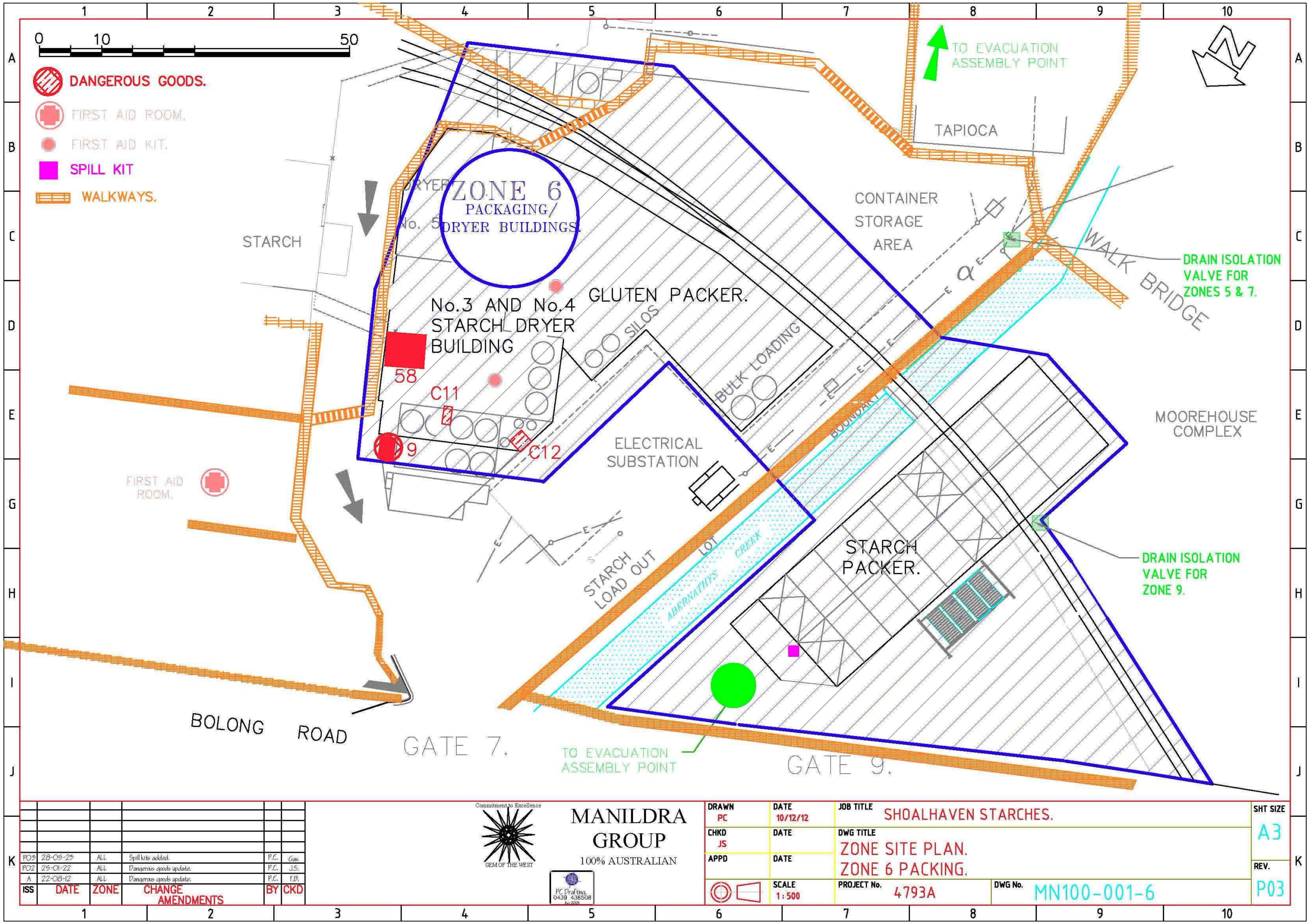

0 10 50
DANGEROUS GOODS.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
DRAIN ISOLATION VALVE FOR ZONE 2.
BIOGAS ISOLATION VALVE.
ZONE 2
ETHANOL & RAIL CONTROL.
Shoalhaven River
EXISTING CONCRETE STRUCTURE
APPROX RAIL POSITIONS
DRAINAGE SUMP
ROADWAY
FERMENTATION AREA
OFFICE
CONTROL ROOM
STAGE 3 ETHANOL
DISTILLERY
GATE 3.
GATE 5.
GATE 7.
MAIN ENTRANCE
STARCH PACKER.
BOLONG ROAD
TO MANILDRA FARM FROM SHOALHAVEN HEADS
STORM WATER DRAIN
EVACUATION ASSEMBLY POINT.
NATURAL GAS ISOLATION VALVE.
TO PRINCES HIGHWAY
EVACUATION ASSEMBLY POINT.
P10 8.05.25 ALL 4 x Spill Kits added
P09 3-01-25 G2 70 & 72 added. Spill kit added.
P08 18-08-23 ALL 64 added.
P07 28-05-23 ALL Spill kits added.
P06 03-01-23 G9 52 Added.
P05 14-12-22 B1 Cooling towers & fermenters added.
P04 14-11-22 B1 Block 61 added.
P03 01-02-22 ALL First aid room relo.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
APPD
SCALE 1:1000
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 2 ETHANOL.
PROJECT No. 4793A
DWG No. MN100-001-2
SHT SIZE A3
REV. P10


DANGEROUS GOODS.
FIRST AID ROOM.
FIRST AID KIT.
WALKWAYS.
Shoalhaven River
BIOGAS ISOLATION VALVE.
TO EVACUATION ASSEMBLY POINT
GRAIN UNLOADING
GRAIN SILOS
FLOUR UNLOADING
FLOUR MILL A
FLOUR MILL B
FLOUR MILL C
BOILER HOUSE
ETHANOL STORAGE
ZONE 3
GLUCOSE PLANT
GRAIN UNLOAD
GLUCOSE PLANT
PLANT ACCESS
STARCH PLANT
ION CONVERTER
CONTROL ROOM
49
25
C3
C4
C5
C6
22
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
APPD
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 3 GLUCOSE.
PROJECT No. 4793A
DWG No. MN100-001-3
SHT SIZE A3
REV. P03
P03 25-11-22 HS 25 was CIO. P.C. J.S.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
A 22-08-12 ALL Dangerous goods update. P.C. T.B.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD

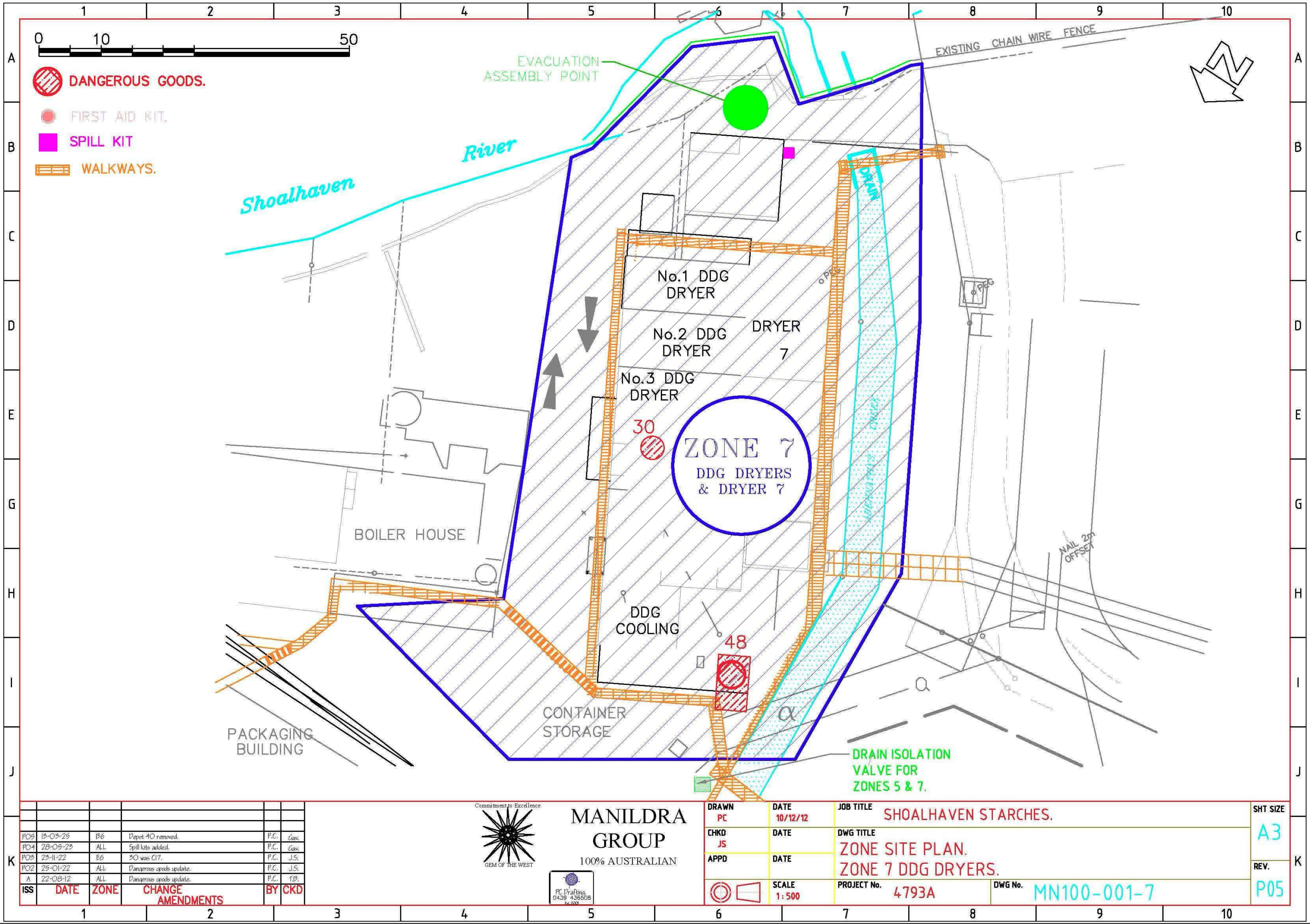

0 10 50
DANGEROUS GOODS.
FIRST AID ROOM.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
Shoalhaven River
GRAIN PLANT
FLOUR UNLOADING
FLOUR MILL A
FLOUR MILL B
FLOUR MILL C
ASH HOPPER
BOILER HOUSE
TO EVACUATION ASSEMBLY POINT
FM
ROADWAY
ION CONVERTER
GLUCOSE PLANT
PLANT ACCESS
No.4 GLUTEN DRYER
No.3 GLUTEN DRYER
26
ETHANOL
GL
ZONE 4
STARCH PLANT
FLOUR MILLS/ UNLOADER
DRYER No. 5
C24
28
60
73
TO EVACUATION ASSEMBLY POINT
TO EVACUATION ASSEMBLY POINT
FIRST AID ROOM.
P08 8-05-25 H7 Removed 67 B.M. Gav.
P07 13-03-25 H7 Depot 73 added. P.C. Gav.
P06 25-06-24 ALL 67 added, 26 relocated. P.C. Gav.
P05 28-05-23 ALL Spill kits added. P.C. Gav.
P04 23-11-22 G7 28 was C21.26 added. P.C. J.S.
P03 01-02-22 ALL Phosphorous Oxychloride removed. P.C. T.B.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
A 22-08-12 ALL Dangerous goods update. P.C. T.B.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
APPD
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 4 FLOUR.
PROJECT No. 4793A
DWG No. MN100-001-4
SHT SIZE A3
REV. P08

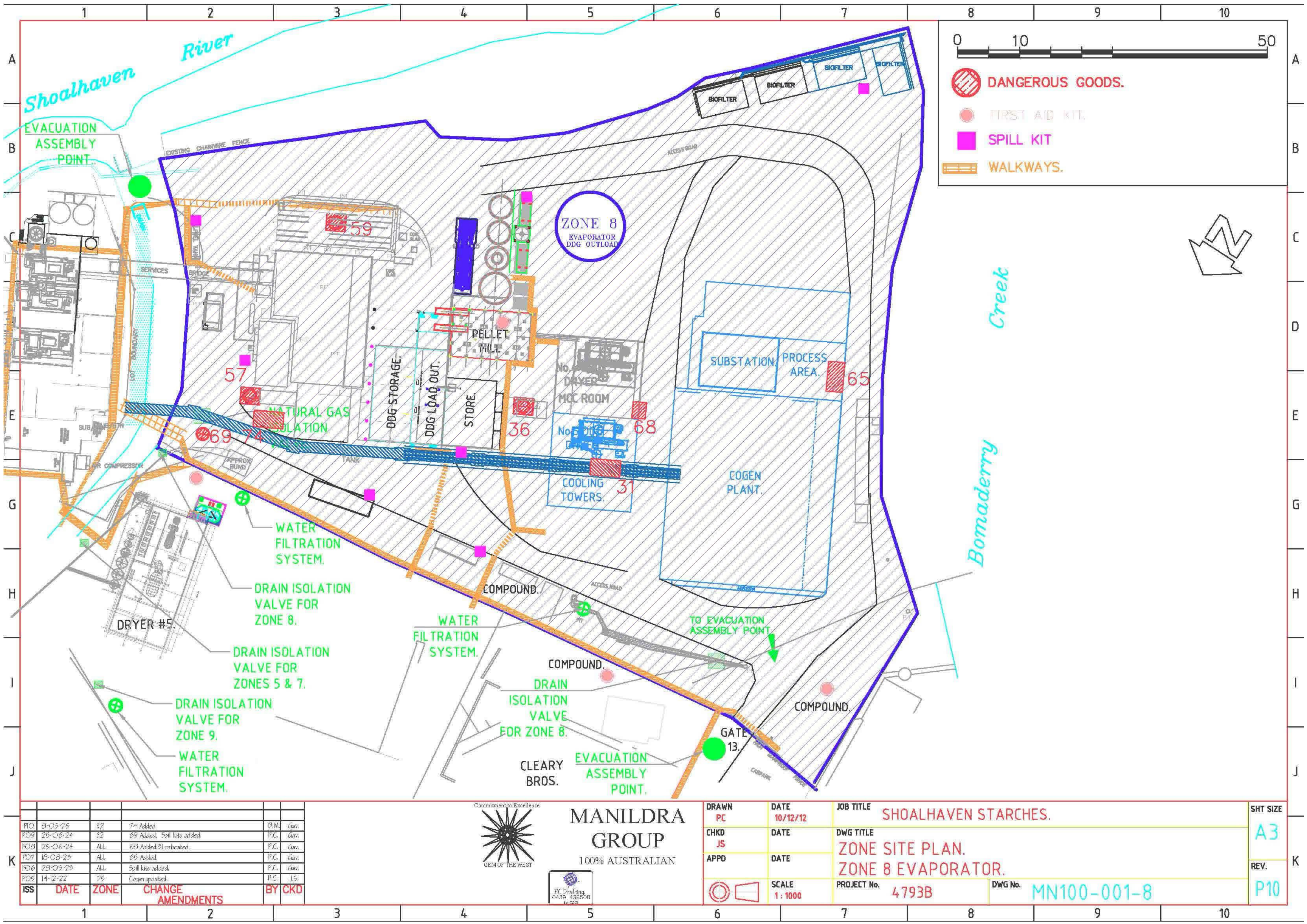


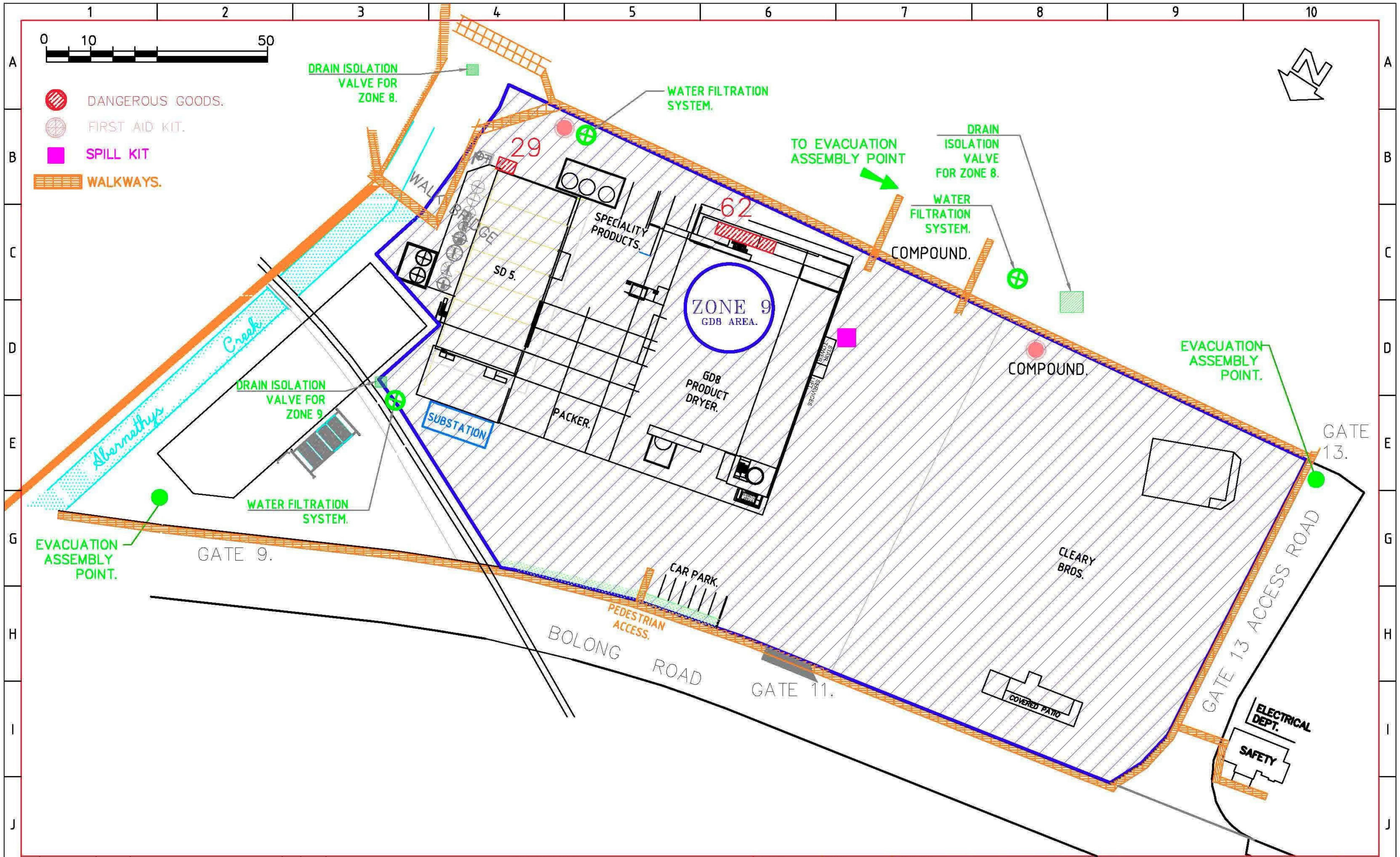
0 10 50
DANGEROUS GOODS.
FIRST AID ROOM.
FIRST AID KIT.
WALKWAYS.
Shoalhaven River
EVACUATION ASSEMBLY POINT
OFFICE
LOT BOUNDARY
OLD TANKS
ZONE 5
BOILER HOUSE
No.1 DDG DRYER
No.2 DDG DRYER
No.3 DDG DRYER
DRYER 7
C13
COAL STOCKPILE
No.6 BOILER
CONVEYOR
ASH HOPPER
BOILER HOUSE
27
EX SW RM
DDG COOLING
TAPIOCA
No.3 GLUTEN DRYER
STARCH FACTORY
PACKER
TO EVACUATION ASSEMBLY POINT
WALK BRIDGE
DRAIN ISOLATION VALVE FOR ZONES 5 & 7.
P03 23-11-22 E6 27 was C23.C14 wood chip removed. P.C. J.S.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
A 22-08-12 ALL Dangerous goods update. P.C. T.B.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
Commitment to Excellence
GEM OF THE WEST
MANILDRA GROUP
100% AUSTRALIAN
PC Drafting. 0439 436508
DRAWN PC
CHKD JS
APPD
DATE 10/12/12
DATE
DATE
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 5 BOILER HOUSE.
PROJECT No. 4793A
DWG No. MN100-001-5
SHT SIZE A3
REV. P03



DANGEROUS GOODS.
FIRST AID ROOM.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
TO EVACUATION ASSEMBLY POINT
TAPIOCA
ZONE 6
PACKAGING/
DRYER BUILDINGS.
DRYER
No. 5
STARCH
CONTAINER
STORAGE
AREA
WALK BRIDGE
DRAIN ISOLATION VALVE FOR ZONES 5 & 7.
No.3 AND No.4 STARCH DRYER BUILDING
GLUTEN PACKER.
SILOS
BULK LOADING
58
C11
C12
9
ELECTRICAL SUBSTATION
BOUNDARY
MOOREHOUSE COMPLEX
FIRST AID ROOM.
STARCH PACKER.
DRAIN ISOLATION VALVE FOR ZONE 9.
STARCH LOAD OUT
LOT
ABERNATHYS CREEK
BOLONG ROAD
GATE 7.
TO EVACUATION ASSEMBLY POINT
GATE 9.
P03 28-05-23 ALL Spill kits added. P.C.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
A 22-08-12 ALL Dangerous goods update. P.C. T.B.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
APPD
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 6 PACKING.
PROJECT No. 4793A
DWG No. MN100-001-6
SHT SIZE A3
REV. P03


0 10 50
DANGEROUS GOODS.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
EVACUATION ASSEMBLY POINT
EXISTING CHAIN WIRE FENCE
Shoalhaven River
DRAIN
No.1 DDG DRYER
No.2 DDG DRYER
DRYER 7
No.3 DDG DRYER
30
ZONE 7
DDG DRYERS & DRYER 7
BOILER HOUSE
NAIL 2m OFFSET
DDG COOLING
48
CONTAINER STORAGE
PACKAGING BUILDING
DRAIN ISOLATION VALVE FOR ZONES 5 & 7.
P05 13-03-25 B6 Depot 40 removed. P.C. Gav.
P04 28-05-23 ALL Spill kits added. P.C. Gav.
P03 23-11-22 E6 30 was C17. P.C. J.S.
P02 25-01-22 ALL Dangerous goods update. P.C. J.S.
A 22-08-12 ALL Dangerous goods update. P.C. T.B.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
Commitment to Excellence
GEM OF THE WEST
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
DATE
APPD
DATE
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 7 DDG DRYERS.
PROJECT No. 4793A
DWG No. MN100-001-7
SHT SIZE A3
REV. P05


Shoalhaven River
EVACUATION ASSEMBLY POINT.
DANGEROUS GOODS.
FIRST AID KIT.
SPILL KIT
WALKWAYS.
ZONE 8
EVAPORATOR DDG OUTLOAD
BIOFILTER
59
PELLET MILL
DDG STORAGE.
DDG LOAD OUT.
STORE.
57
NATURAL GAS ISOLATION
69
74
36
No. 5 DRYER MCC ROOM
68
SUBSTATION
PROCESS AREA.
65
COOLING TOWERS.
31
COGEN PLANT.
Creek
Bomaderry
WATER FILTRATION SYSTEM.
DRAIN ISOLATION VALVE FOR ZONE 8.
DRYER #5.
DRAIN ISOLATION VALVE FOR ZONES 5 & 7.
DRAIN ISOLATION VALVE FOR ZONE 9.
COMPOUND.
TO EVACUATION ASSEMBLY POINT
DRAIN ISOLATION VALVE FOR ZONE 8.
GATE 13.
CLEARY BROS.
EVACUATION ASSEMBLY POINT.
P10 8-05-25 E2 74 Added. B.M. Gav.
P09 25-06-24 E2 69 Added. Spill kits added. P.C. Gav.
P08 25-06-24 ALL 68 Added.31 relocated. P.C. Gav.
P07 18-08-23 ALL 65 Added. P.C. Gav.
P06 28-05-23 ALL Spill kits added. P.C. Gav.
P05 14-12-22 D5 Cogen updated. P.C. J.S.
ISS DATE ZONE CHANGE AMENDMENTS BY CKD
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC DATE 10/12/12
CHKD JS
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 8 EVAPORATOR.
SCALE 1 : 1000
PROJECT No. 4793B
DWG No. MN100-001-8
SHT SIZE A3
REV. P10

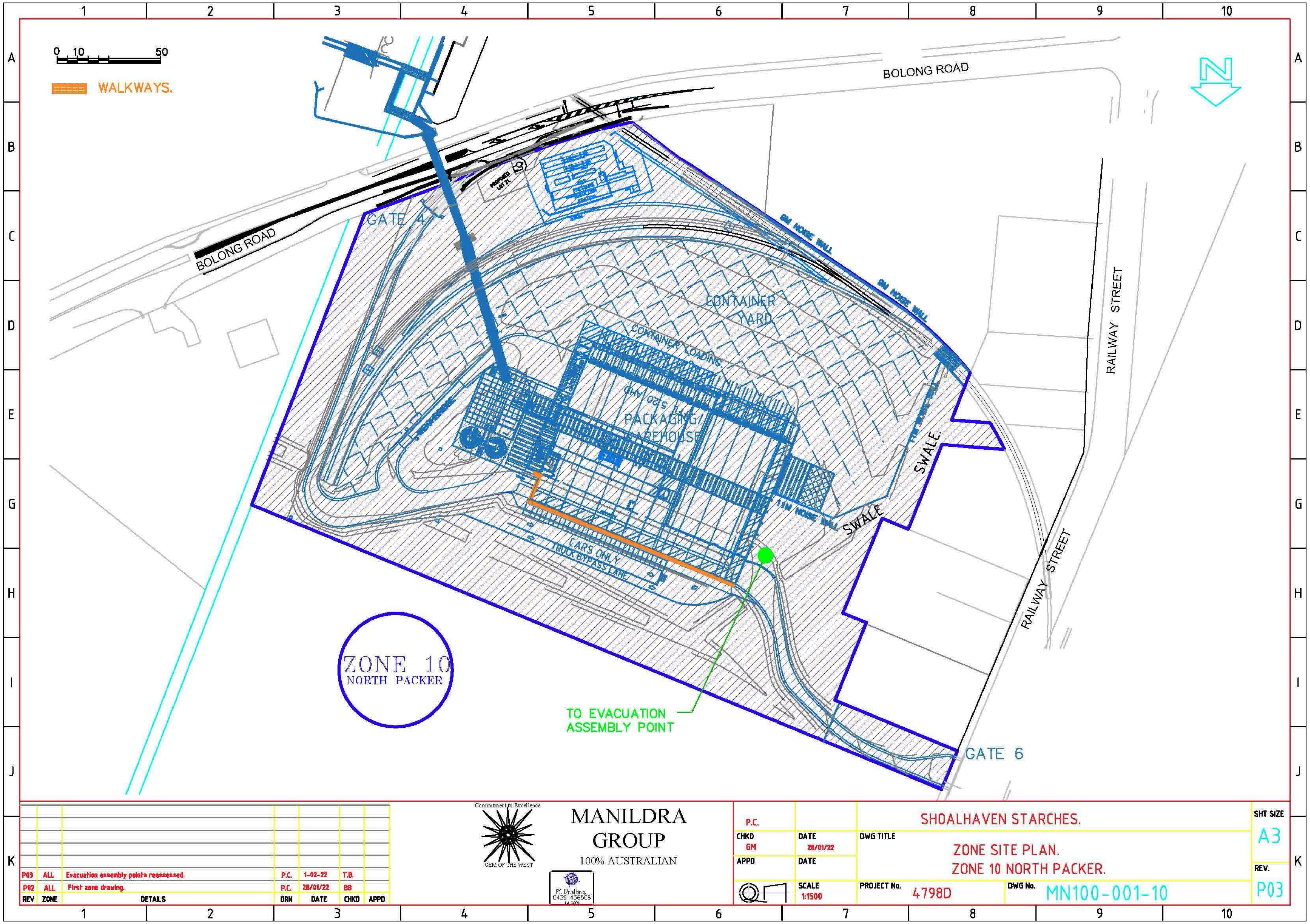


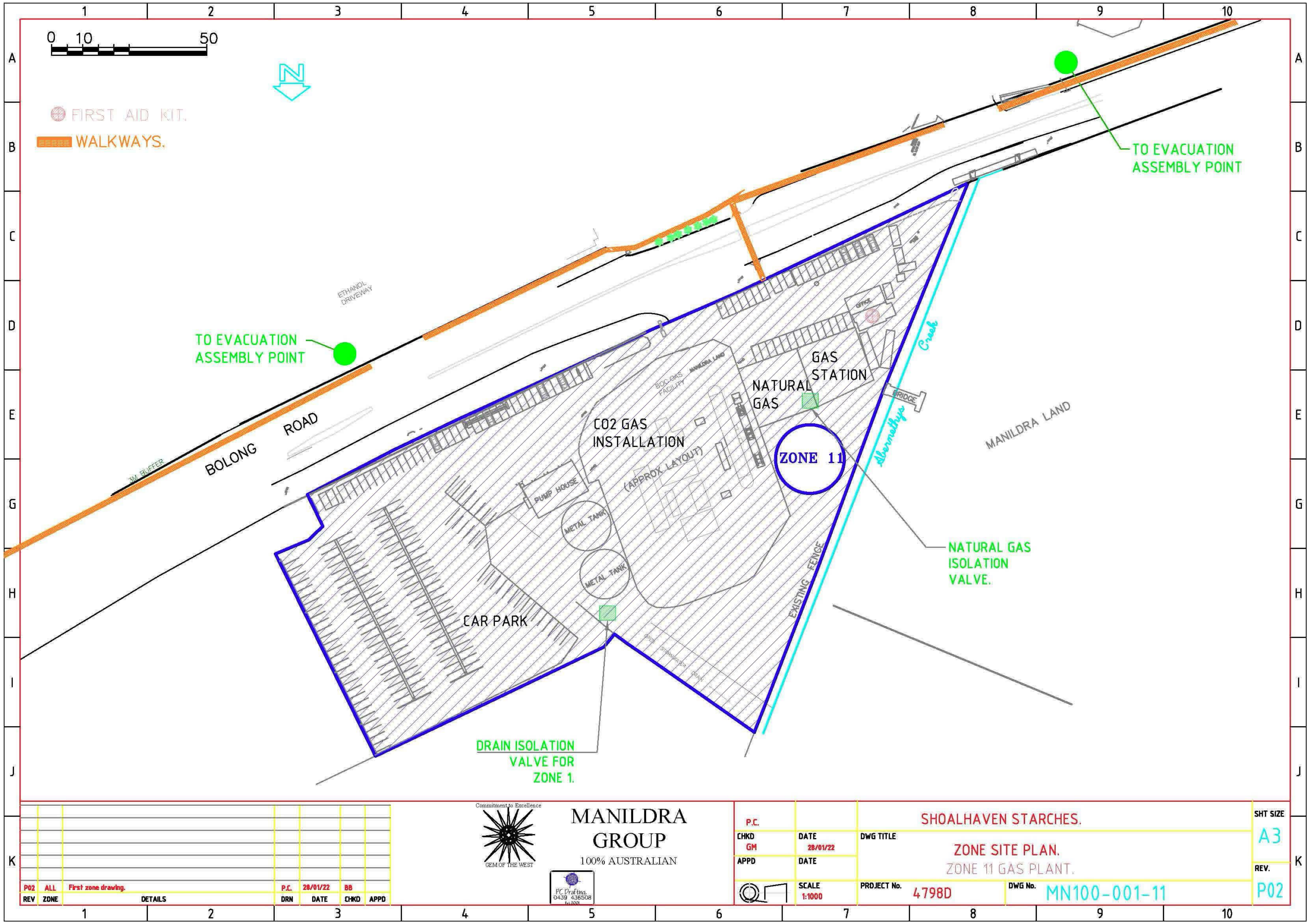
ISS	DATE	ZONE	CHANGE AMENDMENTS	BY	CKD
P07	3-01-25	ALL	Spill kit & cleary bros. added.	P.C.	Gav.
P06	28-05-23	ALL	Depot 62 added.	P.C.	Gav.
P05	05-01-23	E9	Proposed SD 6, GD 10 & office removed.	P.C.	J.S.
P04	23-11-22	B5	29 was C19.Water Filt. Sys. added at starch packer.	P.C.	J.S.
P03	1-02-22	ALL	Evacuation assembly points reassessed.	P.C.	T.B.
P02	25-01-22	ALL	Dangerous goods update.	P.C.	J.S.

MANILDRA GROUP
100% AUSTRALIAN

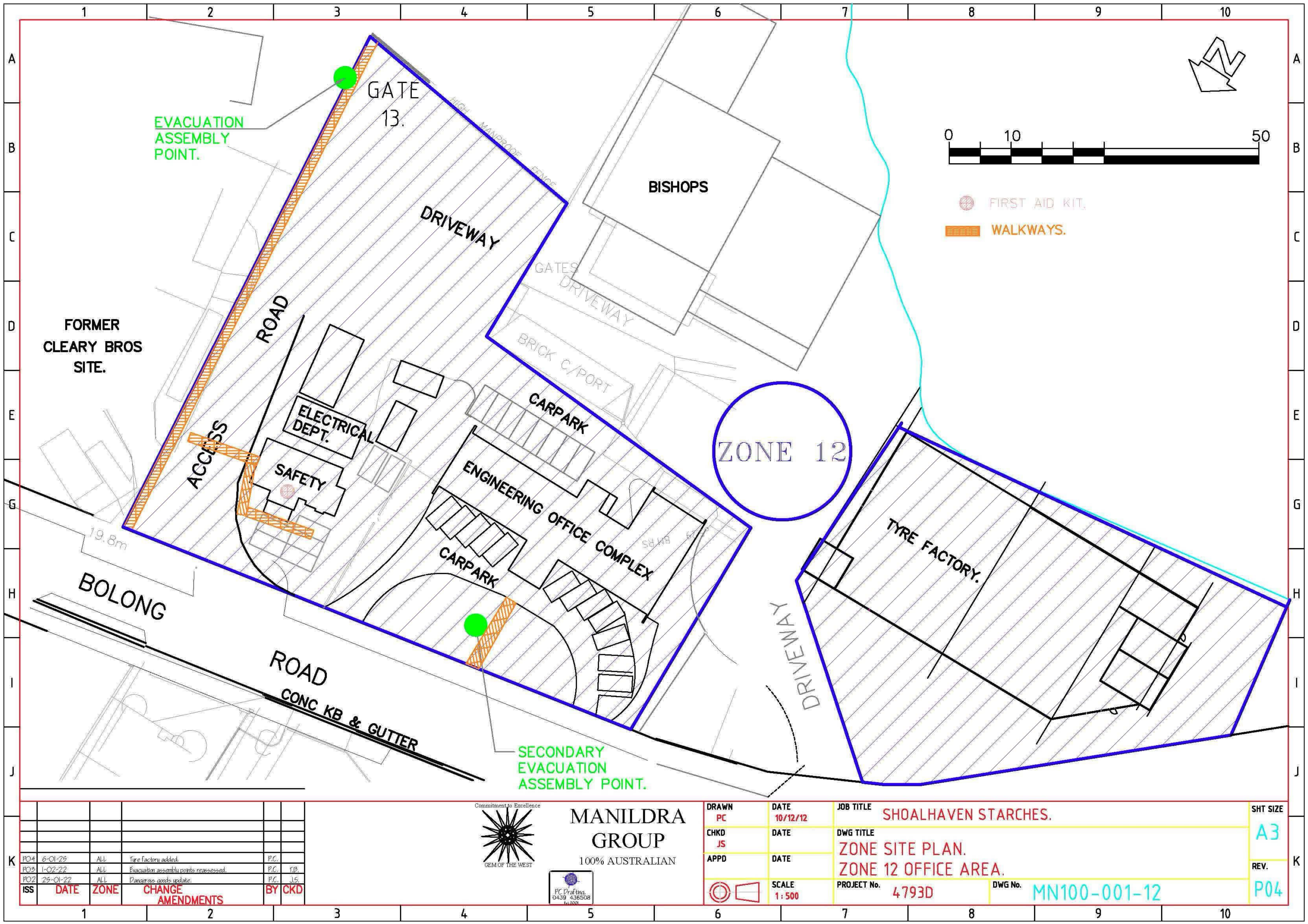
DRAWN PC	DATE 10/12/12	JOB TITLE SHOALHAVEN STARCHES.
CHKD JS	DATE	DWG TITLE ZONE SITE PLAN. ZONE 9.GD8 AREA.
APPD	DATE	
	SCALE 1 : 750	PROJECT No. 4793D — DWG No. MN100-001-9

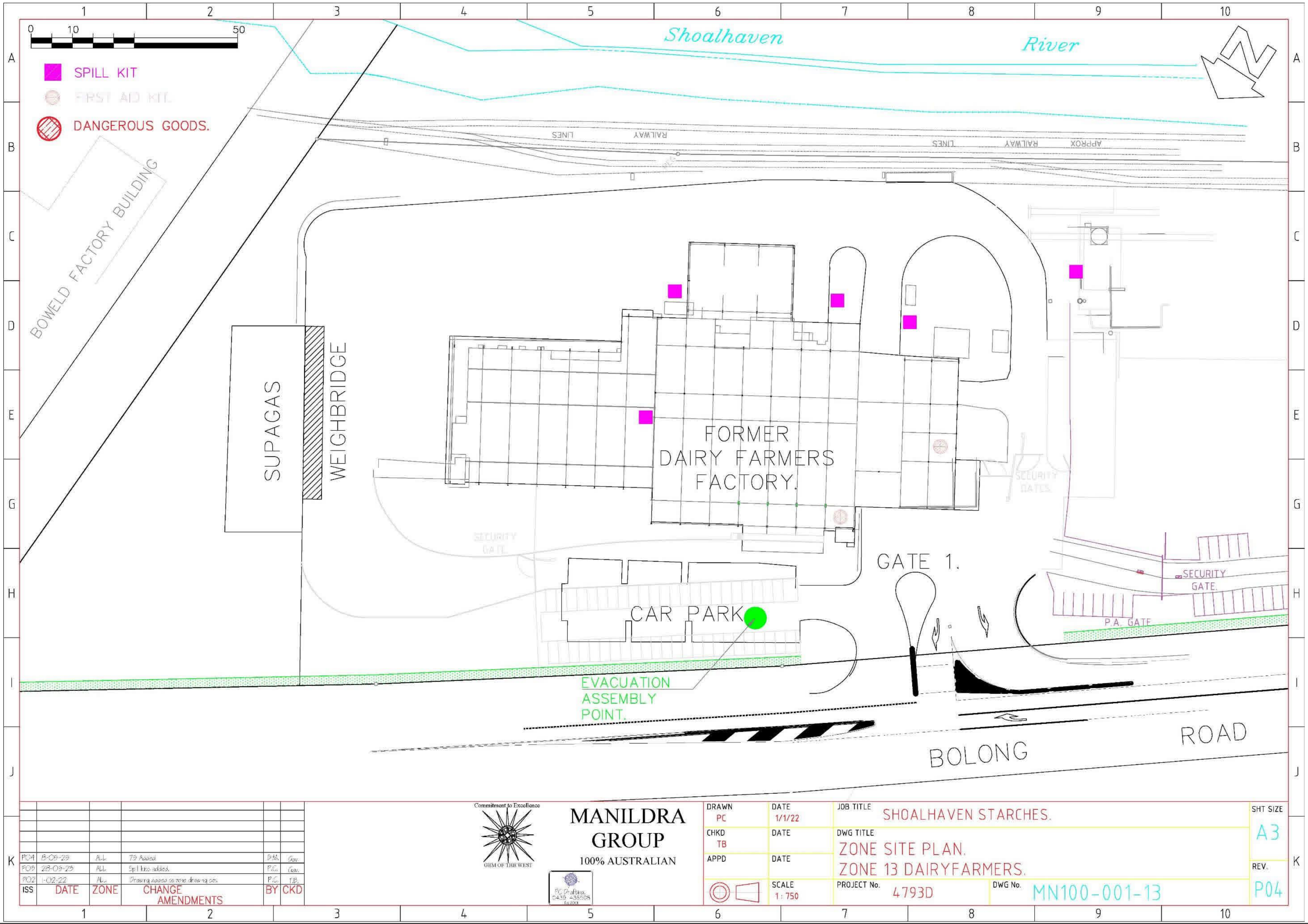
SHT SIZE A3
REV. P07


WALKWAYS.
BOLONG ROAD
BOLONG ROAD
GATE 4
CONTAINER YARD
CONTAINER LOADING
PACKAGING/ WAREHOUSE
CARS ONLY
TRUCK BYPASS LANE
SWALE
SWALE
RAILWAY STREET
RAILWAY STREET
GATE 6
TO EVACUATION ASSEMBLY POINT
ZONE 10
NORTH PACKER
P03 ALL Evacuation assembly points reassessed. P.C. 1-02-22 T.B.
P02 ALL First zone drawing. P.C. 28/01/22 BB
REV ZONE DETAILS DRN DATE CHKD APPD
Commitment to Excellence
GEM OF THE WEST
MANILDRA GROUP
100% AUSTRALIAN
PC Drafting 0439 436508
P.C.
CHKD GM
DATE 28/01/22
APPD
DATE
SCALE 1:1500
SHOALHAVEN STARCHES.
DWG TITLE
ZONE SITE PLAN.
ZONE 10 NORTH PACKER.
PROJECT No. 4798D
DWG No. MN100-001-10
SHT SIZE A3
REV. P03

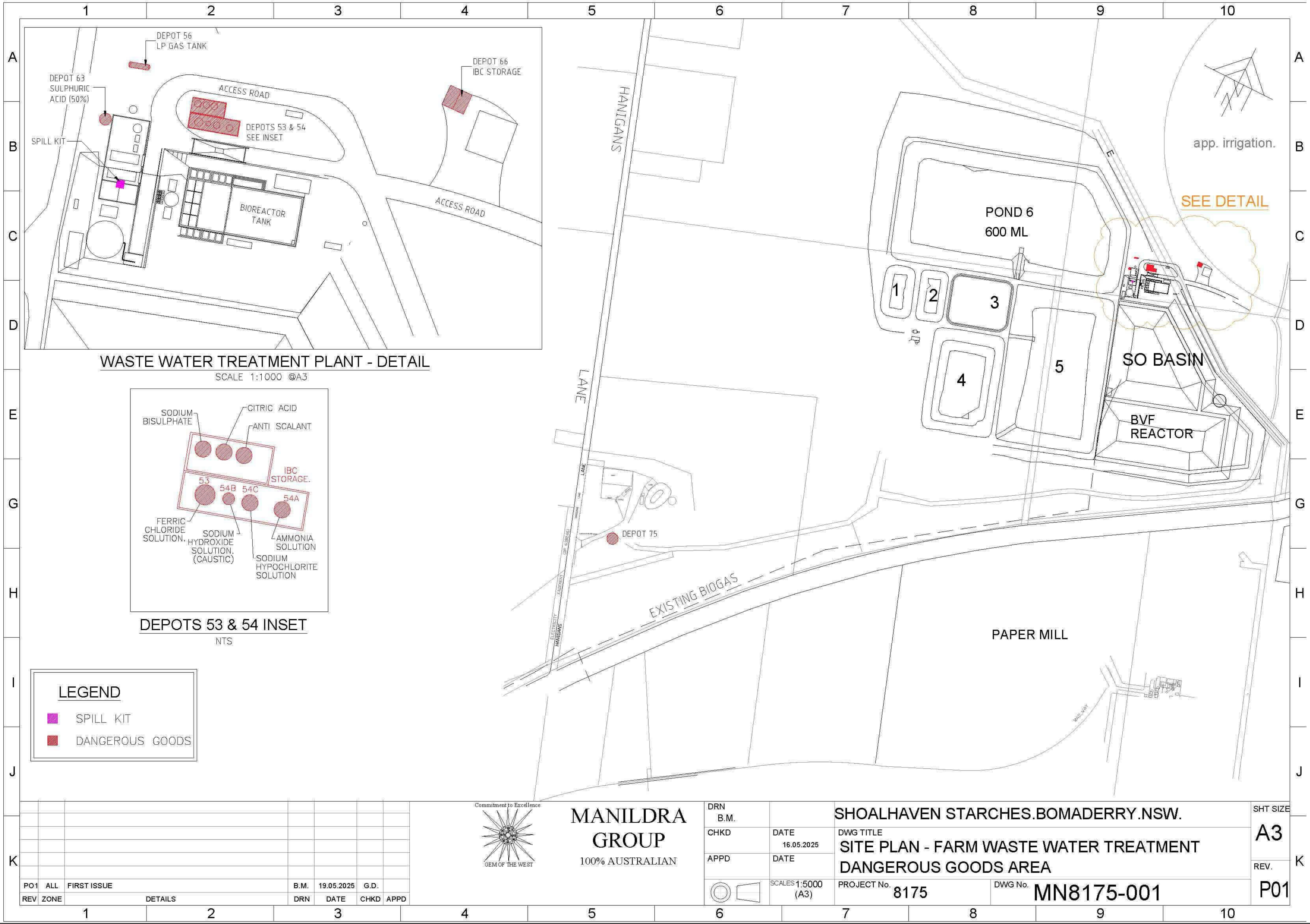


0 10 50
FIRST AID KIT.
WALKWAYS.
TO EVACUATION ASSEMBLY POINT
TO EVACUATION ASSEMBLY POINT
BOLONG ROAD
CO2 GAS INSTALLATION
(APPROX LAYOUT)
NATURAL GAS
GAS STATION
ZONE 11
PUMP HOUSE
METAL TANK
METAL TANK
CAR PARK
EXISTING FENCE
Abernethys Creek
MANILDRA LAND
NATURAL GAS ISOLATION VALVE.
DRAIN ISOLATION VALVE FOR ZONE 1.
MANILDRA GROUP
100% AUSTRALIAN
SHOALHAVEN STARCHES.
DWG TITLE
ZONE SITE PLAN.
ZONE 11 GAS PLANT.
P.C.
CHKD GM
DATE 28/01/22
APPD
DATE
SCALE 1:1000
PROJECT No. 4798D
DWG No. MN100-001-11
SHT SIZE A3
REV. P02
P02 ALL First zone drawing. P.C. 28/01/22 BB
REV ZONE DETAILS DRN DATE CHKD APPD


GATE 13.
EVACUATION ASSEMBLY POINT.
DRIVEWAY
BISHOPS
FIRST AID KIT.
WALKWAYS.
ROAD
ACCESS
FORMER CLEARY BROS SITE.
ELECTRICAL DEPT.
SAFETY
CARPARK
ENGINEERING OFFICE COMPLEX
CARPARK
ZONE 12
TYRE FACTORY.
DRIVEWAY
BOLONG
ROAD
CONC KB & GUTTER
19.8m
GATES
DRIVEWAY
BRICK C/PORT
SECONDARY EVACUATION ASSEMBLY POINT.
0 10 50
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 10/12/12
CHKD JS
APPD
SCALE 1:500
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 12 OFFICE AREA.
PROJECT No. 4793D
DWG No. MN100-001-12
SHT SIZE A3
REV. P04
P04 6-01-25 ALL Tyre factory added. PC
P03 1-02-22 ALL Evacuation assembly points reassessed. PC TB
P02 25-01-22 ALL Dangerous goods update. PC JS
ISS DATE ZONE CHANGE AMENDMENTS BY CKD



SPILL KIT
FIRST AID KIT
DANGEROUS GOODS.
Shoalhaven River
BOWELD FACTORY BUILDING
SUPAGAS
WEIGHBRIDGE
FORMER DAIRY FARMERS FACTORY.
GATE 1.
CAR PARK
EVACUATION ASSEMBLY POINT.
SECURITY GATE.
P.A. GATE
BOLONG ROAD
MANILDRA GROUP
100% AUSTRALIAN
DRAWN PC
DATE 1/1/22
CHKD TB
APPD
SCALE 1 : 750
JOB TITLE SHOALHAVEN STARCHES.
DWG TITLE ZONE SITE PLAN. ZONE 13 DAIRYFARMERS.
PROJECT No. 4793D
DWG No. MN100-001-13
SHT SIZE A3
REV. P04
ISS DATE ZONE CHANGE AMENDMENTS BY CKD


DEPOT 56
LP GAS TANK
DEPOT 63
SULPHURIC
ACID (50%)
SPILL KIT
ACCESS ROAD
DEPOTS 53 & 54
SEE INSET
DEPOT 66
IBC STORAGE
BIOREACTOR
TANK
ACCESS ROAD
WASTE WATER TREATMENT PLANT - DETAIL
SCALE 1:1000 @A3
SODIUM
BISULPHATE
CITRIC ACID
ANTI SCALANT
IBC
STORAGE.
53
54B
54C
54A
FERRIC
CHLORIDE
SOLUTION.
SODIUM
HYDROXIDE
SOLUTION.
(CAUSTIC)
AMMONIA
SOLUTION
SODIUM
HYPOCHLORITE
SOLUTION
DEPOTS 53 & 54 INSET
NTS
LEGEND
SPILL KIT
DANGEROUS GOODS
HANIGANS
LANE
DEPOT 75
EXISTING BIOGAS
POND 6
600 ML
1
2
3
4
5
SO BASIN
BVF
REACTOR
app. irrigation.
SEE DETAIL
PAPER MILL
P01 ALL FIRST ISSUE B.M. 19.05.2025 G.D.
REV ZONE DETAILS DRN DATE CHKD APPD
Commitment to Excellence
GEM OF THE WEST
MANILDRA
GROUP
100% AUSTRALIAN
DRN B.M.
CHKD
DATE 16.05.2025
APPD
DATE
SCALES 1:5000 (A3)
SHOALHAVEN STARCHES.BOMADERRY.NSW.
DWG TITLE
SITE PLAN - FARM WASTE WATER TREATMENT
DANGEROUS GOODS AREA
PROJECT No. 8175
DWG No. MN8175-001
SHT SIZE
A3
REV.
P01

15 APPENDIX B - HAZARDOUS EVENT WORD DIAGRAMS

Appendix B - Hazardous Event Word Diagrams

Appendix B Contents:

Zone	Description	Comments
1	Electrical Switchyard, Substations, Laboratory and Amenities Buildings Gluten Dryer Number 6	
2	Ethanol: Fermentation Distilleries (x3) Storage Road Tanker Loadout Ethanol Recovery Area Hand Sanitiser Building Nitrogen Generator Glucose (wet) Products Road Outloading Silos Evaporator, Isocontainer Storage, Substations and Cooling Towers Boiler 8 Substations	
3	Glucose Plant / Building Grain Plant and Grain / Wheat unloading Ion Converters	
4	Starch Plant / Building Gluten Dryers Numbers 1 to 4 / Starch Dryers 1 Flour Unloading Flour Mills A, B and C Substations	
5	Boilers including Coal Stockpile Substation	

Zone	Description	Comments
6	Starch Packing Building Gluten Packing Building Starch Dryer Building – Starch Dryers Numbers 3 and 4 Gluten Dryer Number 5 Substation Glucose Dryer and Packer (Gemspray) Bulk Loading (1 te bulkabags and trucks) Container Storage Area Air Compressor Room	
7	DDG (Dried Distillers Grain) Dryers Numbers 1, 2 and 3 Gluten Dryer Number 7 DDG Cooling	
8	Evaporators Pellet Plant DDG Storage Shed and Out Load Cooling Towers Temporary Container Area Silos (mill feed and DDG pellets) DDG Dryers Number 4 and 5 Cogeneration Plant Substation and Electrical Compound Nitric acid tank	
9	Starch Dryer Number 5 Specialties Product Building Housing the Cationic Starch Process and Packaging, and Ring Dryer 9 Gluten Dryer 8	See Zone 1 HAZID for the generic dryer hazards
10	North Packing Plant	

Zone	Description	Comments
11	Natural Gas Heating, Pressure Reduction and Filtration Offices Fire Water Storage Tanks and Pumps Adjacent to Zone 11 is the BOC Carbon Dioxide Plant	
12	Safety / Work Health Safety Offices Engineering and Administration Offices	No processing facilities
13	Former Dairy Farmers Factory and Site Maintenance Department Supagas Carbon Dioxide Facility	MOD26 modifications included. The Supagas Carbon dioxide Plant is separately assessed and therefore is not included in this study
WWTP	Waste Water Treatment Plant (to the northeast of the main site)	MOD26 modifications included

Zone 1 HAZID - Gluten Dryer Number 6. This HAZID is also applicable to other dryers, e.g. the Cationic Starch Process Dryer, Ring Dryer 9, Starch Dryer 5 and Gluten Dryer 8)

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
1.	Dust explosions within the equipment, e.g. silos / bins, the baghouse filter, grinder, disintegrator, screw conveyer, paddle mixer, rotary seal valves and final hopper	Ignition of combustible dust, e.g. due to smouldering, open flames, hot surfaces, heat from mechanical impact (e.g. foreign objects) or friction, and electrical discharges and arcs	Damage to the processing equipment and injury to personnel. Potential propagation to the combustible material processed and stored at the facility. Products of combustion emitted with the potential to impact people and the environment. The explosion can also travel throughout equipment with the potential for pressure piling and hence more significant explosive energy. Projectiles are possible with the risk of injury to people and damage to equipment	All equipment containing dust is designed to ATEX (or equivalent) standards including explosion vents and airlocks to separate transfer systems. Housekeeping to keep the area dust-free. The building is rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Underspeed detection on the screw conveyors, high level detection on the cyclones. Use of fire hoses and steam to quench smouldering fires. As the minimum ignition temperature for gluten is approximately 470 C(starch is approximately 380 C) and higher,

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
				maintenance of equipment and possibly detection by operators may prevent hot surfaces initiating a dust explosion. Spark arrester installed upstream of the hot air box to mitigate flames being emitted from the air intake
2.	Explosion in a dust collector	Propagation of fire event from elsewhere in the process, e.g. burning embers drawn into the dust collector	Explosion with the potential for injury and equipment damage	Induced draft which keeps the concentration below the LEL (lower explosive limit). All filters are pulsed with air for cleaning. All filters are checked routinely by maintenance for high differential pressure (DP). If issues arise then the socks are changed
3.	Explosion in the dryer	Build-up of solids within the dryer piping	The deposits can self-heat and auto-ignite resulting in a fire / explosion	Routine cleaning of equipment to prevent material build-up. The dryer is operated at a temperature to avoid self-heating as much as possible. The explosion vents for dust explosions will also limit the developed overpressures for an internal dust explosion
4.	Fire in the grinder	Blocked dust collector on the grinder	Material heating due it being trapped in the grinder and therefore continuous grinding. Potential to propagate to a dust explosion within the equipment	High dust collector DP trip on the grinder. High level probe on hopper below the grinder. Grinder amps monitored
5.	Dust explosion	Loss of containment of dust within the dryer building, e.g. failure of product lift pipe	Dust explosion within the building, loss of life, equipment damage, production downtime, potential for both a primary and secondary explosion	Sealed system lowering the likelihood of leaks, aspirated system, instruments and electrics to hazardous zones, housekeeping. No purlins on the inside of the building where dust can accumulate

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
6.	Fire / explosion in the disintegrators	Foreign objects in the disintegrator causing ignition which can propagate to other equipment	Injury to workers, production downtime due to equipment damage and product loss. Secondary explosion possible. Foreign objects can also block the disintegrator feed chute	Temperature sensor, vibration transmitter on the disintegrator. Magnetic separator prior to the grinder. Equipment designed to ATEX (or equivalent) standards
7.	Loss of the dust collectors' fans	Potential for the combustible dust concentration to increase and enter the explosive range	The plant will be tripped on loss of the dust collectors' fans	Hoerbiger valves installed for explosion protection of the grinder, the equipment is rated for hazardous zones including electrics and instruments are suitably rated and all equipment is to be bonded and earthed
8.	Natural gas explosion within the dryer	Natural gas flow when the burners are offline	Buildup of natural gas in the ducting. If ignited, there is the potential for an internal explosion	Burner management system is certified to Australian Standards which includes the need for adequate natural gas isolation and air purging prior to startup. The explosion vents for dust explosions will also limit the developed overpressures for an internal gas explosion
9.	Overheating of the gluten in the dryer	Loss of temperature control	Potential for autoignition of the gluten	High temperature trip on the dryer outlet (hard wired to the burner). Gluten has a relatively high autoignition temperature of 470°C. Spark arrestor on the discharge of the air heater

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
10.	Loss of containment of natural gas from the supply pipe	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 supply pipe is piped into the natural gas supply pipe system that runs through the site. The pipe is protected from impact by locating it in a piperack. Minimum flanges used. Pipe is included in the hazardous zone study. Remote isolation of the natural gas is possible at the gas metering station. The natural gas supply pipe is pressure tested following construction and protected against corrosion by painting
11.	Fire within the building	Electrical fault, loss of containment of dried gluten with subsequent ignition	Damage to the building and equipment, fire hazard to personnel	Hydrants, hose reels and sprinklers (fusible bulbs so that only the sprinklers above the fire activate). Fire water available to all areas via hydrants and hose reels. Extinguishers installed within the site buildings. Fire alarm, e.g. break glass alarms. People can escape via compliance fire escape stairs which are a covered by overhead sprinklers. If use of these stairs is restricted then personnel can use secondary fire escape stairs or secondary emergency exit door on the ground floor

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
12.	Dust release	Failure of the dust collector, e.g. sock failure	Release of dust to the environment, i.e. impact to the environment	Preventative maintenance (PMs) on equipment. Monitoring of the dryer vent by the operators. Duts falling onto Manildra property will be sent and treated at the WWTP. Emergency response including spill cleanup
	Acetic Anhydride Tank			
13.	Acetic anhydride tank or bund fire. This tank is on ground level near to the GD6 building	Tank explosion, e.g. hot work. Tank or piping system leak into the pump, e.g. due to corrosion, a valve leak and a failed joint. Acetic anhydride dissolves in and reacts with water to give acetic acid (this is an exothermic reaction), hence the potential for tank overpressure and failure	The acetic anhydride tank is on the boundary to Bolong Road (just west of Fermenter 1). As acetic anhydride is flammable then there is the potential for a pool fire, e.g. within the bunded area (approximately 2.5 m by 2.5 m). The radiant heat could be harmful to personnel and equipment. A tank explosion could result in projectiles, i.e. harm to personnel and/or damage to equipment. Any spills outside of the bunded tanks flow to local drains and then to the WWTP, i.e. limited probability of environmental impact	Preventative maintenance (PMs) on equipment. The tank is bunded to limit pool spread. Control of ignition sources, e.g. permit to work and hazardous area assessment. Procedures and training to prevent water ingress into the tank. Bonding and earthing. Fire protection includes extinguishers, hydrants and portable monitors

Zone 2 HAZID – Fermenters, Distilleries and Boiler 8. The potential hazardous events associated with the gas-fired Boiler 8 are identical to those for the gas-fired boilers in the boilerhouse and are shown in the HAZID table for Zone 5.

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
	Distilleries (i.e. the original distillery and the two beverage grade distilleries)			
14.	Loss of containment of flammable liquid with subsequent ignition in the bunded area. This scenario applies to the proposed heat recovery project modifications as well	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. Pressure relief valve (PRV) opens, e.g. T540 reflux PRV	Bund fire can lead to equipment damage and injury to people. Total ethanol inventory has been approximated as 20 te or 25 m^3. If the release of flammable liquid occurs at height then there can be a 3-dimensional fire, i.e. there can be burning liquid falling to grade from the point of release. If the wind is strong then the burning liquid could be blown outside of the bunded area	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. Deluge system, foam monitors, hydrants, hose reels and extinguishers. The deluge system has a capacity of 39,251 LPM for cooling and extinguishment of a pool fire. Authority to Work Permits - Hot work permits. Vessels are emptied by running the liquid out of the plant and then steam purging

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
15.	Pump fire. This scenario applies to the proposed heat recovery project modifications as well	Deadheading an ethanol pump, 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
16.	Catastrophic vessel failure. This scenario applies to the proposed heat recovery project modifications as well	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 are pressure protected as per AS1210. The maximum direct steam pressure is limited to 1.6 bara
17.	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	Prevention and Mitigation Control Measures
18.	Release from pressurised equipment, e.g. the molecular sieves	Losses of containment due to valves passing, pipe or vessels leaks and gasket	The ethanol could immediately ignite and form a jet fire or there could be delayed ignition with a flash fire or explosion (if the vapour is confined)	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. Deluge system, foam monitors, hydrants, hose reels and extinguishers. Plant can be tripped and isolated remotely
19.	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	Prevention and Mitigation Control Measures
	Tanks and Road Tanker, Isocontainer, IBC and Drum Filling			
20.	Loss of containment into the tank storage bund	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. The latter trips 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 and monitors. 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	Prevention and Mitigation Control Measures
21.	Tank top fire	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	Tank and site fire protection facilities including foam pourers and monitors. Earthing of all tanks, no splash filling and ignition control procedures, e.g. hot work permits
22.	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 located on a piperack to avoid impact damage. Pipes fully welded where possible

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
23.	Leak during road tanker, Isocontainer, IBC or drum transfers involving materials such as: Ethanol Propanol Butanol Petrol Methyl Isobutyl Ketone	Failure of transfer hose or loading arm. Leak from valves or fittings. Road tanker, Isocontainer, IBC or drum overfill	Spillage of ethanol. Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property. Potential for the vessels and/or containers to BLEVE (boiling liquid expanding vapour explosion). Potential for impact to the environment	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. Sealed area with 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
24.	Road tanker drive-away incident (i.e. driver does not disconnect the hose and drives away from the loading 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	Driver training. Driver not in cab during filling. Road tanker bays fitted with automatic foam deluge system. Dry-break hose couplings Manual gates in front of the road tankers or Isotanks are closed by the driver which are confirmed as closed by the Manildra operator at the start of the transfer, i.e. performing the inspection

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
25.	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
26.	Leak from Isocontainer, IBC or drum in the storage areas	Valve passing, flange leak, corrosion, impact	Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property. Potential for the vessels and/or containers to BLEVE	Storage area complies with Dangerous Goods Regulations. 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, e.g. from the monitors. IBCs and drums stored in contained areas. Bunding and drainage system designed to prevent environmental impact due to a release of ethanol and foam contaminated firewater

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
27.	Internal explosion and/or fire at the denaturant tanks	Overfilling a tank. Tank failure, e.g. corrosion. Pipe failure, e.g. corrosion, flange failure. Tank drain valve left open Pump seal, shaft or casing failures. Hot work on the tanks	An internal explosion will result in the tanks rupturing, i.e. harm to personnel and/or equipment (e.g. from overpressures and/or projectiles). Fire if ignited. Impact to people (radiant heat and/or exposure to products) and property. Potential for the tanks to BLEVE	Pipes designed to AS4041. Regular maintenance and inspection procedures. Tank and site fire protection facilities including foam monitors. 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. The tanks and pumps are located within a dedicated bund
28.	Release of dosing chemicals for Boiler 8 or the cooling towers	IBC valve leak. IBC punctured (e.g. fork lift truck tynes). Dosing line leak, e.g. joint failure	Release of chemicals, some of which are corrosive, i.e. impact to personnel and/or the environment	PMs on equipment. Routine inspections and response to a leak. Fork lift truck operator licensed. The dosing chemicals IBCs are stored in self-bunded DG containers. Safety showers / eyewash units installed near all dosing chemicals

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
29.	Release from the fermenters	Tank or piping system failures, e.g. due to corrosion or joint failures	A fermenter tank failure will release a significant quantity of liquid (beer – up to 2.8 ML of liquid) with the potential to flood the local area and hence impact to people and/or the environment	Stainless steel construction materials. PMs on the equipment. Tanks designed to AS1170

Zone 3 HAZID – Glucose Plant

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
30.	Fire within the building	Electrical fault, loss of containment of dried glucose with subsequent ignition	Damage to the building and equipment, fire hazard to personnel. If sufficient dried glucose exists then there is the risk of a dust explosion within the building	Hydrants, hose reels and sprinklers (fusible bulbs so that only the sprinklers above the fire activate). Fire extinguishers. Fire alarm, e.g. break glass alarms. People can escape via compliance fire escape stairs which are a covered by overhead sprinklers. If use of these stairs is restricted then personnel can use secondary fire escape stairs or secondary emergency exit door on the ground floor

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
31.	Losses of containment of hydrochloric acid (HCl), caustic or nitric acid	Losses of containment due to: - Transfer failures, e.g. hose or pipe leaks. - Tank failures, e.g. corrosion, or tank overfills. - Failure of the 50 mm DN HDPE (high density polyethylene) underground pipes from the HCl and caustic fill points to the tanks	Corrosive impact to people, equipment and/or the environment	PMs on equipment. Routine inspections and response to a leak. Tank level monitoring / instruments. The HCl tank bund is being refurbished, i.e. new liner. The caustic tank bund is to be replaced in the near future (2024). Any leaks from the caustic or HCl tanks and their bunds will flow to the WWTP. Spills from the HCl and caustic unloading operations flow to a local pit and also to the WWTP. The nitric acid IBC and pump are within Perspex enclosures. There is a dedicated IBC secondary containment bund for the nitric acid. Safety showers / eyewash units installed near all dosing chemicals

Zone 4 HAZID – Starch Plant / Building, Gluten and Starch Dryers, Flour and Wheat Unloading, Flour Mills A, B and C

Note: See Zone 1 HAZID for the generic dryer hazards. This includes building dust and natural gas explosions.

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
	Starch Plant / Building			
32.	Fire or dust explosions within the silos and conveying equipment, e.g. screw conveyer	Ignition of combustible dust, e.g. due to open flames, hot surfaces, heat from mechanical impact or friction, self-heating and electrical discharges and arcs	Damage to the equipment and injury to personnel. Products of combustion emitted with the potential to impact people and the environment. Projectiles are possible with the risk of injury to people and damage to equipment	All equipment containing grain and dust is designed to ATEX (or equivalent) standards. Equipment rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Underspeed detection on the screw conveyors, high level detection on the silos. Use of fire hoses to quench smouldering grain fires. Silos are continuously emptied and refilled to prevent self-heating

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
33.	Fire within the building	Electrical fault, loss of containment of flour with subsequent ignition	Damage to the building and equipment, fire hazard to personnel. If sufficient flour exists then there is the risk of a dust explosion within the building	Hydrants, hose reels and sprinklers on every level (fusible bulbs so that only the sprinklers above the fire activate). When one fusible bulb fails, this raises a site alarm as well as alarming direct to the fire brigade. Extinguishers. Fire alarm, e.g. break glass alarms. People can escape via compliance fire escape stairs which are a covered by overhead sprinklers. If use of these stairs is restricted then personnel can use secondary fire escape stairs or secondary emergency exit door on the ground floor
34.	Release of chemicals, e.g. for CIP. Chemicals are sulphuric acid (50%), phosphorous oxychloride, sodium chlorite, hydrochloric acid, chlorine dioxide (generator and tank) and bioxysan	IBC valve leak. IBC punctured (e.g. fork lift truck tynes). Dosing line leak, e.g. joint failure	Release of chemicals, i.e. corrosive impact to personnel and/or the environment	PMs on equipment. Routine inspections and response to a leak. Fork lift truck operator licensed. The dosing chemicals IBCs are stored in self-bunded DG containers. Safety showers / eyewash units installed near all dosing chemicals. The sodium chlorite fill point uses a dry-break coupling and is a different coupling to the sulphuric acid given the risk of chlorine dioxide formation

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
	Flour and Wheat Unloading, Flour Mills A, B and C			
35.	Ignition of confined wheat dust or flour, e.g. within the rail unloading areas or within the mill equipment	Foreign object. Belt slip, poor belt tracking. Baghouse fire / explosion propagating back to the bucket elevators. High equipment temperatures, e.g. due to friction. Static	Product and equipment fire, potential for internal dust explosion. Hence injury to people, damage to equipment and impact to production	Bearings are external to machines. Belt drift / misalignment sensors. Aspiration system (with interlocks). Equipment designed to ATEX including hazardous area assessment. Foreign objects removed via screen and separators. Earthing of equipment. Daily checks on magnetic separators (cleaned every morning)
36.	Grain fire	Grain heated by strong ignition source, self-heating	Local smouldering fire with the potential to damage equipment or injure those near to the fire if the containment fails. If a wheat silo fails (from a fire or any other cause) then the wheat can flow into the Shoalhaven River	Silos are continuously emptied and refilled to prevent self-heating. Hydrants, sprinklers, hose reels, extinguishers
37.	Dust explosion within the building	Loss of containment of dust within the building, e.g. failure of a product lift pipe	Dust explosion within the building, loss of life, equipment damage, production downtime	Sealed process systems lowering the likelihood of leaks. Aspirated system. Instrument and electrics to hazardous zones. Regular housekeeping.

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
				Permit to work system requiring adequate cleaning and control of ignition sources
38.	Dust explosion in a hammer mill	Foreign objects in the hammermill causing ignition which can propagate to the bin / dust collector. Thrown hammer	Point of ignition for dust explosion is the hammermill. Injury to worker, production downtime due to equipment damage and product loss. Secondary explosion possible. Foreign objects can also block the hammermill feed chute	Upstream magnetic separator. Temperature sensor. Vibration switch and transmitter. Level / flow sensor on the outlet chute. Rotary airlock to dust collector. Interlocks on dust collector. Explosion vents in the dust collector
39.	Screw conveyor fire	Broken roller, failed roller mechanism, failure of equipment	Dumping of product in front of inspection flap, i.e. flour pushed up the inlet chute and a loss of containment from choking of the system. Dust in the area that can settle on motors causing heat build-up. This can result in ignition of product from the hot motor. Build-up of product on the roller that continues to roll. Overfill the inlet chute as above, heating of the flour due to the rollers and hence a possible smouldering fire	Covers over motors. High level switch on chutes. Programmed maintenance every three months. Housekeeping. Testing of sensors to ensure sensitivity is suitable. Hydrants on every level, fusible bulb sprinklers, hose reels, extinguishers

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
40.	Fire within the building	Loss of containment of wheat or flour, e.g. a hand hold leak leading to flour settling on a motor and hence will heat up (source of ignition)	Heat from motor causing fire hazard, propagation throughout the building	Operators trained to replace inspection hatch covers. Walkthroughs to detect abnormal conditions. Regular housekeeping. Hazardous area zones. Hydrants on every level, fusible bulb sprinklers, hose reels, extinguishers
41.	Fire / explosion due to a sifter problem	Mechanical / electrical problems, counter weight within sifter coming loose (1 te each), choke underneath one of the sifters leading to too much flour on one side of a sifter	Sifters out of alignment, structural damage to building, worn electrical cables due to excessive vibration which could lead to ignition	When the sifter motors stop, it is alarmed and the mill will trip. Safety cables (16mm stainless cable) on the sifters. Canes (nylon or timber) on each corner of sifter. Rotation sensor on top of each of the sifters
42.	Failure of a sifter connecting socks	Excessive vibration and movement (e.g. wear and tear)	Loss of containment of flour dust with potential of ignition, i.e. fire or explosion in the building	Sensors on each of the bottom socks, i.e. if the socks fail then a beam is broken and the mill is stopped. Walkthrough observations. Routine sock replacement

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
43.	Dust explosions and fires within silos and bins	Ignition of grain or combustible dust, e.g. due to open flames, hot surfaces, heat from mechanical impact or friction, self-heating and electrical discharges and arcs	Confined dust explosion with damage to the silos and bins, potential for injury to people. Projectiles are possible with the risk of injury to people and damage to equipment	All equipment containing dust are designed to ATEX (or equivalent) standards. The mill is rated for hazardous zones including electrics and instruments are suitably rated and equipment is to be bonded and earthed. Permits to work. Earthing of equipment. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Underspeed detection on the conveyors, high level detection on the silos. Use of fire hoses to quench smouldering grain fires

Zone 5 HAZID – Boilers including Coal Stockpile

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
44.	Fire in a baghouse	Ignition of carryover fly ash and socks smouldering	Damage to equipment, environmental impact, loss of production	Obscuration meter in the stacks. Alarm on high temperature in the baghouses. Hydrant system and hoses for fire attack response. Emergency Response Team on site
45.	Coal dust explosion	Attrition of coal particles and ignition of the fine particulates e.g. static in the denseveyor, hopper, hot work adjacent to the denseveyor seals where losses of containment of particles can occur	Equipment damage, injury (engulfment) from dust fire / explosion	Unlikely event given the limited quantities of coal dust expected as per the history of operation for Boilers 5 and 6 and hence operating below the lower explosion limit. Earthing of equipment. Sprinklers are installed over the denseveyor so product is moist (not dusty). Control of ignition sources (hot work permit).

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
46.	Coal stockpile fire	Source of ignition such as hot work, lightning strike and self-heating	Local coal fire resulting in products of combustion (i.e. environmental impact) which could include methane and carbon monoxide. Potential for the firefighting water (including coal particles) to enter the Shoalhaven River	Control of ignition sources (hot work permit). Direct water injection to the coal bunkers and isolations on the chutes. Hydrant system and hoses for fire attack response. Emergency Response Team on site. Operator response to the initial combustion, i.e. by smell and/or sight. Water sprinklers on coal stockpile (adjacent to the boilerhouse). The coal stockpile has concrete walls for containment and the area is drained to the WWTP
47.	Fire propagation back through the coal feed system	Fire from grate burns upward to the coal bunker, in particular, when the feed system is shutdown	Equipment damage, injury coal fire	Steam sparge system that will extinguish a fire, controlled automatically via thermocouples. Guillotine door closes when feed system stops
48.	Natural gas or biogas explosion within a boiler (this event applies to Boiler 8 as well)	Natural gas or biogas flow when the burners are offline	Buildup of natural gas or biogas in the boiler. If ignited, there is the potential for an internal explosion	Burner management system is certified to Australian Standards which includes the need for adequate natural gas / biogas isolation and air purging prior to startup

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
49.	Loss of containment of natural gas or biogas from the supply pipe (this event applies to Boiler 8 as well)	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 supply pipe is piped into the natural gas supply pipe system that runs through the site. The pipes are protected from impact by locating it in a piperack. Minimum flanges used. Pipes are included in the hazardous zone study. Remote isolation of the natural gas is possible at the gas metering station. The natural gas supply pipe is pressure tested following construction and protected against corrosion by painting. The maximum pressure in the biogas pipe is 55 kPag, i.e. relatively low

Event Number	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
50.	Release of Reverse Osmosis (RO) or boiler dosing chemicals. Chemicals include amines, and RO / ultrafiltration (UF) chemicals such as citric acid, caustic bisulphites and a 100 L sodium hypochlorite tank	IBC valve leak. IBC punctured (e.g. fork lift truck tynes). Dosing line or tank leak, e.g. joint failure or corrosion	Release of chemicals, i.e. corrosive impact to personnel and/or the environment	PMs on equipment. Routine inspections and response to a leak. Fork lift truck operator licensed. The dosing chemicals IBCs and drums are stored in self-bunded DG containers. Safety showers / eyewash units installed near all dosing chemicals. Limited quantities stored, e.g. the amines are in a 20 L drum. The UF chemicals are stored in the adjacent Stillage Plant (building to the west of the boilerhouse) with secondary (self-bunded) and tertiary bunding (the process is contained and flows to the WWTP)

Zone 6 HAZID – Packaging (bags) and Bulk Loadout (1 te bulkabags and trucks)

Note: See Zone 1 HAZID for the generic dryer hazards

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
51.	Fire or dust explosions within the silos and packaging machines	Ignition of combustible dust, e.g. due to open flames, hot surfaces, heat from mechanical impact or friction, self-heating and electrical discharges and arcs	Damage to the equipment and injury to personnel. Products of combustion emitted with the potential to impact people and the environment. Projectiles are possible with the risk of injury to people and damage to equipment. If sufficient dust exists then there is the risk of a dust explosion within the building	All equipment containing grain and dust is designed to ATEX (or equivalent) standards. Equipment rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Underspeed detection on the screw conveyors, high level detection on the silos. Sprinklers, hydrants, hose reels and extinguishers. Regular housekeeping

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
52.	Fire or explosion within the building or bulk loadout area	Electrical fault. Loss of containment of starch, gluten or glucose with subsequent ignition. Paper bags ignited, e.g. hot work. Fork lift truck or bulk truck fire	Damage to the building and equipment, fire hazard to personnel. If sufficient dust exists then there is the risk of a dust explosion within the building	All equipment containing grain and dust is designed to ATEX (or equivalent) standards. Equipment rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Sprinklers, hydrants, hose reels and extinguishers. Regular housekeeping. Fire alarm, e.g. break glass alarms. People can escape via the building doors (ground level). Fork lift truck routine maintenance

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
53.	Chlorine dioxide gas above 10% vol in air is explosively unstable	Loss of dilution water allows strong solution to be stored. Partial draining of reactor allows air ingress to reactor	Gas concentration greater than 10% results in chlorine dioxide decomposition to chlorine and oxygen, i.e. rupturing the vessel and releasing toxic gas	Purpose-built, vendor supplied chlorine dioxide generator. Dilution water low flow trip. High and low flow trips on all chemicals supplied to the rig. Optical sensor that trips the rig on high concentration. The maximum concentration is 3000ppm. Maintenance requires flushing with water
54.	Battery explosion in the recharging area	Hydrogen gas emitted with subsequent ignition	Spraying of the battery acid, e.g. onto people in the area. Explosion could adversely impact people and the recharging area with the potential to propagate throughout the building	Battery inspections. Fire protection includes hydrants, hose reels and extinguishers. Emergency response plans. Battery recharging area located away from packaged goods

Zone 7 HAZID – DDG Dryers 1, 2 and 3, Gluten Dryer Number 7 and DDG Cooling

Note: See Zone 1 HAZID for the generic dryer hazards

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
55.	DDG fire in a dryer	DDG high temperature and/or too dry with autoignition	Damage to the equipment from the smouldering fire. Products of combustion emitted with the potential to impact people and the environment	Steam deluge within the dryers. This is manually operated, e.g. operator response to high temperature or smoke. Hydrants, hose reels and extinguishers. Dryer temperature and moisture control
56.	Fire or explosion within the DDG baghouse filter and cooler	DDG high temperature and/or too dry with autoignition. Static. Hot work	Damage to the building and equipment, fire hazard to personnel. If sufficient dust exists then there is the risk of a dust explosion within the building	All equipment containing combustible dust is designed to ATEX (or equivalent) standards. Equipment rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Sprinklers, hydrants, hose reels and extinguishers. Fusible bulb sprinklers within the DDG cooler baghouse filter as well as within the DDG cooler building. Regular housekeeping within the DDG cooler building

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
57.	Loss of containment of caustic (50wt%) or nitric acid (60wt%)	IBC valve leak. IBC punctured (e.g. fork lift truck tynes). Dosing line, pump or tank leak, e.g. joint failure or corrosion. Overfilling the caustic tank. Leak from the caustic road tanker transfer system, e.g. hose failure or driveaway	Release of chemicals, i.e. corrosive impact to personnel, equipment and/or the environment. Nitric acid can react with incompatible materials, e.g. organics, to generate nitrogen oxides (toxic to personnel). If the caustic transfer pipe fails then there is the potential for caustic to fall into Abernethys Creek	The nitric acid is stored in self-bunded IBCs in a locked DG container. The nitric acid dosing lines are fully welded and the pumps have a Perspex screen to prevent sprays impacting people. The site's main caustic tank (located just north of GD7) is bunded and there are splash walls installed. The caustic tank level is monitored via a level transmitter with a high level trip on the transfer pump as well as a high level alarm for operator response. The caustic transfer pipe from the road tanker transfer bay to the tank is in a piperack across Abernethys Creek and is fully welded. PMs on equipment. Routine inspections and response to a leak. Fork lift truck operator licensed. Safety showers / eyewash units installed near all dosing chemicals

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
58.	There is the potential to mix nitric acid and caustic in the CIP Tank	This event can occur if there is a procedural failure when performing a CIP	Strong reaction between the nitric acid and the caustic generating fumes, heat and potentially overpressurising the tank leading to failure, i.e. potential impact to personnel, equipment and/or the environment	Caustic and nitric acid are separately pumped to the CIP Tank as per the CIP procedures. Operator training and procedures. This tank is in the plant bunded area that flows to the WWTP
	Diesel Storage Tank			
59.	Diesel fire	Loss of containment with subsequent ignition	Fire involving the tank and vehicle, i.e. potential for equipment damage and injury to people	Diesel is a combustible liquid and therefore has a higher flash point (i.e. more difficult to ignite). Control of ignition sources (hot work permit). Hydrant system, hoses and extinguisher for fire attack response

Zone 8 HAZID – Pellet Plant, DDG Dryers 4 and 5 (see Zone 7 for the hazards), DDG Storage Shed and Out Load, Silos, Cooling Towers, Cogeneration Plant and the Proposed Nitric Acid Tank

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
	Pellet Plant			
60.	Dust explosions, i.e. within equipment or within the building	Ignition of combustible dust	Damage to the processing equipment and injury to personnel. Potential propagation to the combustible material processed and stored at the facility. Products of combustion emitted with the potential to impact people and the environment	Explosion vents. Housekeeping to keep the building structure dust-free. The pelletising plant is rated for hazardous zones including electrics and instruments are suitably rated and equipment is bonded and earthed. Processing equipment that generates dust is operated at a slight vacuum so that the dust is drawn into dedicated dust filters
61.	Combustible materials fire	Ignition of the millfeed pellets or DDGS from a strong ignition source, e.g. hot work, electrical fault or equipment failures such as friction in a conveyor	Historically these materials have resulted in smouldering fires with limited radiant heat impact. Potential for the fire to propagate throughout the Pellet Plant with significant damage to the equipment and structures. Propagation could include a dust explosion as above. Products of combustion emitted with the potential to impact people (on and off site) as well as the environment	The millfeed pellets and DDGS have a moisture content of approximately 13% which limits the combustibility. The millfeed pellets and DDGS is contained within the processing equipment to limit exposure to strong ignition sources. Fire protection includes sprays, hoses and extinguishers. Fire Brigade response also included in the emergency response plan. Fire protection equipment is maintained as per the requirements of AS1851.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Permits to work for any hot work. Maintain and service plant and equipment as per manufacturer's requirements. Regular workplace inspections performed to identify hazards and rectify immediately. Prestart check to ensure equipment is in good condition and operating correctly
	DDG Storage Shed, Out Load and Silos			
62.	Fires and/or dust explosions	Ignition of combustible dust, e.g. hot work or smoking	Damage to the buildings and silos, and injury to personnel. Products of combustion emitted with the potential to impact people and the environment	DDG is a coarse fibrous material that is too large to be involved in a dust explosion unless ground or dust is present, e.g. due to attrition. Instruments and electrical equipment rated for combustible dust hazards. Permits to work for any hot work. No smoking allowed on site. Sprinklers, hydrants, hose reels and extinguishers

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
	Biofilters			
63.	Failure of the biofilters	Wall failure. Loss of the biogrowth, e.g. due to drying out	Potential leachate release impacting the environment. Odour from the failed biofilter (affecting people on and off site)	PMs on the equipment. Wetting of the biofilters Routine inspections and maintenance on the biofilters
	Transformers			
64.	Transformer oil fire	Transformer failure, e.g. arc flash, with loss of containment of oil	Local fire involving the transformer, i.e. potential for equipment damage and injury to people	Routine maintenance performed on the transformers. Transformers are bunded. Hydrant system, hoses and extinguisher for fire attack response

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
	Cogeneration Plant			
65.	Natural gas explosion within the turbines or HRSGs	Natural gas flow into the turbines or HRSGs when they are offline	Buildup of natural gas in the turbines' or HRSGs' systems. If ignited, there is the potential for an internal explosion, i.e. damage to the turbines' or HRSGs' systems. This is a local event and does not pose any credible off-site risks as the cogeneration plant will be approximately 160 m from the nearest site boundary (Bolong Road)	Burner management system is certified to Australian Standards which includes the need for redundant actuated natural gas isolation and air purging prior to startup
66.	Loss of containment of natural gas from the supply pipes (outside the co-generation plant building)	Pipe failure, e.g. corrosion or weld defect, gasket failure, valve leak, impact	If ignited, potential for a jet fire, flash fire or explosion (if confined) which can impact personnel and equipment	The pipes are protected from impact by locating them in piperacks. Minimum flanges used. Pipes included in the hazardous zone study. Remote isolation of the natural gas is possible at the gas metering station. The natural gas supply pipe is pressure tested following construction and protected against corrosion by painting. The natural gas piping and equipment items are compliant with the Australian Standards

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
67.	Loss of containment of natural gas from the pipes within the co-generation plant building	Pipe failure, e.g. corrosion or weld defect, gasket failure, valve leak or hose failure	If ignited, there is the potential for an internal building explosion, i.e. damage to the building and equipment as well as the potential for injury to personnel. This is a local event and does not pose any credible off-site risks as the co-generation plant will be approximately 160 m from the nearest site boundary (Bolong Road)	The natural gas supply pipe is pressure tested following construction and protected against corrosion by painting. The natural gas piping and equipment items are compliant with the Australian Standards. Routine pipe inspections and maintenance. Actuated isolation valves are provided on the gas supply and will close on detection of gas or failure of the ventilation system. The LEL detectors / function are SIL (Safety Integrity Level) 2 rated
68.	Oil fire within the cogeneration plant building	Release of oil with subsequent ignition, e.g. due to a hot surface or spark	Damage to equipment within the building and possible injury to personnel. Combustion products will include carbon dioxide and soot	Industry standard hydraulic oil system designs to be used, e.g. designed for containment. Control of ignition sources, e.g. permits to work and hazardous area rated instruments and electrics. Fire protection includes sprinkler system through the cogeneration plant building and fire extinguishers (for smaller fires)

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
69.	Release of dosing chemicals for the Cogeneration Plant, the RO unit or the cooling towers	IBC valve leak. IBC punctured (e.g. fork lift truck tynes). Dosing line leak, e.g. joint failure	Release of chemicals, some of which are corrosive, i.e. impact to personnel and/or the environment	PMs on equipment. Routine inspections and response to a leak. Fork lift truck operator licensed. The dosing chemicals IBCs are stored in self-bunded DG containers. Safety showers / eyewash units installed near all dosing chemicals
	Proposed Nitric Acid Tank			
70.	Loss of containment of nitric acid from the proposed new tank	Releases due to: - Transfer system failures, e.g. hose leak. - Piping system or tank failures, e.g. corrosion or flange leak. Tank overfill	Release of a corrosive material. This could lead to harm to personnel (e.g. corrosive burns), equipment damage (from corrosion) and environmental impact. If there is incompatible material in the bund, e.g. dirt or combustible material, then the nitric acid will react and form NOx (toxic gas) and potentially start a fire	The nitric acid is to be stored in an AS3780 compliant tank within a bunded area. Inspections and housekeeping to check that the bunded area is free from incompatible materials. Preventative maintenance on all equipment. Tank and scrubber level monitoring including level instruments and alarms / trips. Fire protection includes hydrants, hoses, fire extinguishers and monitors. Procedures and training for handling the materials. Safety shower and eyewash units. Emergency response plans exist for the site, e.g. including spill response

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
71.	Failure of the nitric tank scrubber	Recirculation pump failure. Loss of liquid level in the scrubber, e.g. failure of the make-up water. Concentrated recirculation water	Release of acidic fumes. This has the potential to impact people, equipment and the environment close to the scrubber	Preventative maintenance on all equipment. Scrubber level monitoring including a level instruments and alarm. High recirculation conductivity alarm. Safety shower and eyewash units. Emergency response plans exist for the site, e.g. including spill response

Zone 9 HAZID – Starch Dryer 5, Cationic Starch Process (Specialties Products Building), Dryer 9 and Gluten Dryer 8

Note: See Zone 1 HAZID for the generic dryer hazards. The following hazards are additional to those shown in Zone 1.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
	Starch Dryer 5 and Cationic Starch Process			
72.	Fire / explosion within the building	Mechanical / electrical problems, choke underneath the sifter leading to too much starch on one side of the sifter	Sifter out of alignment, structural damage to building, worn electrical cables due to excessive vibration which could lead to dust ignition if a sock fails	Sifter motors trip the plant, safety cables on the sifter, canes (nylon or timber) on each corner of sifter, out-of-balance sensor on top of each of the sifter will trip the sifter, spill detectors (i.e. dust detection monitors), flexible electrical cables, overload trips, PMs for the sifters' bearings
73.	Building explosion	Failure of a sifter connecting socks	Loss of containment of dust with potential for ignition and hence an explosion in the building. This is more likely for a top sock failure with the dust falling on to the moving sifter. Impact to people, equipment and the business	Walkthrough observations by the operators, operators respond to a loss in plant yield, spill detectors, PMs on the sifters
74.	Deadhead the blower in a blowline. This scenario also applies to RD9 and GD8	Material hold-up, discharge valves in the closed position	Maximum pressure within the pipe and hence the potential for a loss of containment. Fire or explosion if ignited. Impact to people, equipment and the business	Pressure safety valve on the blower which will only release air, not product. High pressure trips the process. Steel pipes. Belt driven blower
75.	Explosion within a blowline. This scenario also applies to RD9 and GD8	Low likelihood event, e.g. static or friction	As the blowline is designed for containment then the flame front will travel along the pipe, e.g. to the downstream bin. Potential for an explosion within the bin	Bonding and earthing of the entire blowline. The blower is a rotary lobe machine and hence mitigate reverse flow out through the air inlet. Dust concentration normally below the approximate lower explosion limit (LEL). Non return valves on the rotary lobe blower

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
76.	Fire / explosion within the mixer	Foreign object, contact between the paddles and the mixer shell, i.e. these can cause sparks	Potential for ignition of the product leading to a fire and explosion	Clearance gap for mixer design with PMs on the equipment
77.	Internal explosion within the grinder. This scenario also applies to RD9 and GD8	Broken pin, shaft out-of-alignment, bearing failure, too much feed / choking, foreign object	If ignited, there is the potential for an internal explosion leading to equipment damage and missiles. Potential for injury to personnel	Casing temperature and vibration monitored via the PLC (programmable logic controller), regular PMs including balance checks, motor overload trip, high level switch within the casing, casing rated for 10 barg (i.e. designed for an internal dust explosion)
	Cationic Starch (only)			
78.	Loss of containment of caustic (50wt%), hydrochloric acid (33wt%) or cationic reagent	Valve leak. Dosing line, pump or tank leak, e.g. joint failure or corrosion. Overfilling a tank. Leak from the road tanker transfer system, e.g. hose failure or driveaway	Release of chemicals, i.e. corrosive impact to personnel, equipment and/or the environment	The caustic, hydrochloric acid and cationic reagent tanks are separately bunded. The road tanker bay is also bunded. All spills flow to the WWTP for treatment. Operator response to high level alarm. High level trip on the power supply to transfer pumps. PMs on equipment. Licenced DG drivers and operator supervision. Routine inspections and response to a leak. Safety showers / eyewash units installed near all dosing chemicals. All the Zone 9 buildings are bunded and any

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				spills are collected in a 20,000 L underground tank (HumeCeptor)
79.	Scrubber failure	Loss of scrubber make-up water	Emission of acidic mist to atmosphere, i.e. impact to people, the environment and equipment (e.g. corrosion)	Operator response to low water flow alarm. Low water flow trip to shut down the scrubber and hence the plant
80.	Epoxide exposure	Caustic and Quat react in a short section of pipe to give an epoxide (ethylene oxide and propylene oxide are epoxides, i.e. some are carcinogenic)	If release, the epoxide can cause harm to personnel local to the piping system	Procedures and training including the need for PPE (personal protective equipment) and flushing for maintenance activities

Zone 10 HAZID - North Packing Plant

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
81.	Dust explosions within the new equipment, e.g. the rotary seal valves and silos	Ignition of combustible dust, e.g. due to smouldering, open flames, hot surfaces, lightning, heat from mechanical impact or friction, and electrical discharges and arcs	Damage to the processing equipment and injury to personnel. Potential propagation to the combustible material processed and stored at the facility. Products of combustion emitted with the potential to impact people and the environment. The explosion can also travel throughout equipment with the potential for pressure piling and hence more significant explosive energy. Projectiles are possible with the risk of injury to people and damage to equipment	All equipment containing dust is to be designed to ATEX standards including explosion vents and airlocks to separate transfer systems. Housekeeping to keep the area dust-free. The equipment is to be rated for hazardous zones including electrics and instruments are to be suitably rated and all equipment is to be bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. High level detection on the silos. Use of fire hoses to extinguish smouldering fires. As the minimum ignition temperature for starch is approximately 380 C and higher and gluten is 460 C, maintenance of equipment and possibly detection by operators may prevent hot surfaces initiating a dust explosion

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
82.	Explosion in a dust collector	Propagation of fire event from elsewhere in the process, e.g. burning embers drawn into the dust collector	Explosion with the potential for injury and equipment damage	Inducted draft which keeps the concentration below the LEL (lower explosive limit). All filters are to be pulsed with air for cleaning. All filters are to be checked routinely by maintenance for high differential pressure (DP). If issues arise then the socks are changed
83.	Blockage of the blowline to the silos	Material buildup, blower failure, baghouse failure on the silo	Material build-up with potential for heating and hence fire and explosion	Process tripped on loss of a blower and other essential drives. Pressure monitoring on the blowline
84.	Release of product from the transfer blowline	Erosion, explosion vent opening, gasket failure, impact from a vehicle	Loss of containment of product to atmosphere potential for environmental impact and possible ignition. If the release is near Bolong Road then there is the potential to affect traffic, e.g. causing an accident	Schedule 40 stainless steel pipe for extra thickness, long radius elbows used to minimise the risk of erosion, minimum joints to be installed, pipe bridge to be installed under Bolong Road, impact protection for the pipe bridge supports including being located away from Bolong Road
85.	Overfilling a silo	Failure of the level instrument monitoring the product level within the silos	The product level can overflow the silo via the aspiration system. This can lead to explosions	Independent high level trip on the silos to stop the filling system, the area is to be rated for hazardous zones including electrics and instruments are to be suitably rated and all equipment is to be bonded and earthed

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
86.	Dust explosion within the warehouse / bagging area	Loss of containment of dust within the building, e.g. dust emissions from bags and the filling machine	Dust explosion within the building, loss of life, equipment damage, production downtime, potential for both a primary and secondary explosion	Aspirated system, instruments and electrics to hazardous zones' requirements, housekeeping. Equipment is to be designed for containment. The open building doors will provide explosion venting to minimise the developed overpressures. Regular cleaning. The bags are mechanically filled (air blowing is not to be used)
87.	Static charge on the truck during loading	Free-falling product	Potential source of ignition for explosive / combustible dust	All loading equipment will be bonded to earth

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
88.	Fire in warehouse	Arson, faulty electrics, hot work	Damage to warehouse and loss of product and contaminated fire water	For starch, this is a low risk given the starch is not deemed to be a solid capable of supporting combustion. The product is to be stored within 1 te and 25 kg bags on wooden pallets. The warehouse is to be a concrete and steel construction. Therefore, the fire load is very low and any fires occurring will be of limited radiant heat consequence. Fire protection to comply with Australian Standards as appropriate. Contaminated fire water flows to the Manildra waste water treatment plant. Permit to work system. The new facility is to be located within a new boundary fence and hence only authorised personnel have access. Security patrols, the area is to have adequate lighting

Zone 11 HAZID – Natural Gas Pressure Reduction Facility

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
89.	Loss of containment of natural gas from the supply pipe or gas pressure reduction facility	Pipe failure, e.g. corrosion or weld defect, gasket failure, valve leak, impact, land subsidence, wash-away or Third Party interference	If ignited, potential for a jet fire, flash fire or explosion (if confined) which can impact personnel and equipment	The pipe is protected from impact by locating it underground and providing barriers around the GPRF (Gas Pressure Reduction Facility). Minimum flanges used. Pipe is included in the hazardous zone study. Remote isolation of the natural gas is possible at the Meroo Meadow gas metering station. The natural gas supply pipe was pressure tested following construction and protected against corrosion by trilaminate coating and cathodic protection. The natural gas piping and equipment items are compliant with the Australian Standards, e.g. AS2885 and AS4041. This includes the controls identified in the AS2885 Safety Management Study

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
90.	Overpressure of the piping downstream of the gas pressure reduction station	Failure of the gas pressure reduction valves (including the slam shut valves potentially passing)	Potential to overpressure the downstream piping leading to a failure. If ignited, potential for a jet fire, flash fire or explosion (if confined) which can impact personnel and equipment	Maintenance of all equipment associated with the pipeline. Redundant pressure reduction valves. Actuated high pressure emergency isolation valve prior to each gas pressure reduction facility. Remote isolation of the natural gas is possible at the Meroo Meadow gas metering station. Pressure safety valve downstream of each reduction facility (sized for valve leakage)

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
91.	Overpressure of the GPRF equipment, e.g. the filters and water bath heater	External fire. Burst tube in the water bath heater	Potential to overpressure the equipment leading to a failure. If ignited, potential for a jet fire, flash fire or explosion (if confined) which can impact personnel and equipment	Equipment designed to AS1210, i.e. pressure vessel standard. This includes the installation of pressure safety valves. PMs on the equipment. Hardstand around the GPRF. Emergency response to a fire, e.g. firewater application for a grass fire or to cool heat affected equipment. A gas fire is extinguished by isolation (this is provided by multiple upstream valves). Fully welded schedule 120 pipe for the heater tubes. Chemical dosing of the water in the water bath heater to lower the risk of corrosion. Emergency venting swing hatch on the water bath heater sized for this scenario. Instruments and electrics compliant with hazardous area zoning (to lower the likelihood of ignition)

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
92.	Low temperature embrittlement	Failure of the water bath heater	Lower temperature natural gas to the pressure reduction stations and therefore the potential for lower gas temperature downstream, i.e. below the piping design temperature (minus 30 deg C) due to Joule Thomson cooling. If the temperature drops below minus 30 deg C there is the potential for low temperature embrittlement and therefore pipe failure, i.e. release of gas, fire/explosion if ignited	Two-out-of-three temperature protections downstream of the high pressure regulators. These raise an alarm at 5 deg C and another alarm at 0 deg C, i.e. the operator is required to fault find the cause for the low temperature (e.g. the response would include changing the water bath heaters). PMs on temperature transmitters including the temperature controller. SIL 2 rated low temperature trips downstream of the water bath heater
93.	Confined explosion in the water bath heater	Gas continues to flow into the fire tube when the burners are offline	Potential for confined explosions if ignited, i.e. damage to the fire tube and possible injury to personnel	Australian standard compliant shut off valves (fail closed) to prevent gas flow when it needs to be isolated. Double block actuated valves provided on the fuel gas to the main burner

Event Number	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
94.	Loss of containment of natural gas from the pig trap	Procedural error, e.g. leaving a vent valve open. Equipment or pipe failure, e.g. corrosion or weld defect, gasket failure or valve leak	If ignited, potential for a jet fire, flash fire or explosion (if confined) which can impact personnel and equipment	The pig trap is a standard industry design which includes a mechanical interlock on the door to prevent it being opened when there is pressure within the trap. Pigging performed by specialist contractors only (as per their training and procedures). Control of ignition sources, e.g. hazardous area compliant electrics and instruments, and permits to work. PMs on the pig trap equipment. This includes the use of Snoop to check that all flanges are not passing. Emergency response to a fire, e.g. a gas fire is extinguished by isolation (this is provided by multiple upstream valves)

Zone 13 Former Dairy Farmers Factory and Site – Proposed MOD26 Modifications

Event Number	Facility Area / Activity	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
95.	All new equipment containing confined combustible dust	Dust explosions within the new equipment, i.e. the intake pit, the belt conveyors, the bucket elevators and the silos	Ignition of combustible dust, e.g. due to smouldering, self-heating, open flames, hot surfaces, lightning, heat from mechanical impact or friction, and electrical discharges and arcs	Damage to the processing equipment and injury to personnel. Potential propagation to the combustible material processed and stored at the facility, e.g. along the belt conveyors distributing the wheat to the existing flour mills. Products of combustion emitted with the potential to impact people and the environment. Projectiles are possible with the risk of injury to people and damage to equipment	All equipment items containing dust are to be fitted with baghouse filters to eliminate or mitigate the dust explosion risk. Magnetic separator to be installed on the outlet conveyor from the silos to prevent ferrous material progressing downstream and possibly causing a source of ignition. Housekeeping to keep the area dust-free. The equipment items are to be rated for hazardous zones including electrics and instruments are to be suitably rated and all equipment is to be bonded and earthed. Permit to work system requiring adequate cleaning and control of ignition sources. Condition monitoring of equipment and preventative maintenance to limit the probability of hot surfaces from friction occurring. Out-of-alignment and underspeed detection on the conveyors. Materials stored at ambient temperature, use of fire hoses to quench smouldering fire, rain prevented from entering the equipment and hence causing self-heating. As the minimum ignition temperature for flour dust is approximately 400 C and higher, maintenance of

Event Number	Facility Area / Activity	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
					equipment and possibly detection by operators will lower the likelihood of hot surfaces initiating a dust explosion
96.	Silos	Overfilling a silo	Failure of the level instrument monitoring the grain level within the silos. Slide gate valve on the silo feed stuck open	The grain level can back-up to the belt conveyor resulting in friction. This can lead to explosions (as above)	Independent high level trip on the silos to stop the filling system. Overload protection on the belt conveyors
97.	All wheat storage and handling equipment	Combustible materials fire	Ignition of the wheat from a strong ignition source, e.g. hot work, electrical fault or equipment failures such as friction in a conveyor (such as a belt fire)	Historically these materials have resulted in smouldering fires with limited radiant heat impact. As the silos are to be located more than 20 m from Bolong Road boundary then no off-site impacts from radiant heat are deemed credible. Potential for the fire to propagate throughout the facility with significant damage to the equipment and structures. Propagation could include a dust explosion as above.	The wheat grains have a moisture content of approximately 10 to 12% which limits the combustibility. The wheat grains are contained within the processing equipment to limit exposure to strong ignition sources. Fire protection includes hydrants and extinguishers. Fire Brigade response also included in the emergency response plan. Fire protection equipment to be maintained as per the requirements of AS1851. Permits to work for any hot work. Maintain and service plant and equipment as per manufacturer's requirements. Carry out regular workplace inspections to identify hazards and rectify immediately.

Event Number	Facility Area / Activity	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
				Products of combustion emitted with the potential to impact people (on and off site) as well as the environment. Potential for low levels of contaminated fire water. Products of combustion within a silo can include flammable gases such as carbon monoxide due to inefficient combustion from restricted oxygen supply. These gases will rise and potentially accumulate in the top of the silos. If the flame front reaches the top of the grains in the silo, the flammable gases may be ignited to cause an internal explosion with the same consequences as an internal dust explosion	Prestart check to ensure equipment is in good condition and operating correctly. Waste water from the facility flows to the environmental farm for processing

Event Number	Facility Area / Activity	Hazardous Event	Causes	Consequences	Existing Safeguards - Prevention Detection Mitigation
98.	Baghouse Filters	Explosion	Static, carryover spark. Propagation of fire event from elsewhere in the process, e.g. burning embers from the silos' feed conveyors	Explosion resulting in equipment damage (the baghouse filters are to be located at the top of the silos and hence off-site impact at this location is not expected)	Earthing / bonding of all equipment. Hazardous area zones compliance. The switches on the explosion vents will stop the process including the rotary seal to stop the explosion propagating. Induced draft which keeps the concentration below the LEL (lower explosion limit). All filters are to be pulsed with air for cleaning, pressure is to be measured and checked every day. If issues arise the socks are to be changed. The socks are also to be routinely changed and are to be anti-static socks
99.	Baghouse Filters	Release of product	Failed sock	Product release impacting the environment	All filters are to be pulsed with air for cleaning, pressure is to be measured and checked every day. If issues arise the socks are to be changed. Visual detection, reporting from outside sources. Pressure measurement across the baghouse filters. The socks are also to be routinely changed. LEL levels not reached, i.e. not considered to be an ignition risk

Zone WWTP HAZID – Waste Water Treatment Plant

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
100.	LPG fire	Loss of containment of LPG with subsequent ignition	The LPG tank is located in an open area on the Shoalhaven Starches farm. If ignited, the credible outcomes are jet fire, flash fire and BLEVE (boiling liquid expanding vapour explosion). This can injure people and damage the WWTP equipment	The LPG tank is designed, installed and maintained to AS1596. Control of ignition sources (hot work permit). Fire protection includes fire extinguishers located at the site. Area around the LPG tank is rated as a hazardous area. Bollards for mechanical protection of the LPG pipes. Warning tape over the LPG pipe
101.	Internal explosion under the Bulk Volume Fermenter (BVF) or within the biogas piping This scenario also applies to the MOD26 modifications	Wear and tear, pipe or foreign object piercing the cover. Biogas vent open	Potential for air to be drawn into the biogas and hence the risk of an internal explosion. This could lead to equipment failure and hence the risk of an external fire	Negative suction pressure will draw the cover into the water and hence seals the opening. Control of ignition sources. Flame arrestor at the flare and boilers inlets to prevent flashback (inspected yearly). Bi-annual cover integrity inspections. Pre-startup checks for the vent valves' positions

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
102.	Internal explosion within the biogas blowers building This scenario also applies to the MOD26 modifications	Loss of containment of biogas, e.g. blowers seals, pipe failure or valve passing, with ignition	Destruction of the building and serious injury to personnel (fatality if inside the building). As this building is located on the Manildra farm and there are significant separation distances to off-site receptors then there is no credible off-site risks	Building ventilation fan interlocked to all power users. Equipment rated to hazardous zones. Operators enter building with an LEL detector (treated as a restricted work area on entry)
103.	Internal explosion within the new Waste Water Tank or Equalisation Tank	Potential for build-up of flammable vapours in the vapour space of the tanks with subsequent ignition	Internal tank explosion. As the tanks will be designed as atmospheric tanks then the roof is likely to fail first (typically at approximately 7 kPa). This minimises the generated overpressures that are released. An internal tank explosion can lead to injury or fatality to people near the tanks as well as environmental impact (from the released liquids) and equipment damage	The tanks are to be included in the project's hazardous area assessment. If a hazardous area exists then there will be compliant equipment and control of ignition sources (e.g. permits to work). Emergency response plan including First Aid and spill response
104.	Biogas release This scenario also applies to the MOD26 modifications	Pipeline damage, e.g. excavation, piling or river bank erosion	Potential for loss of containment of biogas and hence fire and/or explosion if ignited, i.e. injury to people, damage to equipment or buildings and company reputation impact (if the release is in a public area). Also, potential for odour complaints due to hydrogen sulphide etc in the biogas	Pipe is approximately 2 m below ground level. Warning tape over pipe. Poly pipe underground (i.e. resistant to corrosion), stainless steel pipe above ground. Sheet piling along the river bank to lower the risk of bank erosion. Pond is rated as a hazardous area (3 m from the pond edge which will include the flanges in the pipe). Biogas can be diverted and burnt within the flare.

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
				The MOD 26 pipes are to be protected from impact by locating them in piperacks or underground. Minimum flanges used for the MOD26 piping. The MOD26 pipes are to be included in the hazardous zone study. Remote isolation of the biogas at the WWTP. The biogas supply pipes are to be pressure tested following construction and protected against corrosion by painting. The biogas piping and equipment items are to be compliant with the relevant Australian Standards (AS3814, AS5601.1) and constructed from stainless steel
105.	Confined explosion within the biogas piping system	Failure of the anaerobic digester cover or suction piping to the biogas blowers	Air can be drawn into the biogas system. If ignited, there can be internal explosions leading to equipment damage and injury to nearby people	Hazardous area compliance and control of ignition sources. Piping designed to Manildra/Australian standards. (AS4041, AS3814, AS5601.1). Stainless steel piping. Bi-directional flame arrestors used at each point of use / upstream of gas appliance

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
106.	Activated carbon filters fire	Accumulation of combustible materials on the activated carbon and then oxygen (air) introduced	Potential for reaction to occur which can lead to an internal carbon bed fire. This will cause damage to the equipment	The cover and piping system is designed to avoid leaks resulting in oxygen (air) ingress. Use of oxygen monitoring upstream of the scrubber to be used to monitor oxygen levels. Elimination of ignition sources in the area. Pressure and temperature sensors to monitor operation and shutdown in case of an internal fire. Water is typically used to extinguish an activated carbon bed fire
107.	Explosion within the aqueous ammonia tank	The ammonia vapour within the tank needs to be within the flammable region plus a strong source of ignition, e.g. hot work	Internal tank explosion, i.e. potential to harm people, damage equipment, release the aqueous ammonia and also projectiles / tank rocketing	Permit to work system requiring adequate cleaning and control of ignition sources. The vapour pressure of ammonia is high, therefore, normally the vapour space ammonia concentration is likely to be above the UEL

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
108.	Loss of containment of dosing chemicals, e.g. sodium hypochlorite, citric acid, sulphuric acid, ferric chloride, ant-scalant, caustic and aqueous ammonia (25wt%) This scenario also applies to the MOD26 modifications	Valve leak. Dosing line, pump or tank leak, e.g. joint failure or corrosion. Overfilling a tank. Leak from the road tanker transfer system, e.g. hose failure or driveaway	Release of chemicals, i.e. corrosive impact to personnel, equipment and/or the environment	The incompatible chemicals'' tanks are separately bunded. The IBCs are self-bunded or within a 20 Foot DG container. The road tanker bay is also bunded. All spills flow to the adjacent WWTP for treatment. Operator response to high level alarm. High level trip on the power supply to transfer pumps. The tanks are adjacent to the road tanker unloading bay and therefore the driver can monitor the tanks during filling. PMs on equipment. Licenced DG drivers and operator supervision. Routine inspections and response to a leak. Safety showers / eyewash units installed near all dosing chemicals
109.	Mixing of incompatible chemicals This scenario also applies to the MOD26 modifications	Ferric chloride transferred into the sodium hypochlorite tank or the caustic tank (or vice versus)	Mixing of incompatible materials causing a reaction, i.e. heat, pressure increase in the tank and possibly toxic fumes (e.g. if the ferric is mixed with the hypo which emits chlorine gas)	Training and procedures. Signage

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
110.	Failure of a pond liner This scenario also applies to the MOD26 modifications	Excavation, tree roots, earth movement	Potential for the contents of a pond to flow into the groundwater, i.e. environmental impact	All ponds are clay lined. Any vegetation, e.g. trees, that grow and potentially cause damage to the clay liner are removed as necessary. Permits to work for any excavation in the area
111.	Biogas scrubber failure	Failure of the scrubbing media, e.g. toxic dose killing the biomass	Reduced hydrogen sulphide removal in the biogas. This will lead to increased acidic conditions in the boilers and hence the potential for long-term failure of a boiler. There will also be increased SOx emissions when the biogas is flared	Biogas scrubber monitoring and sampling. Boiler monitoring, e.g. for corrosion rates
112.	Dust explosion within the MOD34 grain storage shed	Build-up of dust within the building with subsequent ignition	Dust explosion within the building, loss of life, equipment damage, production downtime	There will be no electrical infrastructure installed inside the shed. Equipment, including the tractor and auger, will have preventative maintenance to lower the risk of ignition. Earthing of equipment. Covers over motors. Authority to Work system and Hot Work Permits for any hot works inside the shed

Event ID No.	Hazardous Event	Causes	Consequences	Prevention and Mitigation Control Measures
113.	Fire within the MOD34 grain storage shed	Electrical fault, grain self-heating, blockage in the mobile auger leading to friction, heat and ignition of the grain, arson	Damage to the building and equipment, fire hazard to personnel. Potential for a dust explosion within the building, e.g. dur to combustible dust and/or flammable gases from the combustion process	The shed will always be filled from the same side to maintain consistency in operations. The shed is fully sealed which minimises the risk of moisture ingress. All wheat is tested prior to in-loading into the shed, confirming it meets storage specifications. Equipment, including the tractor and auger, will have preventative maintenance and cleaned regularly to maintain hygiene and prevent contamination and malfunction. Earthing of equipment. Covers over motors. Fire extinguishers to be located within the shed. Authority to Work system and Hot Work Permits for any hot works inside the shed

16 APPENDIX C – CONFINED DUST EXPLOSION MODELLING

Appendix C – Confined Dust Explosion Modelling

PRM Methodology for Approximating Overpressures from a Confined Dust Explosion in a Low Strength Vessel or Building

There is a significant amount of research and methodologies for predicting the overpressures from a ruptured pressure vessel (e.g. TNO, The Yellow Book). Pressure vessels generally being defined as having a maximum allowable working pressure of 1.03 barg or higher.

There are only limited methodologies for predicting overpressures from a non-vented, low strength enclosure or vessel subject to an internal dust explosion. This is partly due to the variations in the developed pressure due to factors such as the location and strength of the ignition source, the amount of turbulence generated and the nature of the dust.

Two similar methodologies for estimating the overpressures from a non-vented, low strength structure that is subject to an internal dust explosion are provided in:

- CCPS, Guidelines for Chemical Process Quantitative Risk Analysis, Second Edition
- Tweeddale, M., Managing Risk and Reliability of Process Plants, 2003.

However, both of these methodologies can overpredict the explosive effects when used for modelling of historical events. This is partly due to the approaches attempting to convert the combustion energy into condensed-phase explosive (TNT equivalent) energy. The following paragraph (from TNO's The Yellow Book) explains the differences.

> *"Compared to a TNT explosion, the shock wave produced by bursting vessels has lower initial overpressures, a slower decay of overpressure with distance, longer positive-phase durations, much larger negative phases and strong secondary shocks. Therefore, the TNT equivalent method gives only reasonable result in the far range, which definition is related to the explosion energy. Usually, the far range is a distance of 10 to 20 times the vessel diameter or more."*

Hence, for an internal explosion modelled using a TNT equivalent approach, the overpressures in the near-field are likely to be over-estimated. This poses difficulties for dust hazard analysis when assessing the risk of propagation impacts to nearby structures or people.

When a dust explosion occurs in a low strength structure, the walls (or a significant portion of the walls) catastrophically fail due to brittle fracture (i.e. failure without any appreciable prior plastic deformation). Once this occurs, there is limited or no further increase in pressure.

Eckhoff (Eckhoff R. K., *Dust Explosions in the Process Industries*, 2003), performed experiments on a 500 m^3 silo (approximate dimensions: L/D = 4; D = 5.4 m and L = 21.6 m). The quantities of dust blown inside the silo were:

Wheat grain dust = 300 kg

Corn starch = 200 kg.

The vent cover used in the experiments was a sheet of plastic with a low static opening pressure, in the order of 0.01 to 0.02 barg. The final, exceptional corn starch explosion (300 kg), named turbulent jet, was so violent that the silo wall (nailed steel plates) ruptured at about 0.6 barg. This produced an additional vent of 50 m^2 ***which prevented the pressure from rising further.*** The surface area of the silo is approximately 412 m^2, i.e. the opening was approximately 12% of the surface area.

The impact of large vent areas on the maximum pressure within the enclosure is also discussed in the GexCon, *Gas Explosion Handbook*, 1992, as follows.

If a fuel-air cloud explodes within a compartment with no or very little venting, even slow burning can cause pressure build-up. In extreme cases, a slow flame can, in a closed compartment, cause pressures up to 8 bar ***if the compartment does not disintegrate***.

This is illustrated in the following graph.

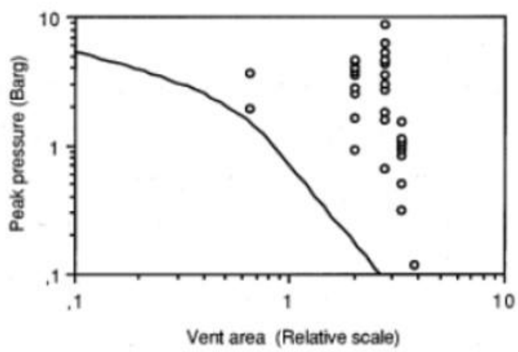


Figure 10.2. *Maximum overpressure observed in a 50 m^3 tube, Moen et al. (1982), compared with the upper pressure bound (solid curve) based on vent areas for central ignition in near-spherical vessels as proposed by Bradley and Mitcheson (1978).*

As can be seen from the above figure, as vent area increases, the peak pressure within the vessel or structure decreases. The maximum peak pressure then becomes the rupture pressure of the vessel or structure for catastrophic failures.

The dynamics of an explosion in buildings and enclosures (Ref: BS EN14491:2006, *Dust Explosion Venting Protective Systems*) will be affected by several parameters such as the shape of the building, the presence of equipment and structural elements, the possibility of propagation from room to room and the presence of combustible dust left to lie on surfaces such as window sills, pipework and floors. The dust explosion may be limited to a small part of the total volume. Pressure development will vary according to circumstances and a wide range of dust explosion loads can be expected.

From Taveau, J., *Correlations for Blast Effects from Vented Explosions*, Journal of Loss Prevention in the Process Industries, 2010:

- Vented explosions are complex and therefore difficult to model
- External explosions (due to vented dust) lead to higher overpressures and greater hazards than the internal explosions
- The relevant factors for evaluating the intensity of the external explosions are the reactivity of the fuel, the size and the opening pressure of the vent opening, as well as the location and intensity of the ignition
- Large vent openings lead to spherical fireballs whereas small vents lead to a high-velocity jet flame and hence an external explosion at a greater distance
- The most detrimental ignition location would appear to be far away from the vent opening.

Hence, modelling of confined dust explosions in low-strength, non-vented structures is complex and further research is required for accurate modelling.

The following methodology is an approximation only. The methodology makes use of the significant research on vented dust explosions with some assumptions based on experiments and judgement. It will, however, provide an approximation for overpressure prediction for hazard analysis purposes.

Correlations for vented dust explosions use the following main parameters:

- Vessel volume
- Vent area
- The maximum pressure (Pmax) reached within the enclosure.

Other parameters are also used, e.g. the number of vents, depending on the method.

The first of the above main parameters is vessel volume. This is relatively easy to estimate, e.g. the volume of a building (normally the piping and equipment volume can be neglected unless significant) or a silo that is, say, 10% full with material.

The second parameter, i.e. vent area, requires some judgement. When a low-strength, non-vented structure ruptures, typically a significant sized hole appears. For example, the above-mentioned experiment by Eckhoff on a 500 m^3 silo yielded a 50 m^2 opening or approximately 12% of the silo surface area. It is also possible that the enclosure is fully demolished, i.e. the opening will be large.

The following table shows the impacts of large vent sizes on the estimation of overpressures using the EN14491 2012 correlations. Vessel volume is 500 m^3 (surface area is 412 m^2) and Pmax is 60 kPag.

Impacts of Large Vent Sizes on Overpressures (EN14491:2012)

		Distance (m) to the Following Overpressures		
Vent Area, m^2	Percent of Surface Area	21	14	7
10	2.4	16	21	32
20	4.9	16	21	33
30	7.3	17	22	34
40	9.7	17	22	35
50	12	18	23	37
100	24	26	34	55
200	49	34	45	73

From the data in the above table, the larger the area, the greater the distance to selected levels of overpressure. Hence, the worst-case consequences are predicted when the enclosure catastrophically fails. To avoid being overly conservative, anecdotal results are used. The following summarises the impacts from a review of previous dust explosions:

- Vessels with a high L/D ratio (3 or more), e.g. silos. Whilst these can catastrophically fail, the most common outcome is the roof being blown away due to the flame-front travelling up the silo and accelerating. Therefore, the cross-sectional area of the vessel could be used as the area for the catastrophic failure

- Buildings are more challenging as, historically, there have been many different types of openings generated, i.e. as small as 20 to 30 m^2 to loss of an entire wall to complete destruction of the building. If the building is elongated then loss of an entire wall could be justified, i.e. similar to a silo, as the flame will travel the furthest in the longest direction within the building, accelerate and hence the entire wall can be lost. The historical events where the entire building is destroyed, e.g. West Pharmaceutical Factory, USA, 2003, and Imperial Sugar Refinery, Port Wentworth, Georgia, USA, February 7, 2008, are thankfully rare and require a significant amount of dust and turbulence. Good manufacturing practice should be able to avoid these types of explosions, e.g. a good housekeeping program. Based on typical explosion events in low-strength structures, 20 to 30% of the total building surface area as the opening would be typical

- For relatively small enclosures, e.g. 1 to 50 m^3, near-complete destruction could be assumed (note: the generated overpressures do not travel that far for such structures). In this case, again, the opening could be taken as 20 to 30%.

The third main parameter is the maximum (reduced) pressure (Pmax) reached within the enclosure. Based on experiments, e.g. Eckhoff's 500 m^3 silo rupture and Figure 10.2 (above) from the GexCon, *Gas Explosion Handbook*, 1992, the maximum reduced pressure is approximated as the enclosure material's failure overpressure.

EN14491:2006, *Dust Explosion Venting Protective Systems*, states that $P_{red, max}$ shall always exceed P_{stat} by at least 2 kPa. P_{stat} is normally the vent static opening pressure. In this context, it is taken to be the enclosure's failure pressure. Therefore, 2 kPa is added to the enclosure's failure pressure. Note that this additional 2 kPa has a minor effect only and could be neglected.

Typical materials of construction and their failure pressures are shown in the following table. Add 2 kPa to these values to provide an estimate for $P_{red, max}$.

Table – Overpressure Impacts on Buildings and Enclosures

OVERPRESSURE, kPa	PHYSICAL EFFECT	Ref No.
7	Chipboard failed	1
7 to 14	Shattering of corrugated asbestos siding. Connection failure, followed by buckling, of corrugated steel or asbestos panelling. Wood siding panels, standard house construction, usually failure at the main connections allowing a whole panel to be blown in	1
7 to 15	In typical 'English' brick-built houses, not habitable without very major repair works. Partial roof failures, 25% of walls fail, serious damage to remaining carrying elements. Damages to windows, doors and frames	2
10 to 38	Shattering of concrete or block wall panels (not reinforced, 200 to 300 mm thick)	1
10	Unreinforced masonry building complete collapse	3
15 to 20	Walls made of concrete blocks (Besser blocks) collapse	2

OVERPRESSURE, kPa	PHYSICAL EFFECT	Ref No.
15 to 30	Corrugated steel or aluminium panelling – connection failure followed by buckling (Lees, 3rd Edition, Table 17.43)	1
15 to 30	Corrugated asbestos siding shattered (Lees, 3rd Edition, Table 17.42)	1
15 to 30	Wood siding panels, standard house construction. Usually failure occurs at the main connections allowing a whole panel to be blown in (Lees, 3rd Edition, Table 17.42)	1
17	Steel framed / metal siding building – all walls destroyed	3
17	Steel frame building with reinforced masonry – complete frame collapse	3
20 to 80	Concrete or cinder-block wall panels (200 or 300 mm thick) not reinforced, shattering of a wall (Lees, 3rd Edition, Table 17.42)	1
21 to 28	Collapse of self-framing steel panel building	1
30	Cladding of light industry building pulled away	2
35	114 mm brick walls destroyed	1
35	In typical 'English' brick-built houses, damage is not repairable. 50 to 75% of the outer walls are lightly to heavily damaged. The remaining walls are unreliable	2
41	Reinforced concrete building – complete collapse	3
45 to 145	Brick wall panel (200 or 300 mm thick) not reinforced – shearing and flexible failures (Lees, 3rd Edition, Table 17.42)	1
50	200 to 300 mm thick brick walls collapse	2
105	228 mm brick wall destroyed	1

References:

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

2. TNO, *Methods for the Determination of Possible Damage (The Green Book)*, 1992

3. API 752, *Management of Hazards Associated with Location of Process Plant Permanent Buildings*

For low-strength process vessels, e.g. dust collectors, bucket elevators and ducting, the rupture pressure is normally 7 to 10 kPag. Add 2 kPa (as per EN14491) and this provides an estimate for the maximum pressure attained when a dust explosion occurs within these vessels (assuming an opening occurs).

For vessels with a known, higher design pressure, the typical rupture pressure is estimated to be 3 to 4 times the maximum allowable working pressure (see TNO's The Yellow Book for further details).

This method assumes the predicted side-on pressures, i.e. the overpressures, results in the same impact to all types of generic structural designs. This does not take into consideration the impulse pressure (duration dependent) which can affect the same structural designs in different ways. However, the method does provide a useful tool for approximations.

The steps for estimating distances to various levels of overpressure are therefore summarised as:

- Of the venting methods available, use the 2012 EN14491 correlations. These have been shown to be in good agreement with experiments on dusts with K_{st}'s up to 200 bar m/s, i.e. agricultural dusts
- Determine the maximum pressure within the enclosure. This is the rupture pressure, e.g. from design data or published experimental data, plus 2 kPa (as per EN14491)
- Approximate the area (m^2) and perimeter (m) of the opening
- Determine the volume of the enclosure (m^3). Normally the presence of equipment and piping within the enclosure can be ignored
- Define the angle from the vented gases direction for estimating the overpressures of interest: 0 if in front of the vent, 90 if orthogonal to the vented gases or 180 if the overpressures are required for the area behind the vent. The default should always be in front of the vent, i.e. the angle is 0
- Estimate the overpressures using the EN14491 correlations (shown on the following pages).

Note that this method would only apply for the external effects of an explosion within a low-strength enclosure or vessel, for example, a relatively thin vessel such as a silo or a building with weak cladding, such that the restraint imposed on the explosively expanding gas cloud is insufficient to affect the overpressures. This method is not suitable for assessing the effect within the containment. If the design pressure for the vessel is 1.03 barg or higher then the methods detailed in TNO's The Yellow Book (or similar) should be used.

Also, given the approximations used within the methodology, it should not be used for design purposes. It can, however, be used for approximating overpressures for dust hazard analyses.

Using the 500 m^3 silo experiment by Eckhoff, the following table compares the CCPS, Mark Tweeddale and PRM methodologies. Pmax is taken to be 60 kPag as this was measured during the experiment. The vessel volume = 500 m^3, the vent area = 50 m^2 and the vent perimeter is approximated as (2 x 10) + (2 x 5) = 30 m.

Comparison of Overpressure Prediction Methods for an Internal Dust Explosion

Overpressures, kPa	35	21	14	7
CCPS: Distance, m, from Centre of the Explosion	53	73	94	144
Mark Tweeddale: Distance, m, from Centre of the Explosion	30	42	54	84
PRM Methodology: Distance, m, from Centre of the Explosion	13	18	23	37

The PRM method approximates the event better than the CCPS and the Mark Tweeddale methods. It could also be conservative given the lack of reported propagation damage.

EN14491 Correlations:

From EN14491 2012:

Explosion overpressures outside a vented explosion can be due to:

1. Explosion of the dust cloud in the area outside the vent (i.e. dust that doesn't initially combust within the enclosure and is subsequently vented and then ignited)

2. Overpressure due to the vented explosion (the overpressures from this event are directional, i.e. emanating in-line and directly away from the vent).

The maximum external overpressure (Pmax) arising at any location outside the vented enclosure is the highest value from these two causes.

Equation 1. Overpressures from dust cloud explosion outside the vent:

$$Pmax = 0.2 \times Pred \times A^{0.1} \times V^{0.18}$$

Where:

Pred = the highest pressure within the enclosure (bar or kPa)

A = the vent area, m^2

V = the volume of the enclosure, m^3

The maximum external overpressure, Pmax, can be expected at a distance:

R = 0.25 x L where L = flame length, m

(L can be approximated using Equation 8.9.2 in NFPA 68:2013 *Standard on Explosion Protection by Deflagration Venting*).

At larger distances away from the vent, the overpressure decreases according to:

$$P = Pmax \times (R/r)^{1.5}$$

where r = distance away from the vent, m (r>R)

Equation 2. Overpressures due to a vented explosion:

$$P = 1.24 \times Pred \times (D/r)^{1.35} / (1 + (a/56)^2)$$

Where:

D = hydraulic diameter of the vent, m

Hydraulic diameter = 4 x A / p

p = perimeter of the vent, m

a = defines the direction towards the vent:

a = 0 deg means in front of the vent

a = 90 deg means sideways from the vent area

a=180 deg means behind the vent area

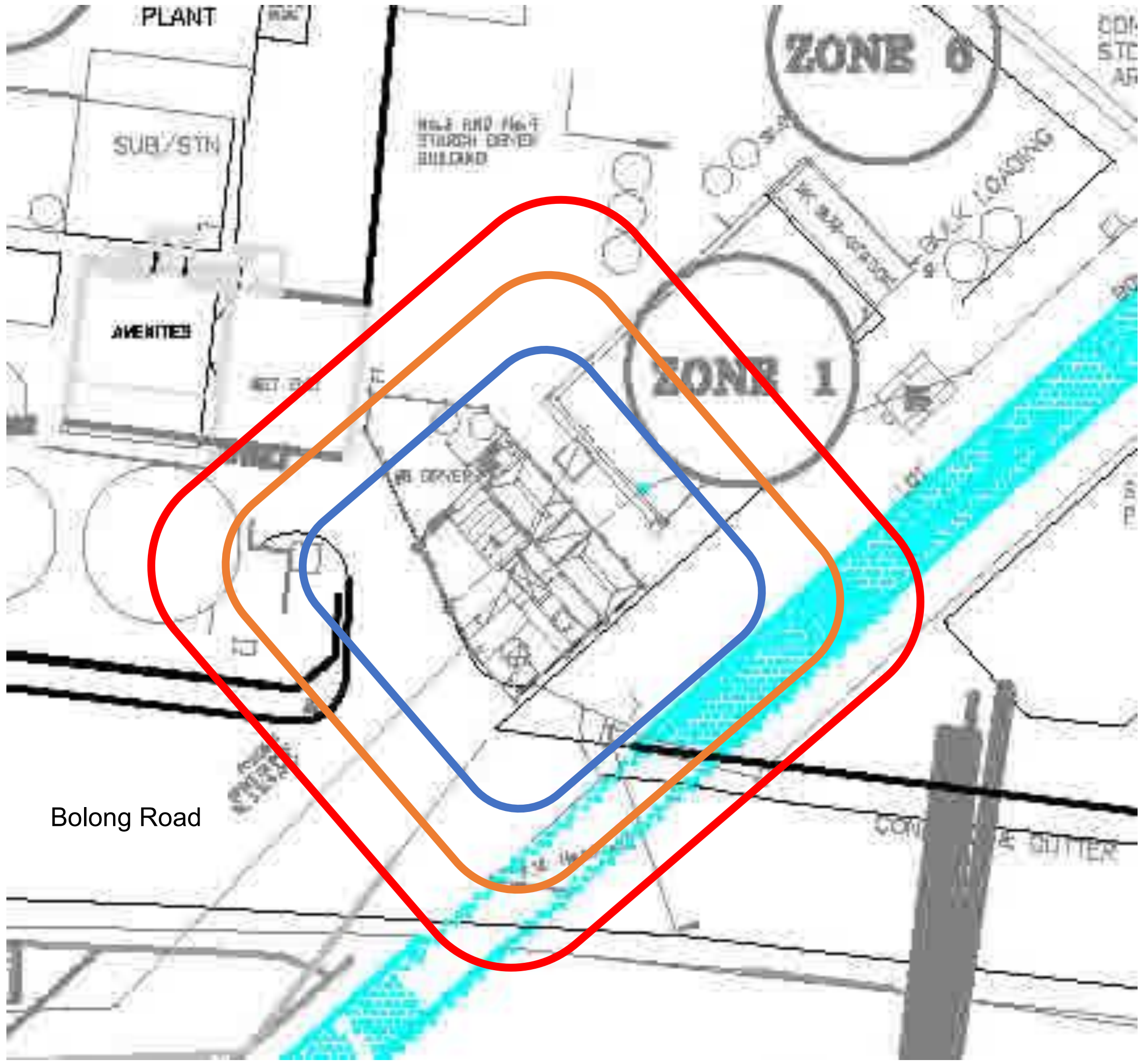
As stated above, the highest of the values from Equations 1 and 2 are used.

17 APPENDIX D – CONFINED BUILDING EXPLOSIONS FIGURES

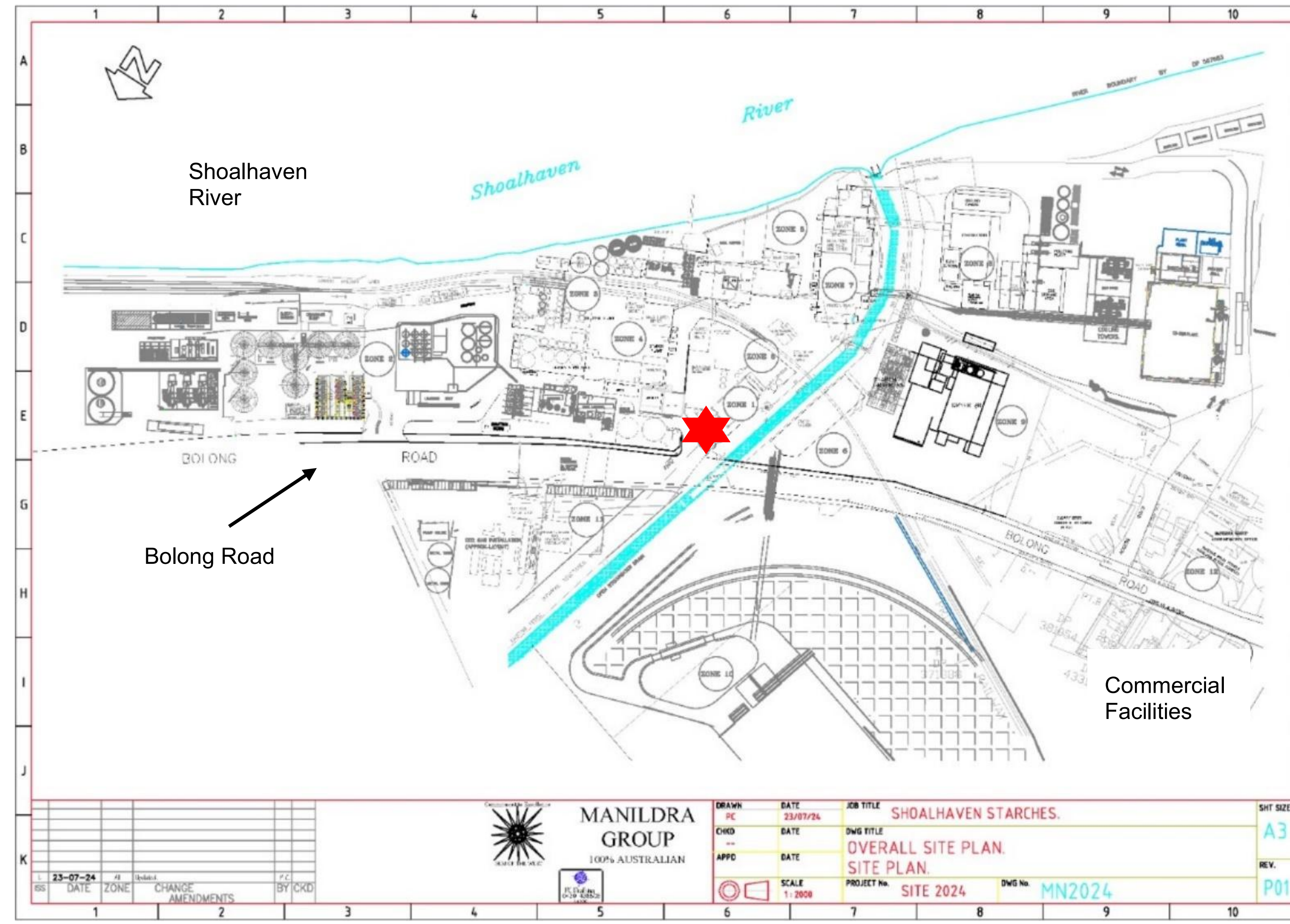
Appendix D – Confined Building Explosions Figures

Zone 1 – GD 6 Building:

Overpressure Contours:



Location on the Site:

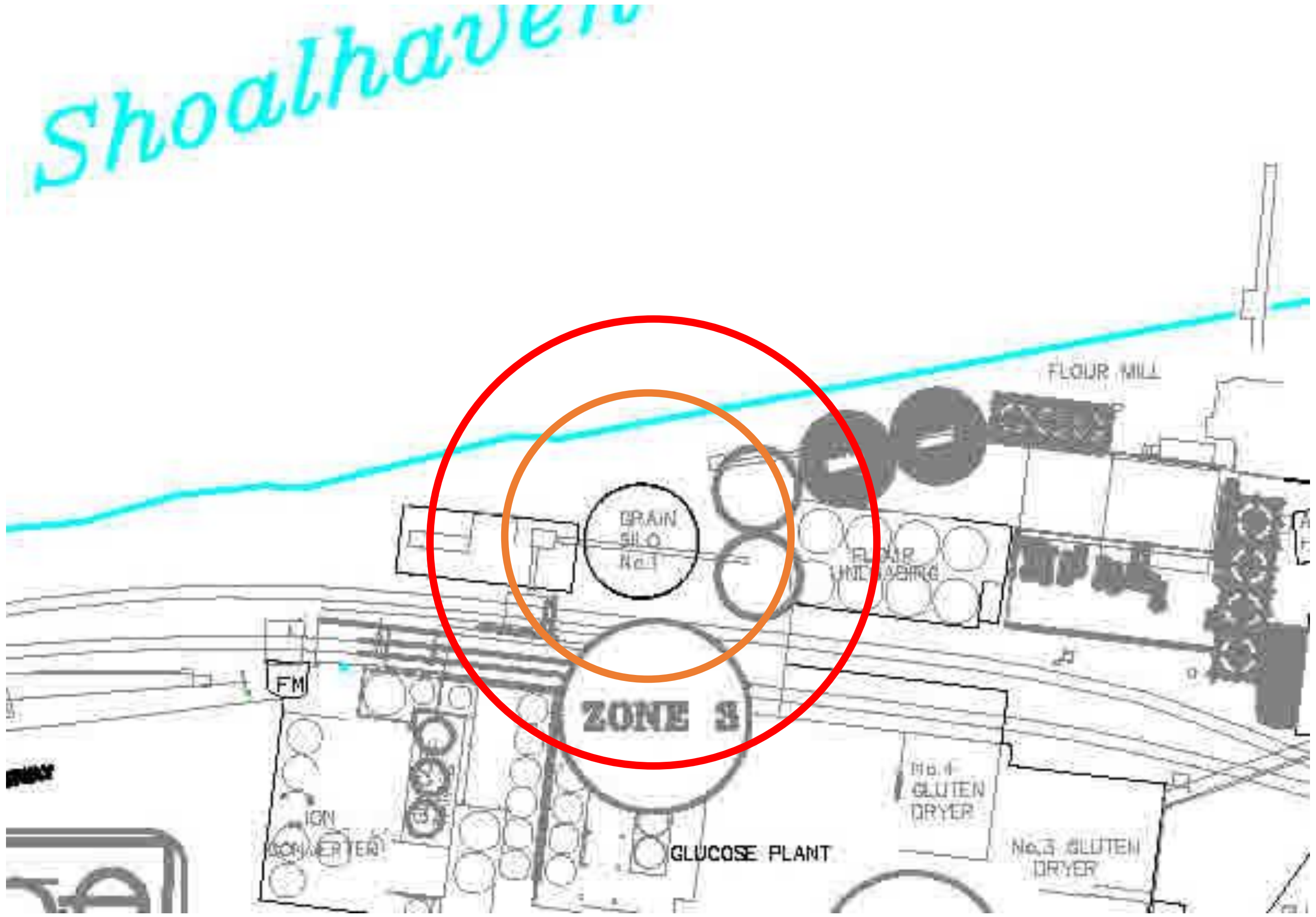


Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 3 – Wheat Silo (Silo 101):

Overpressure Contours:



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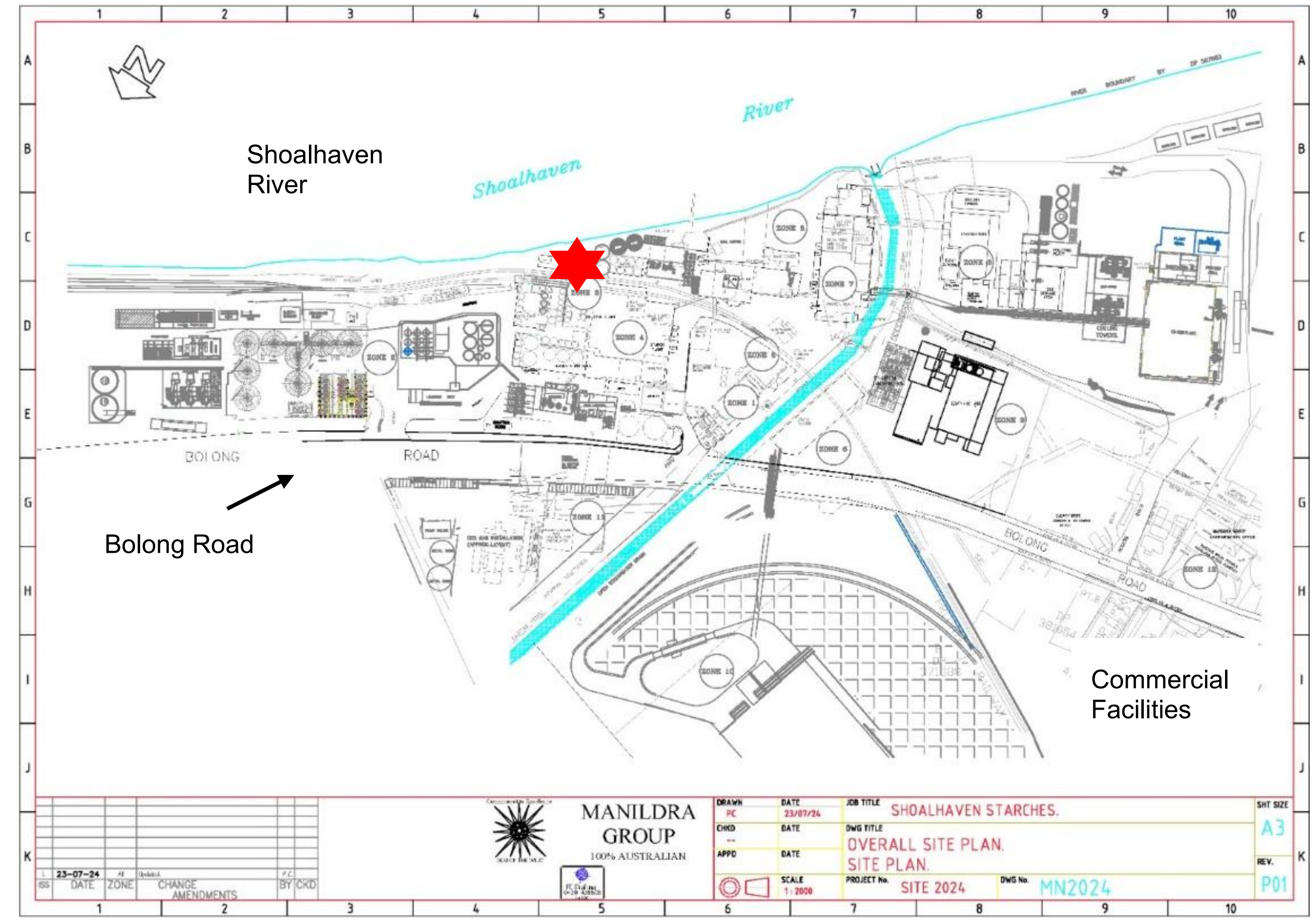
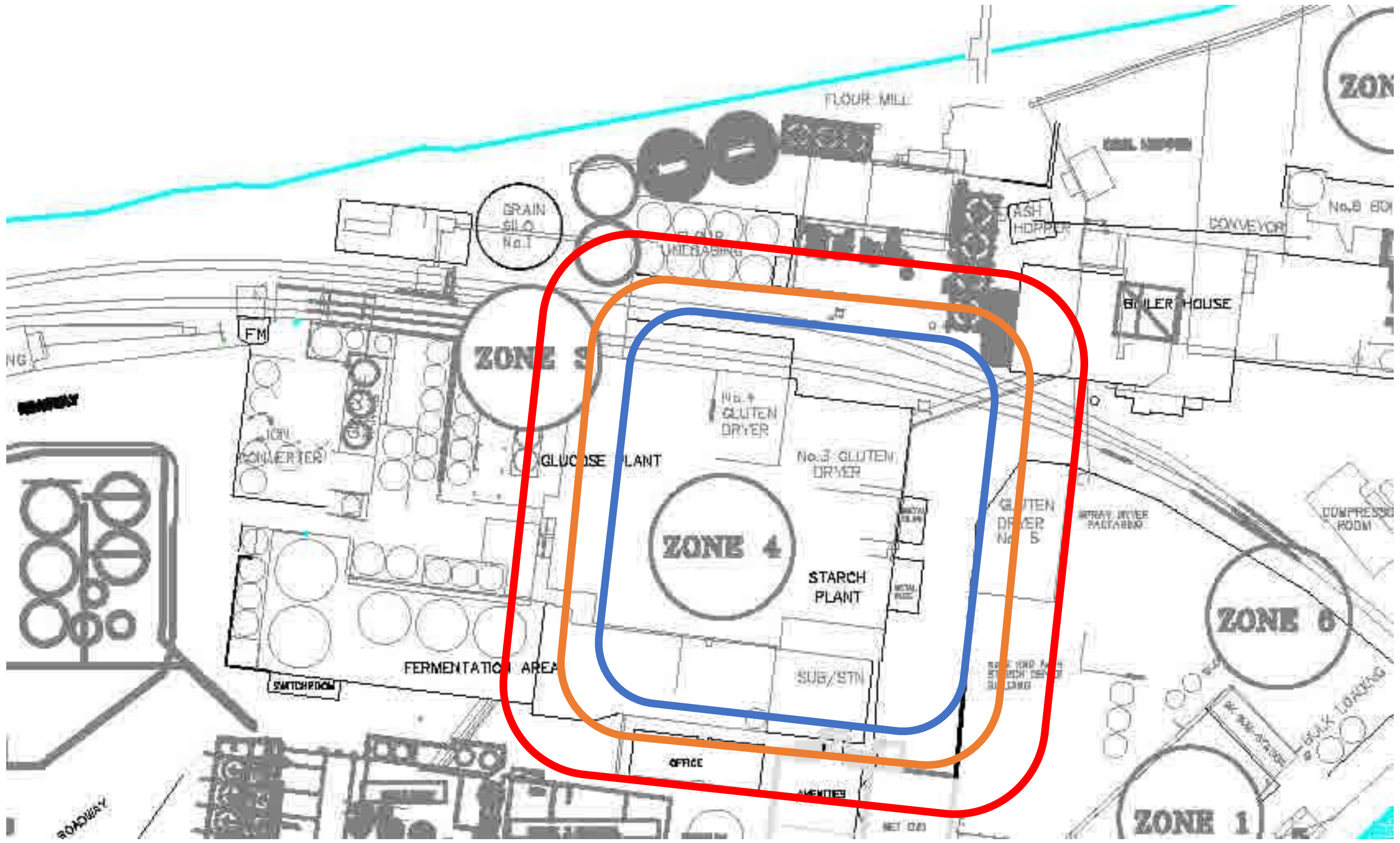


Overpressure Contours:

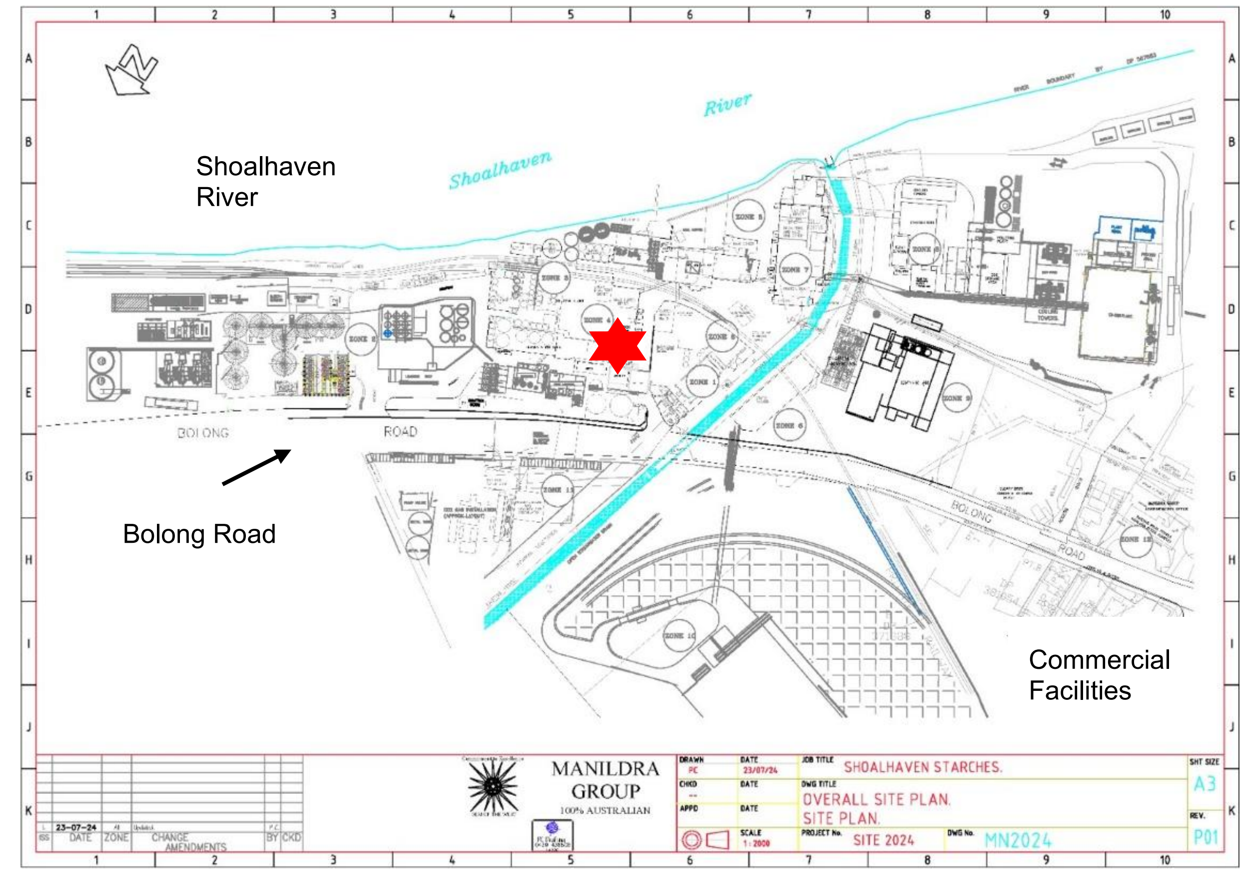
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa (no contour)

Zone 4 – Starch Plant Building:

Overpressure Contours:



Location on the Site:



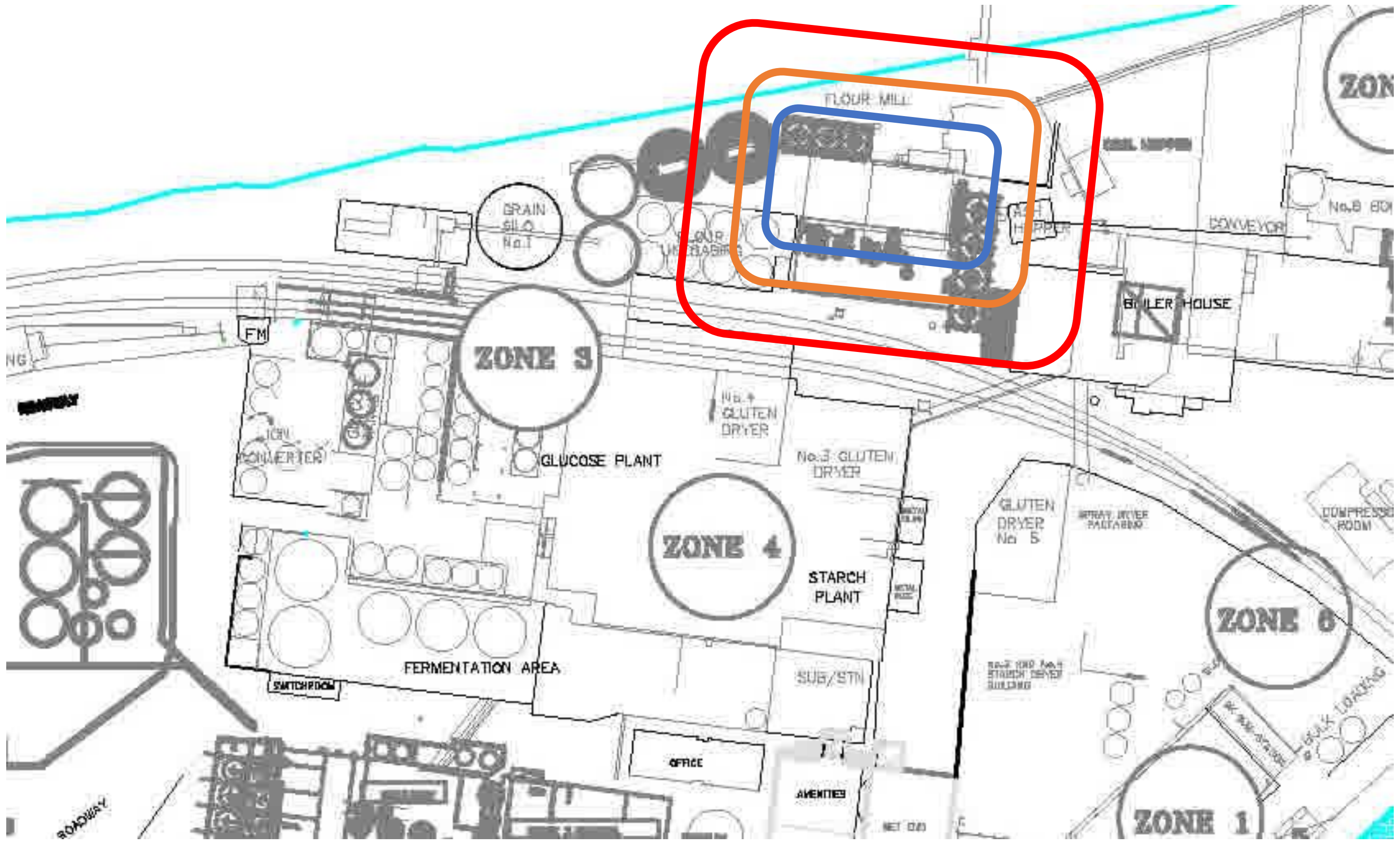
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

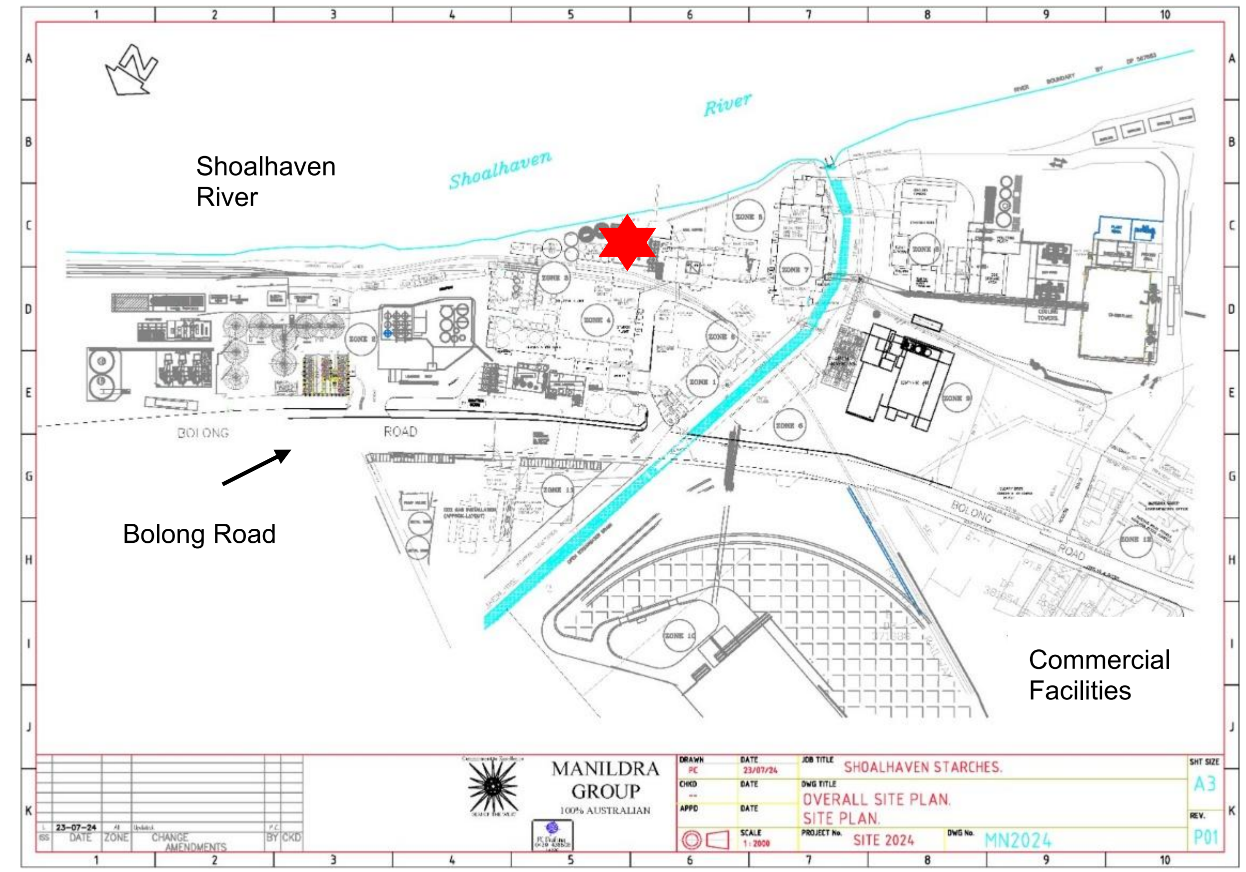
Note that the eastern end of this building is the Glucose Plant which is a which wet process and does not have a dust explosion hazard.

Zone 4 – Flour Mill A Building:

Overpressure Contours:



Location on the Site:

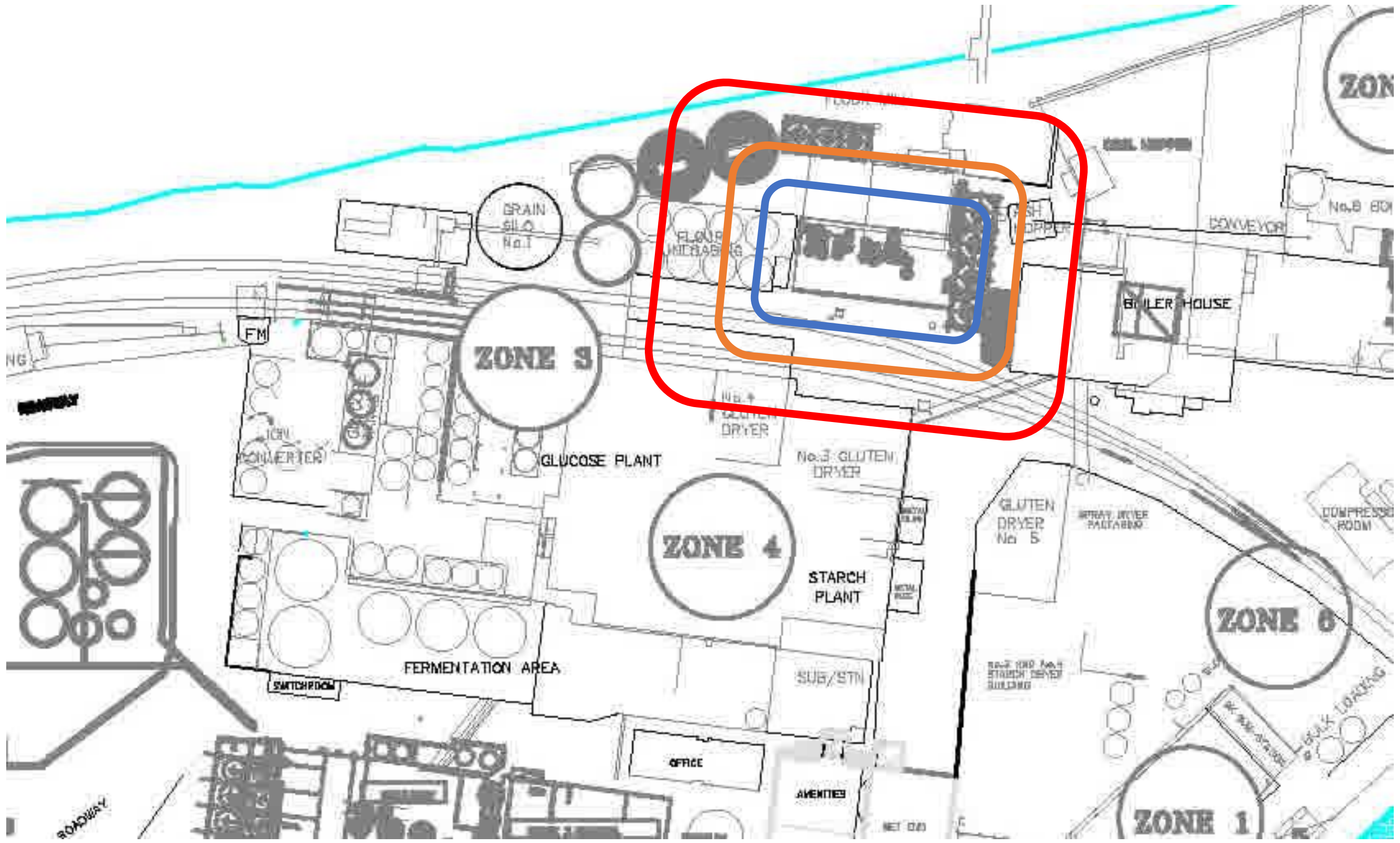


Overpressure Contours:

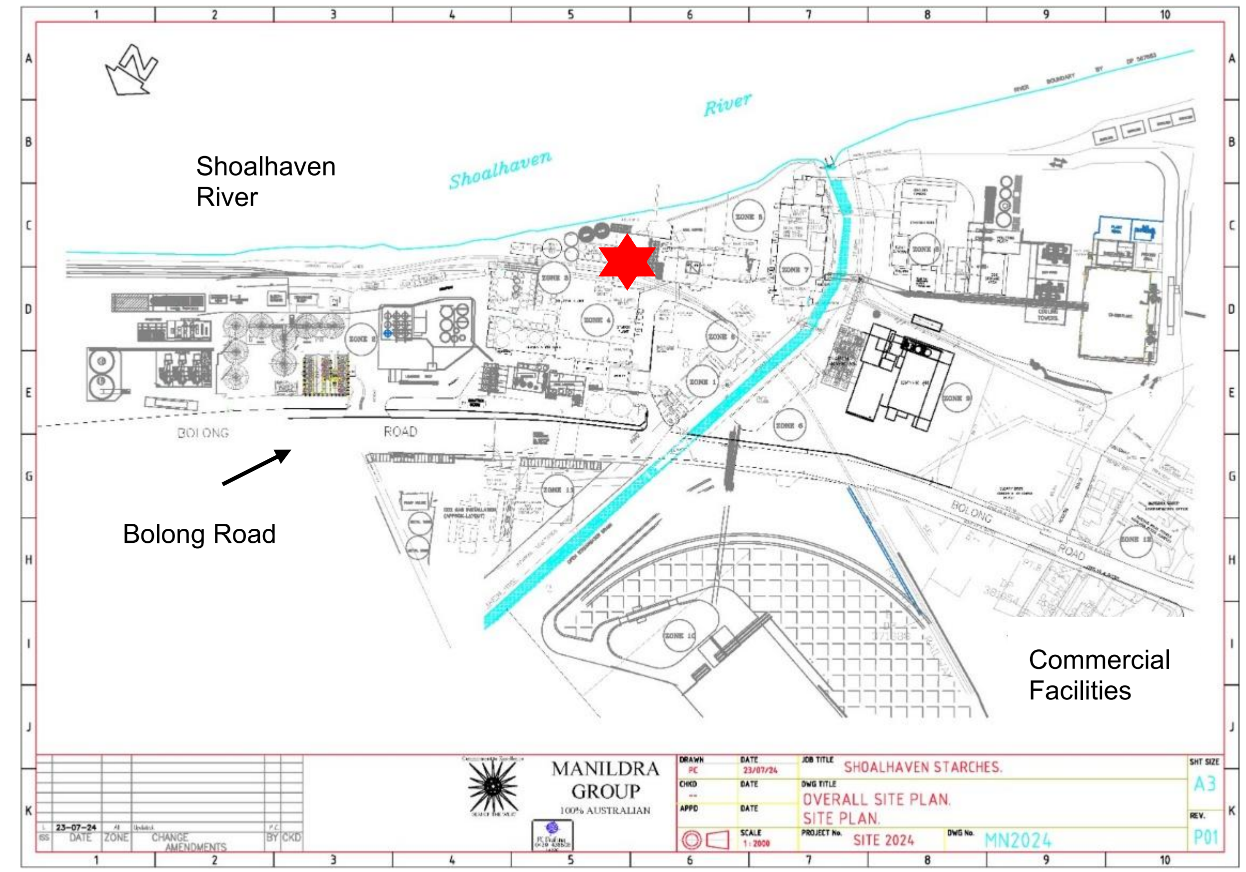
Red = 7 kPa   **Orange** = 14 kPa   **Blue** = 21 kPa

Zone 4 – Flour Mills B and C Building:

Overpressure Contours:



Location on the Site:

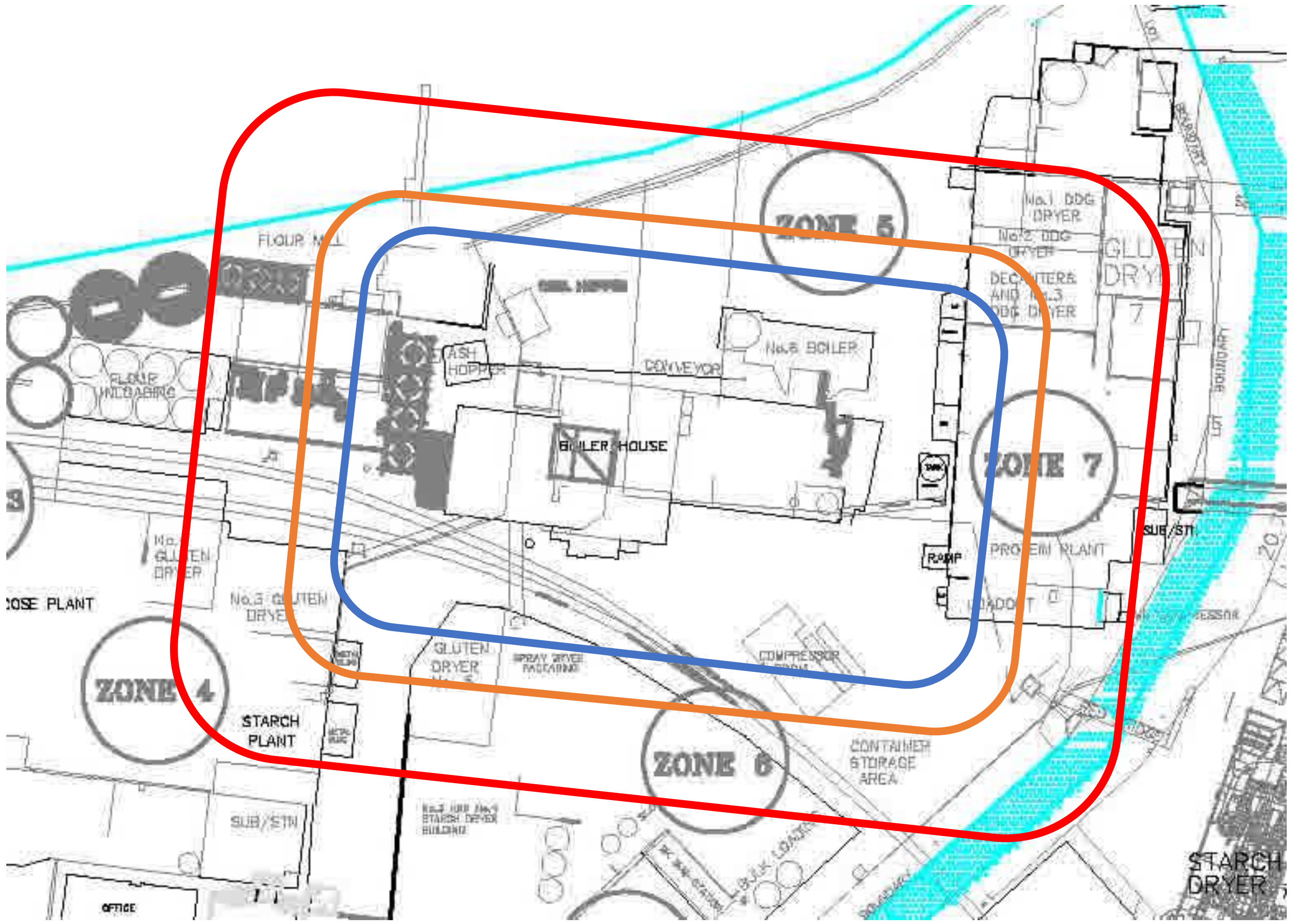


Overpressure Contours:

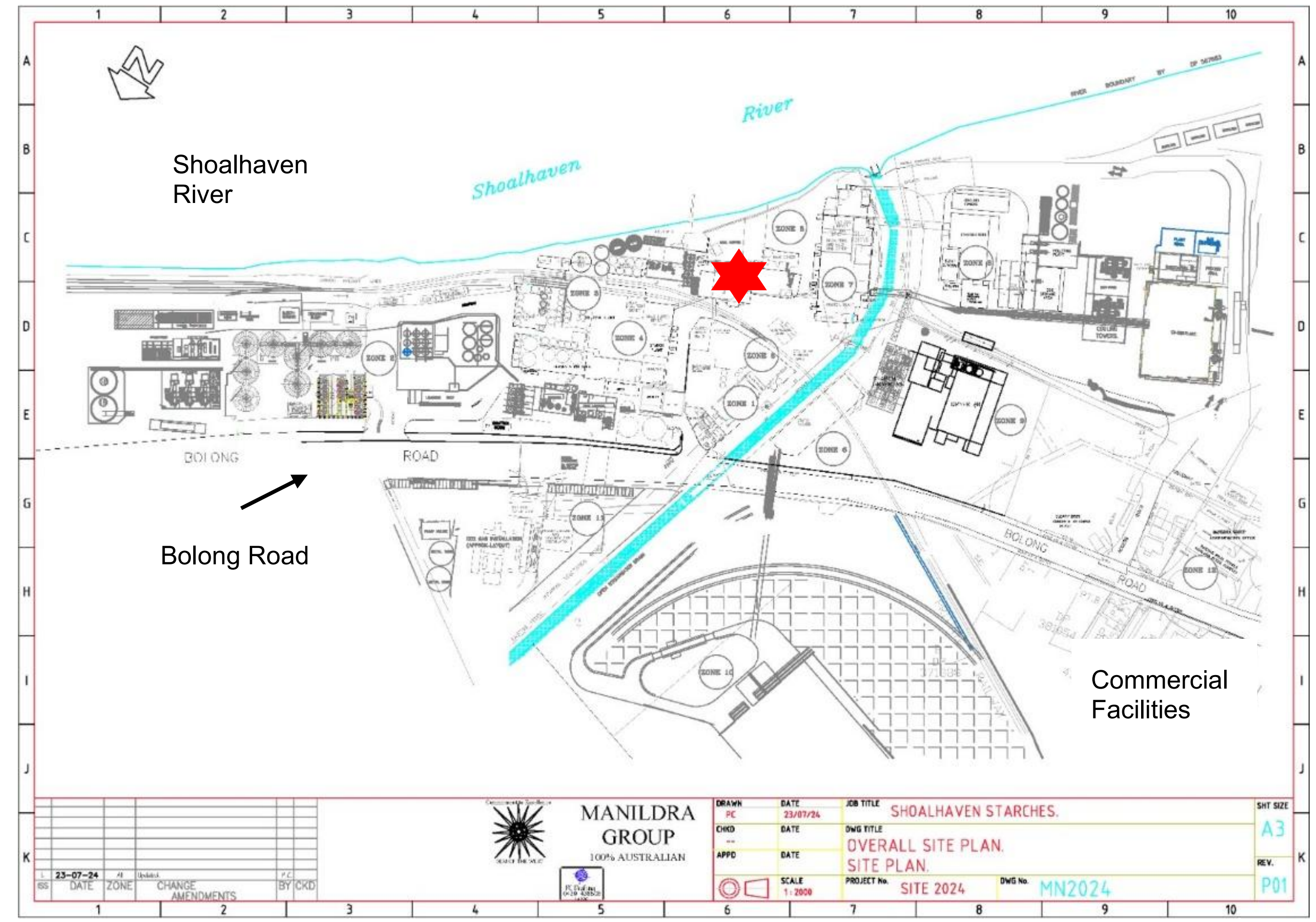
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 5 – Boilerhouse:

Overpressure Contours:



Location on the Site:

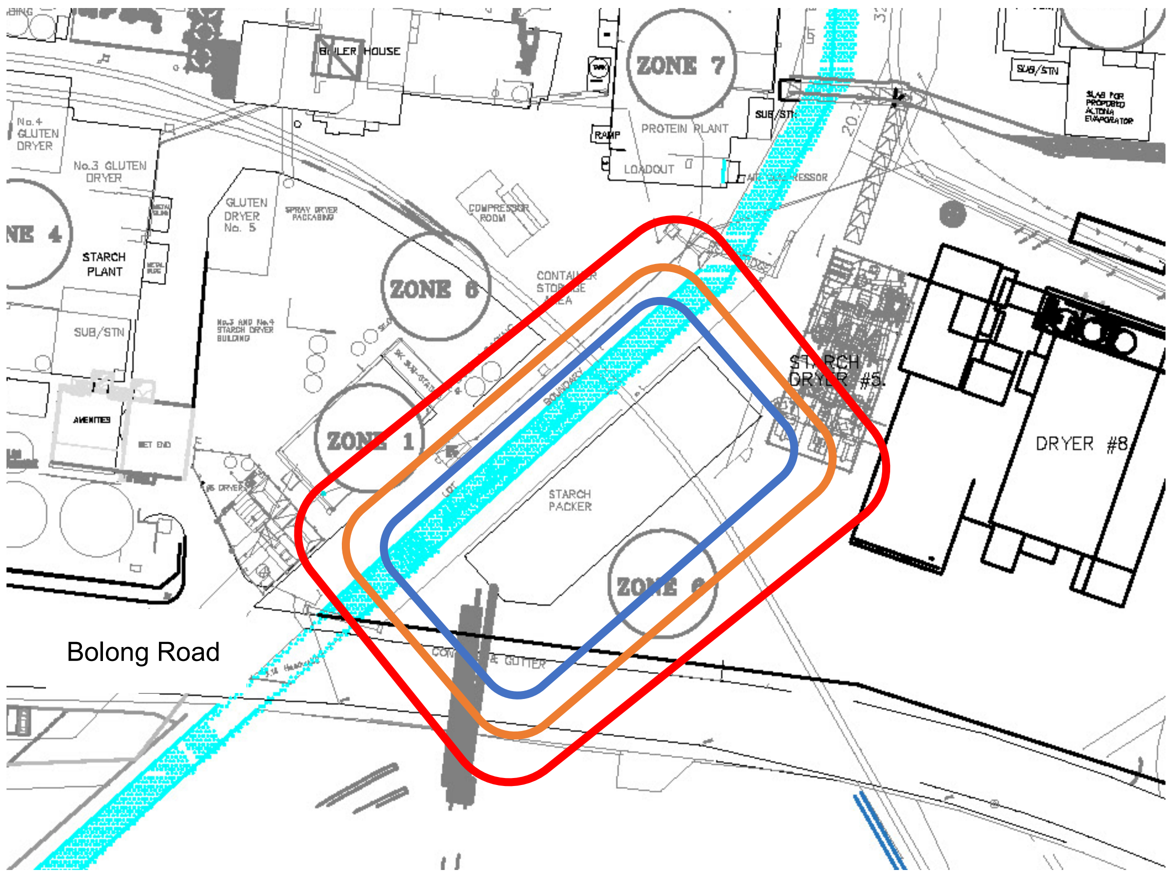


Overpressure Contours:

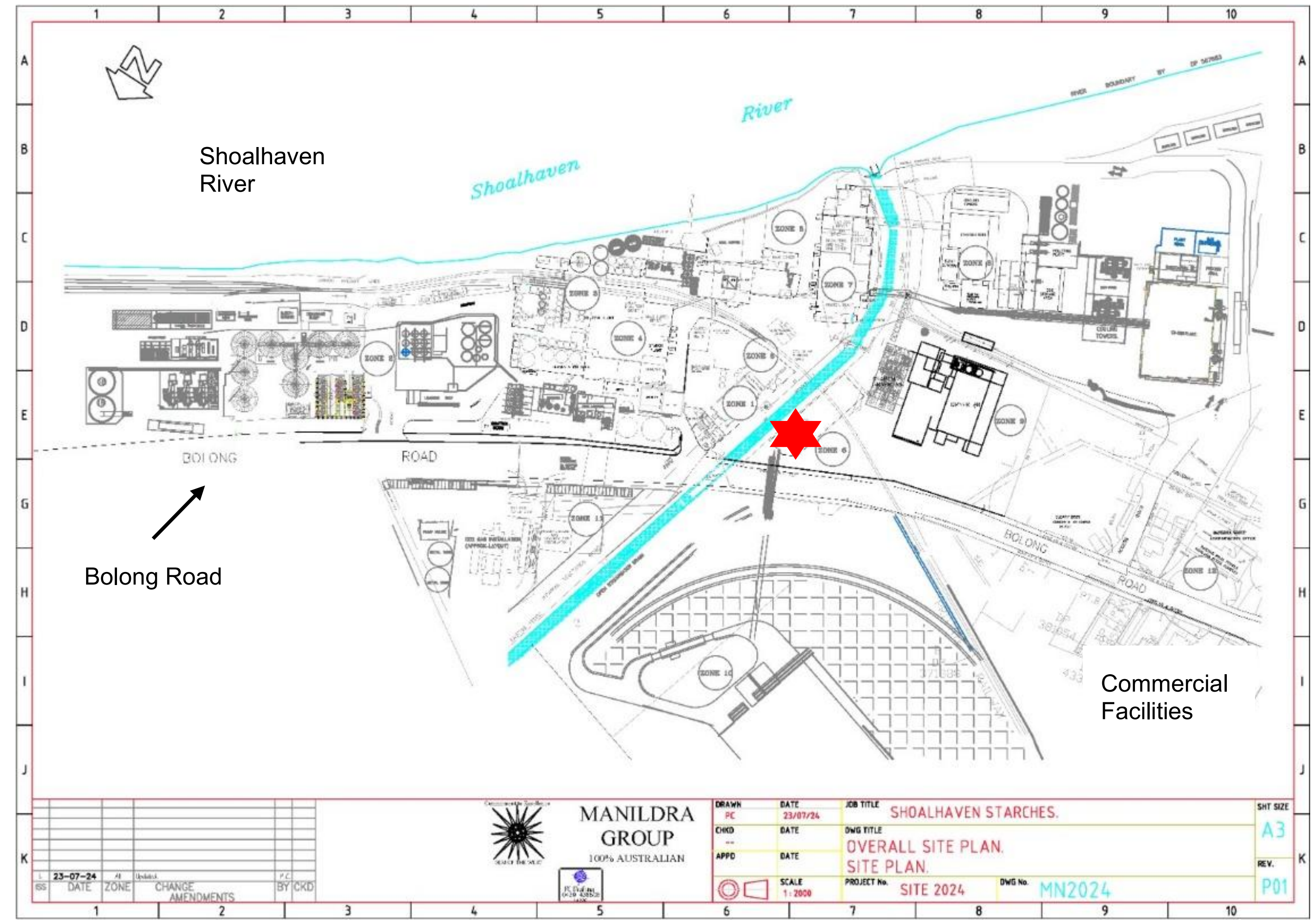
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 6 – Starch Packing Building:

Overpressure Contours:



Location on the Site:

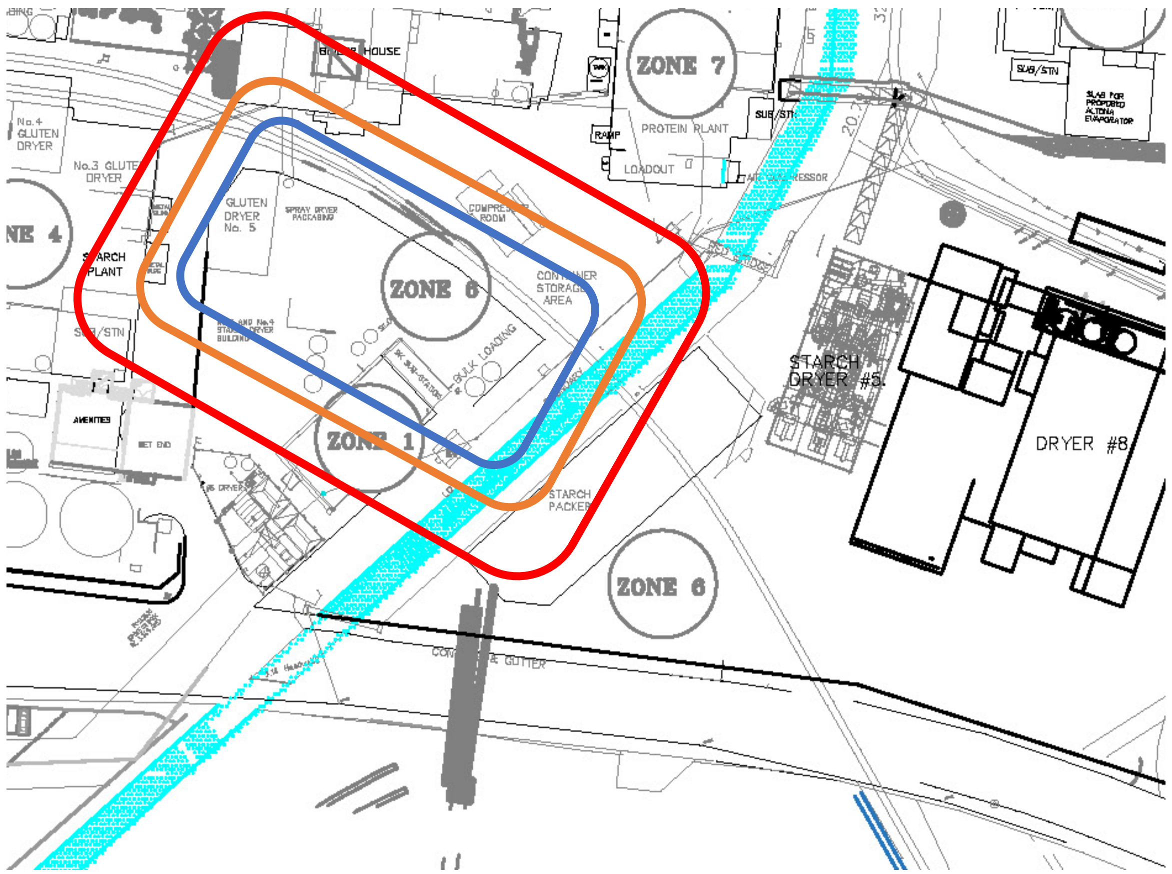


Overpressure Contours:

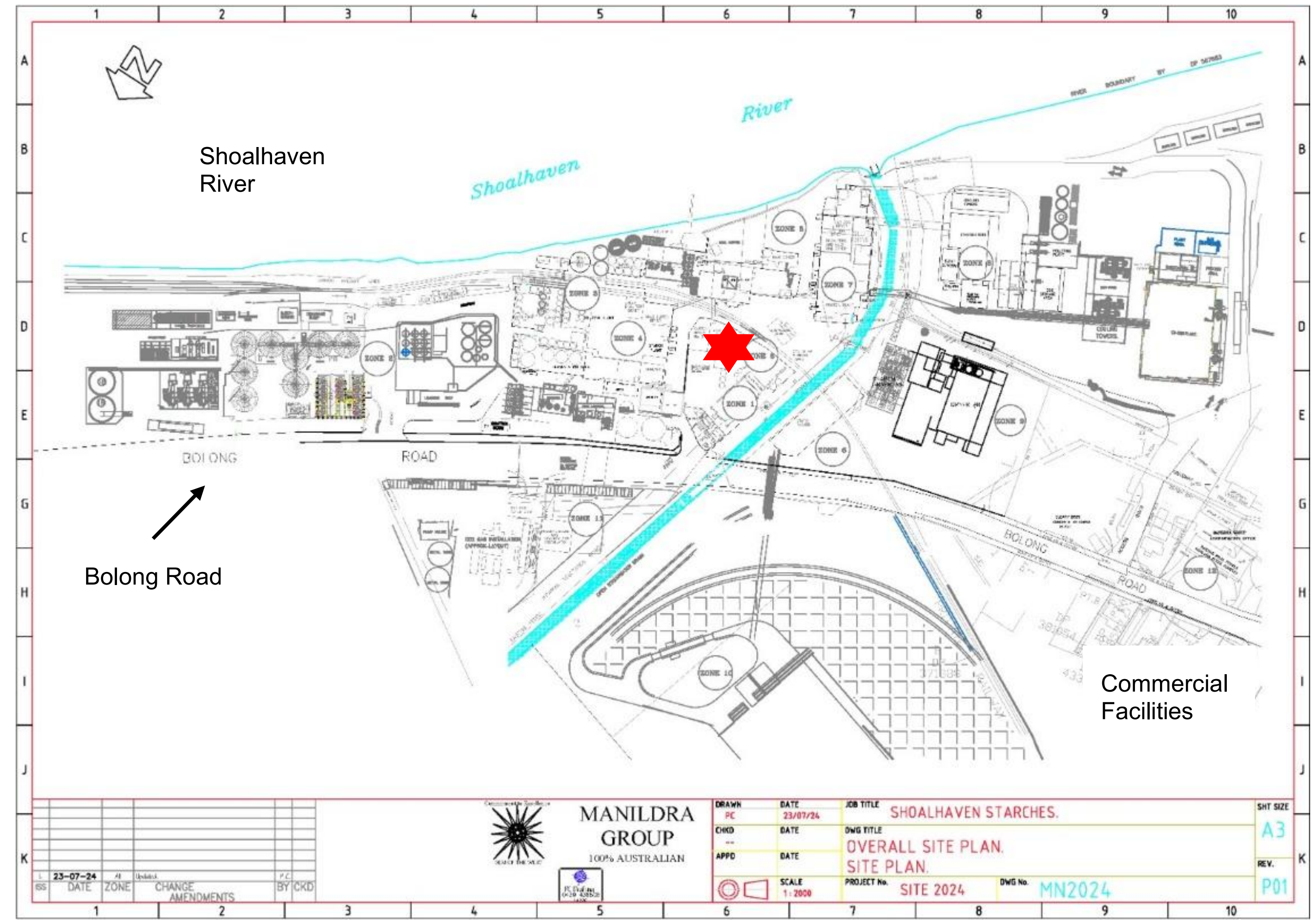
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 6 – Gluten Packing Building:

Overpressure Contours:



Location on the Site:



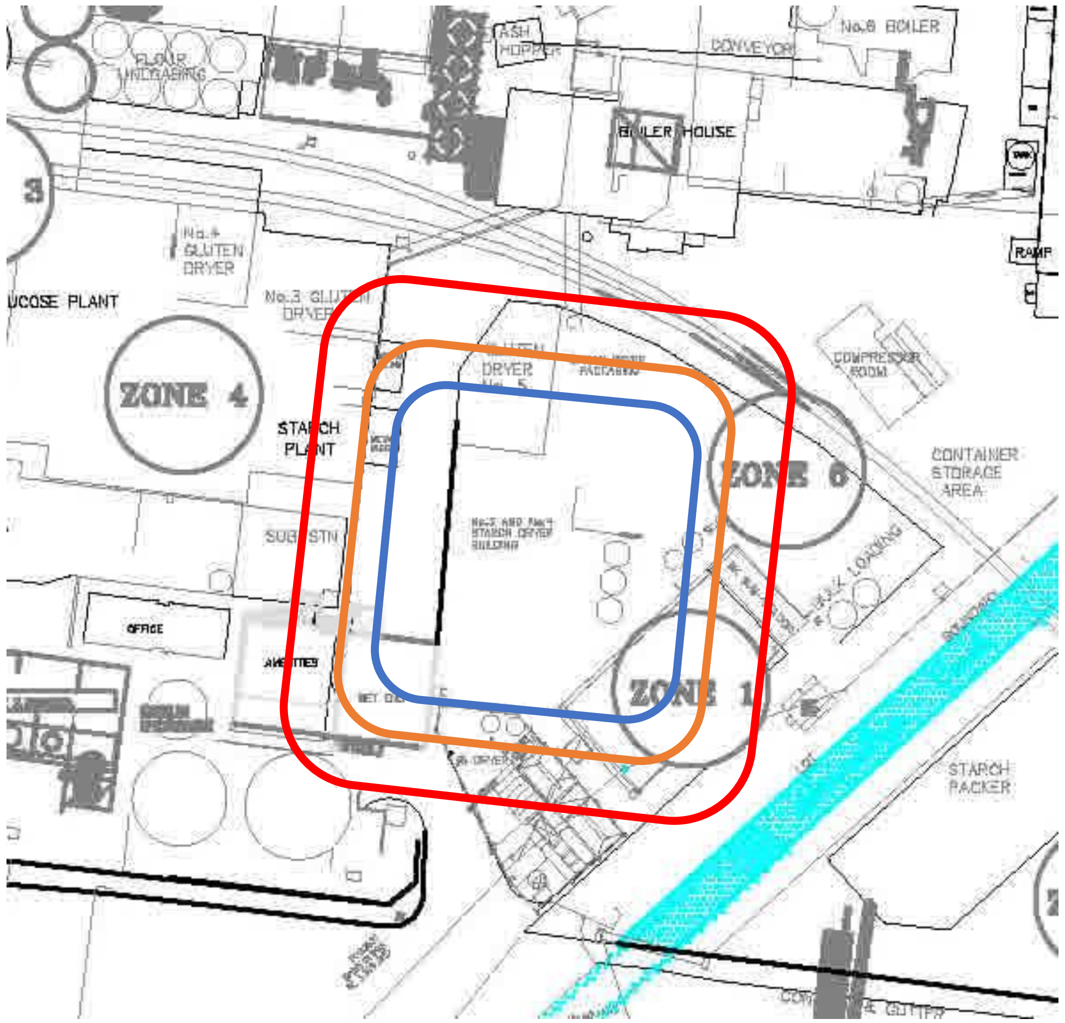
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

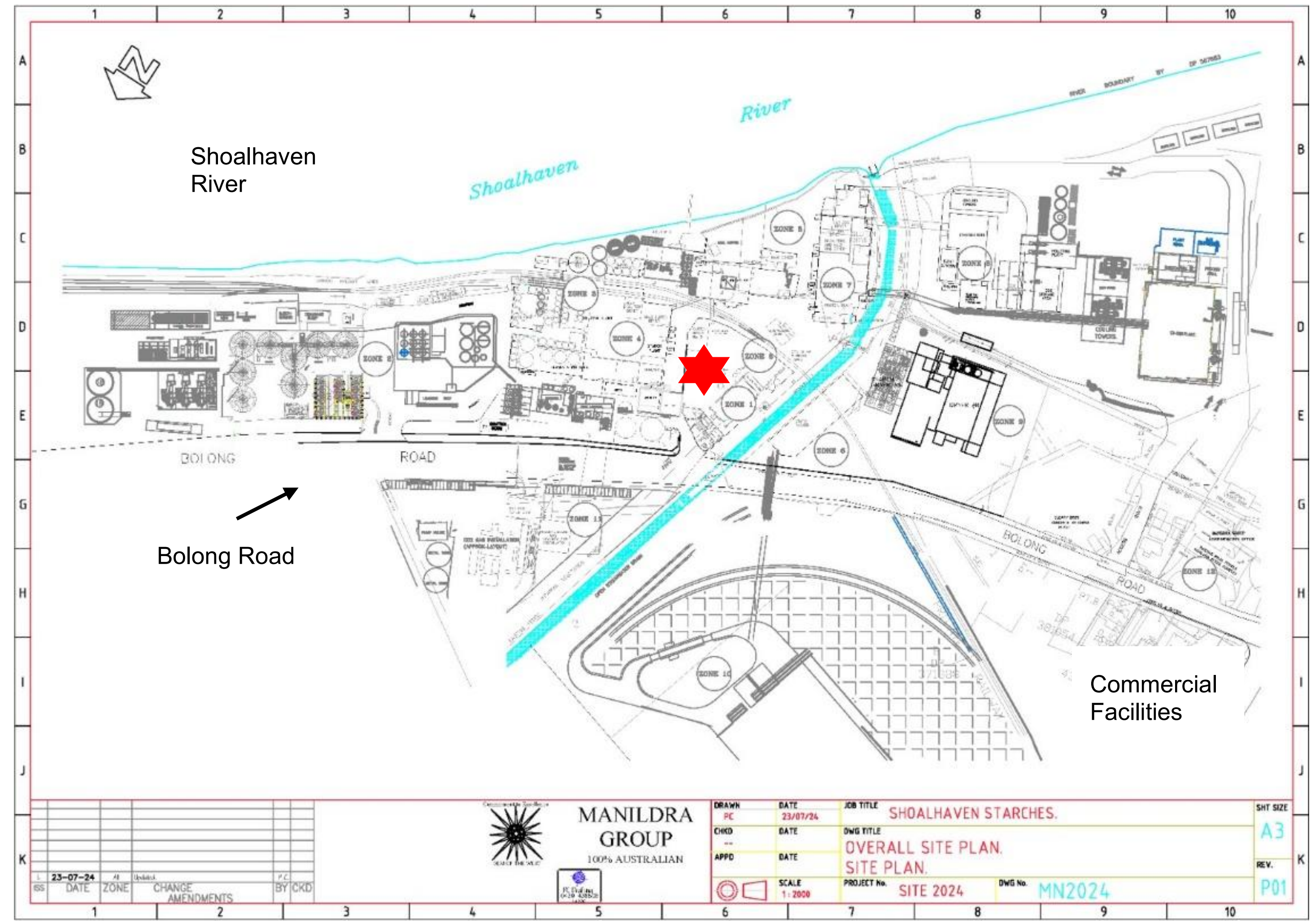
Note: Contours are approximate given the irregular shape of the building.

Zone 6 – SD 3 and 4 Building:

Overpressure Contours:



Location on the Site:

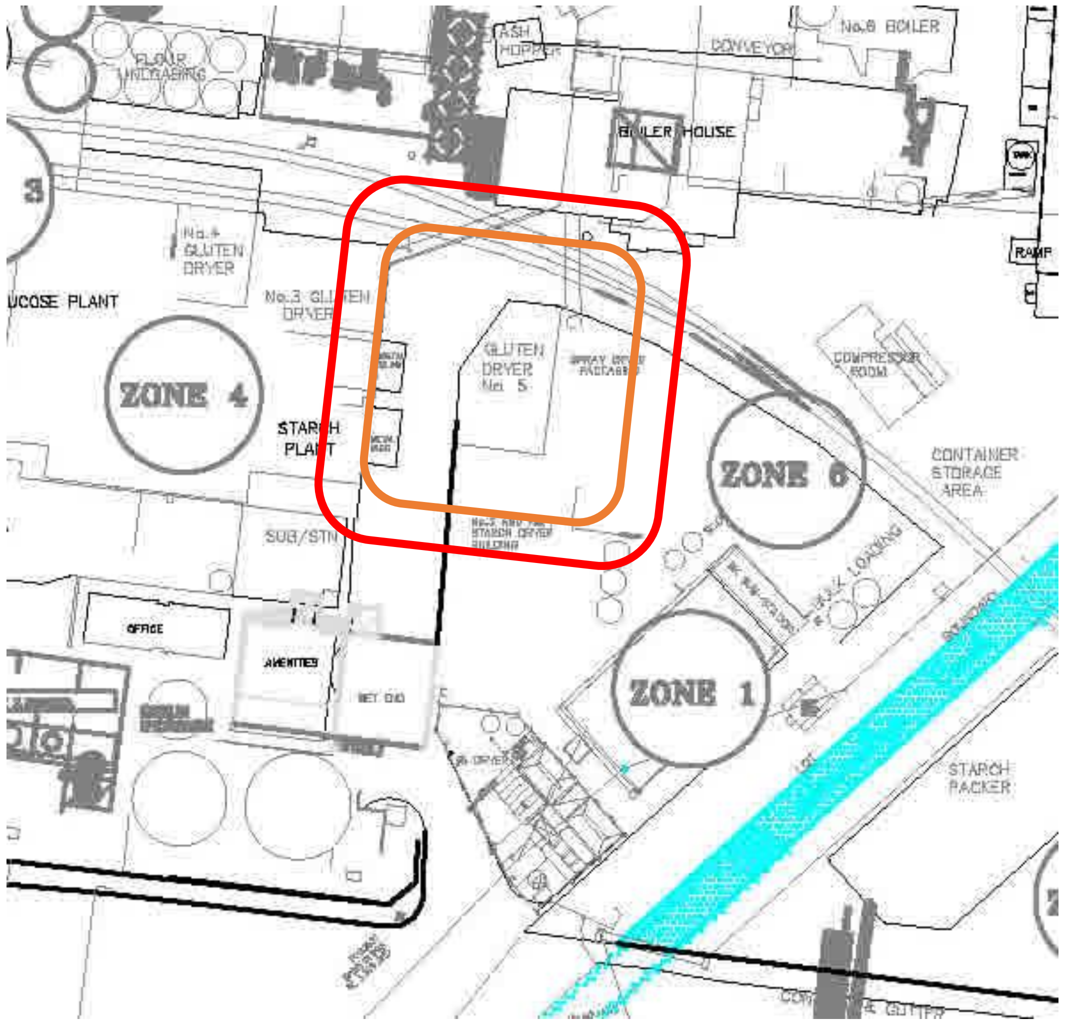


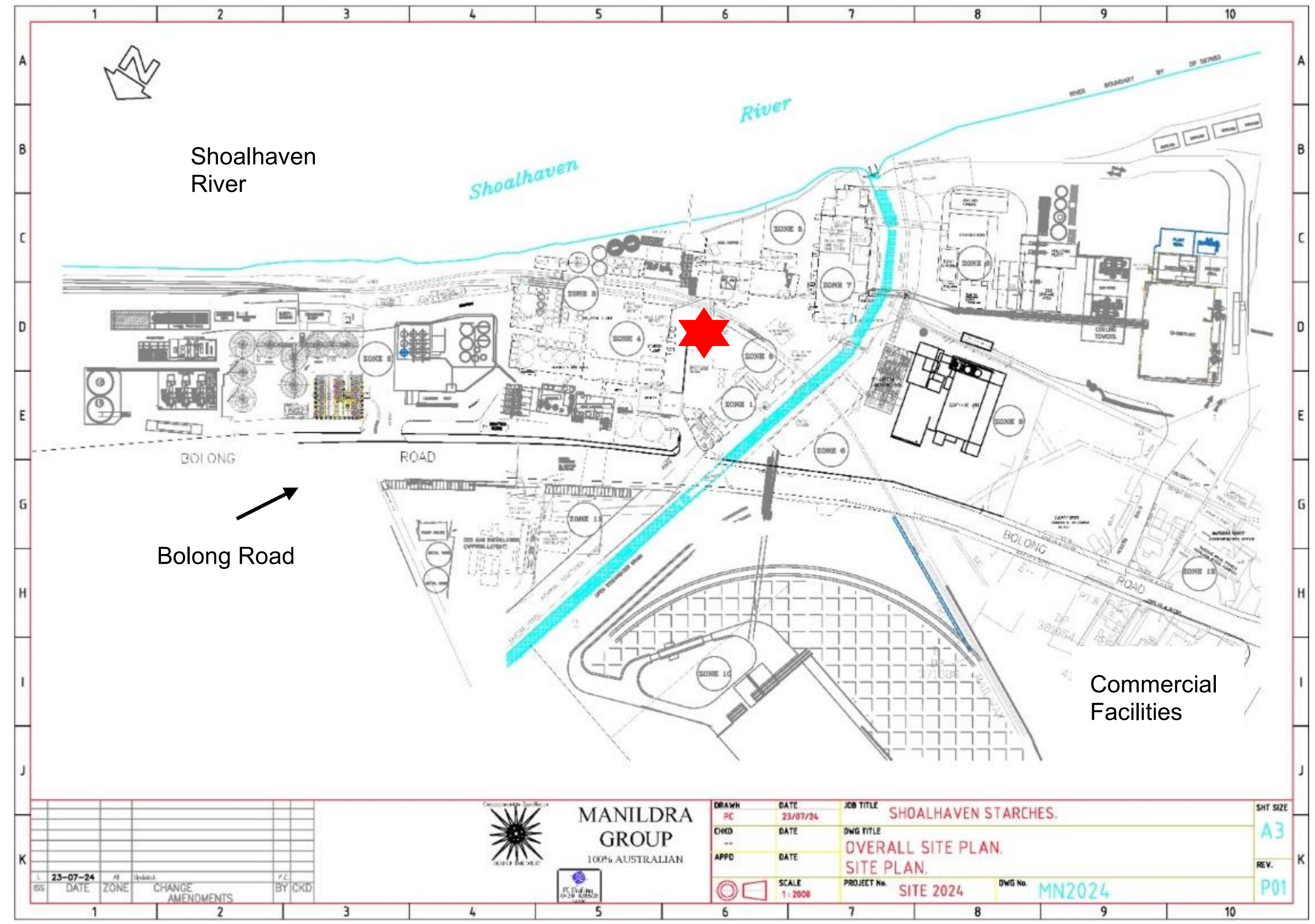
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 6 – RD 5 (GD5) Building:

Overpressure Contours: ***Location on the Site:***



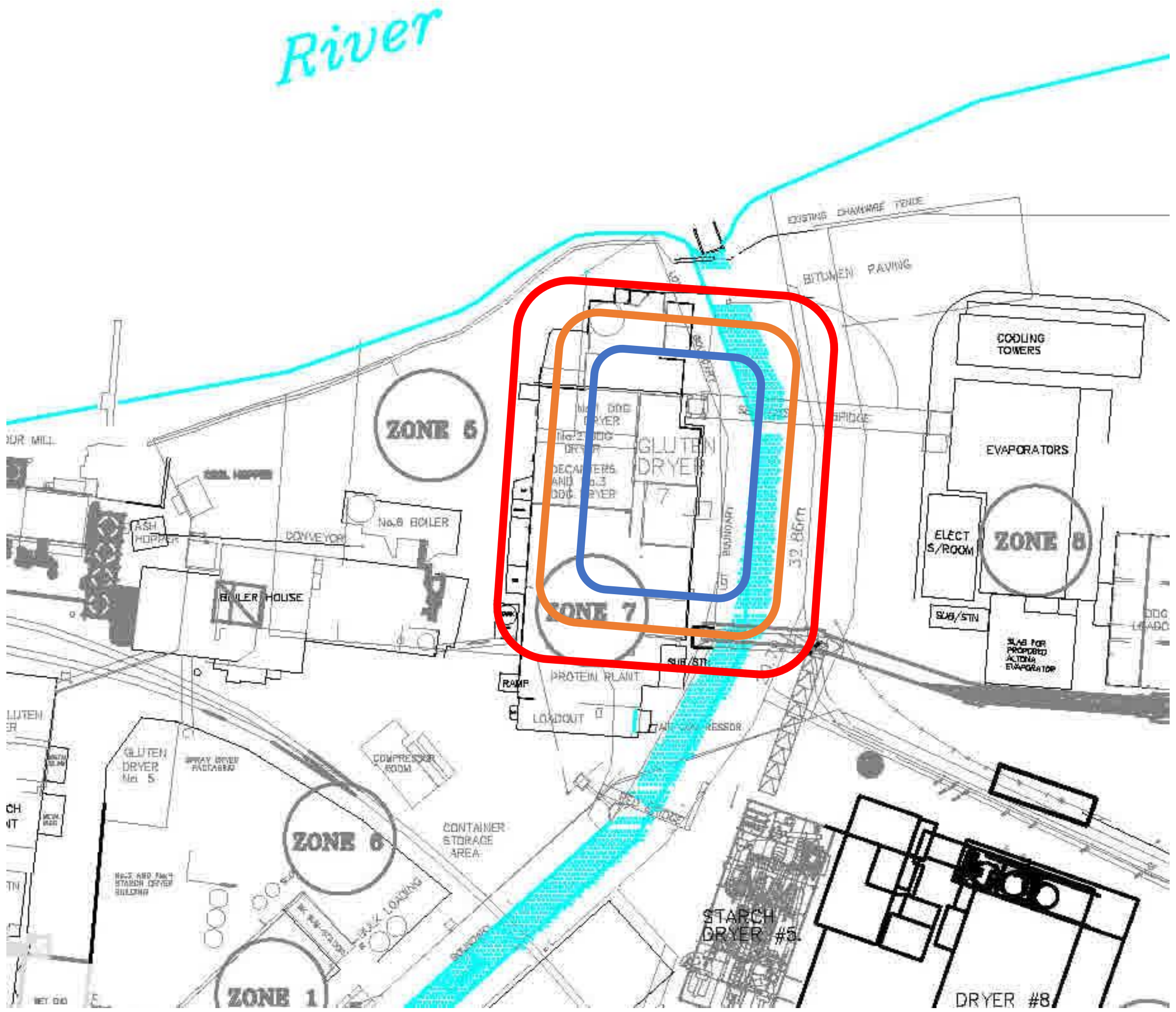


Overpressure Contours:

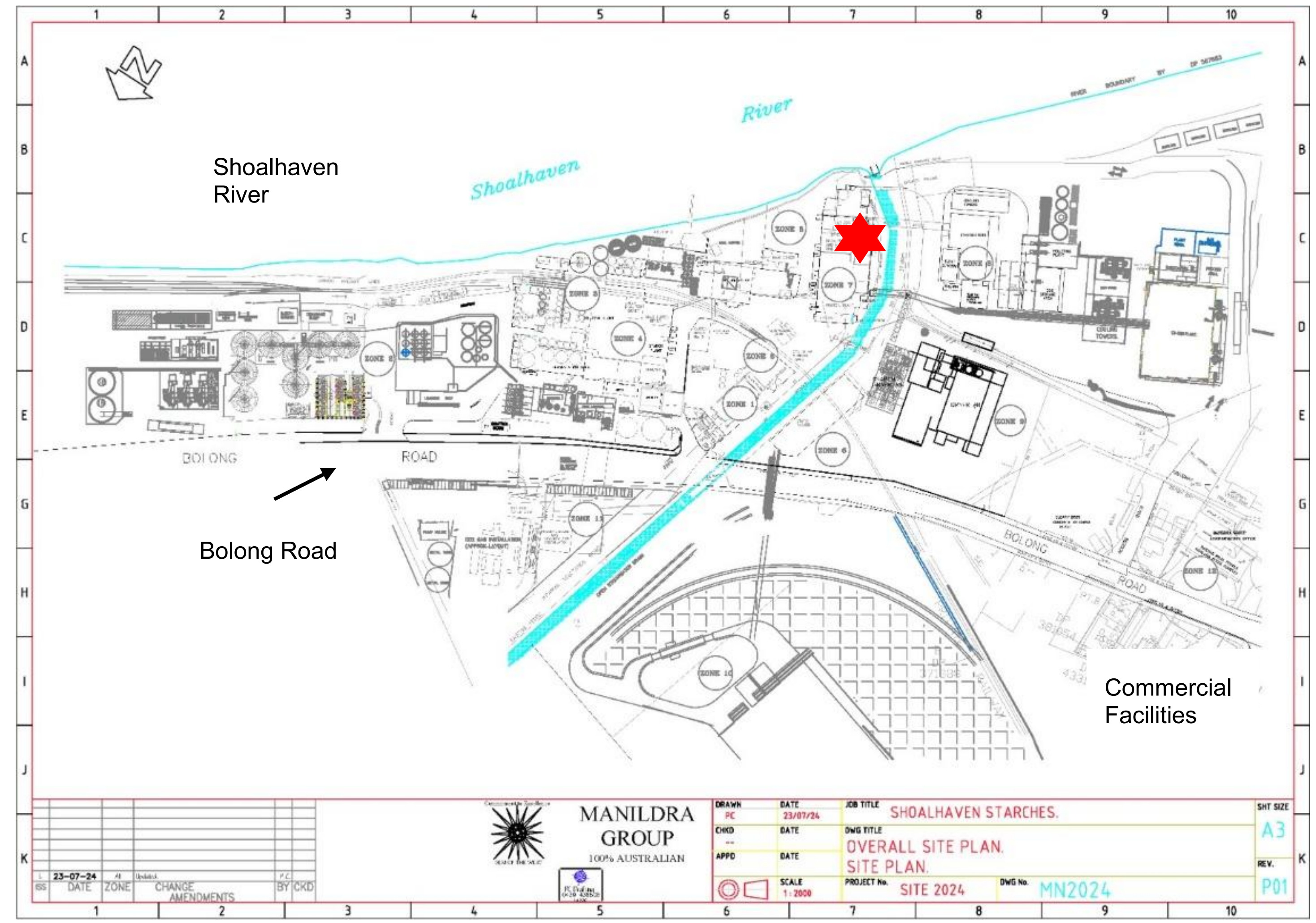
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa (no contour)

Zone 7 – GD7 Building:

Overpressure Contours:



Location on the Site:

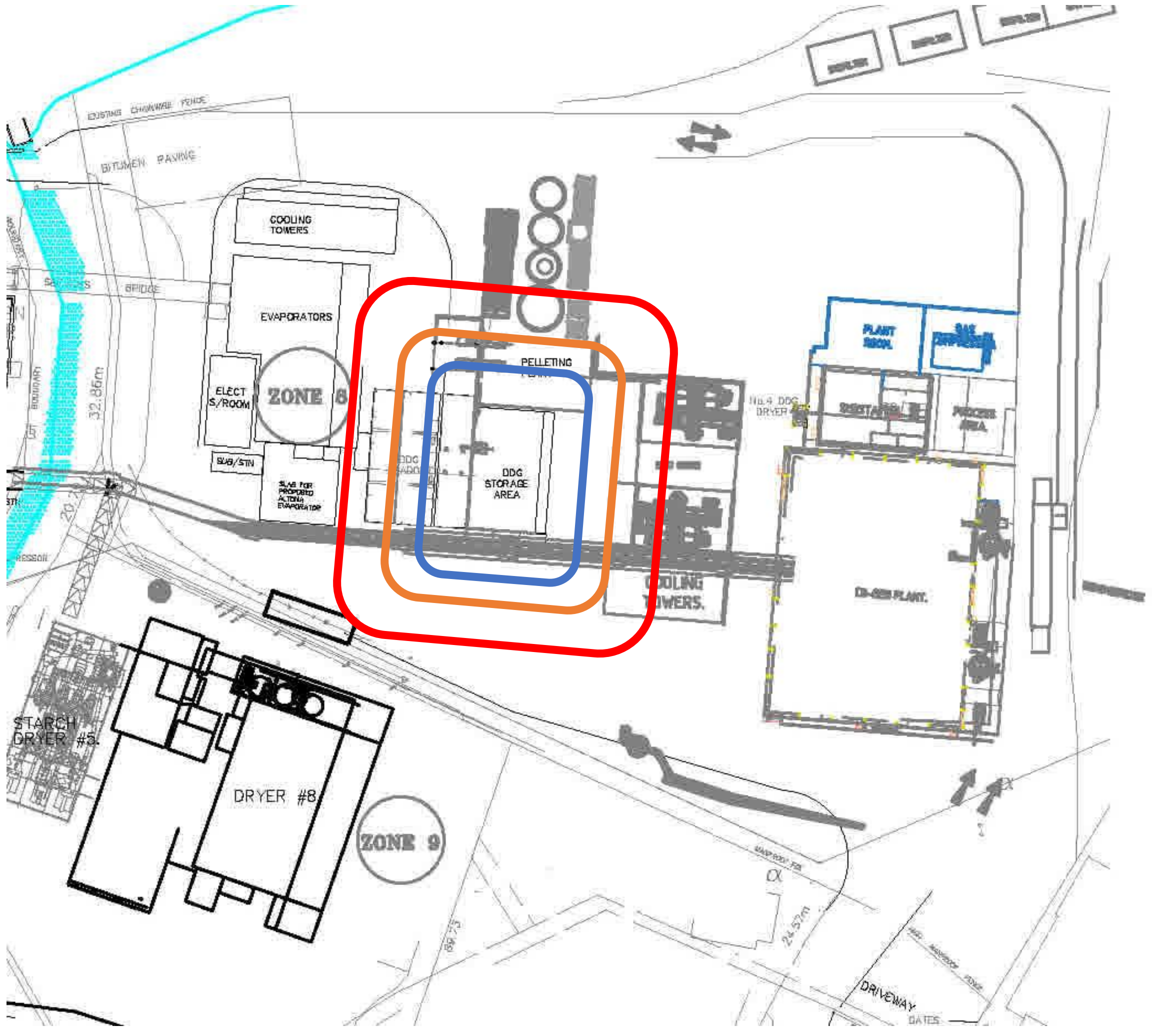


Overpressure Contours:

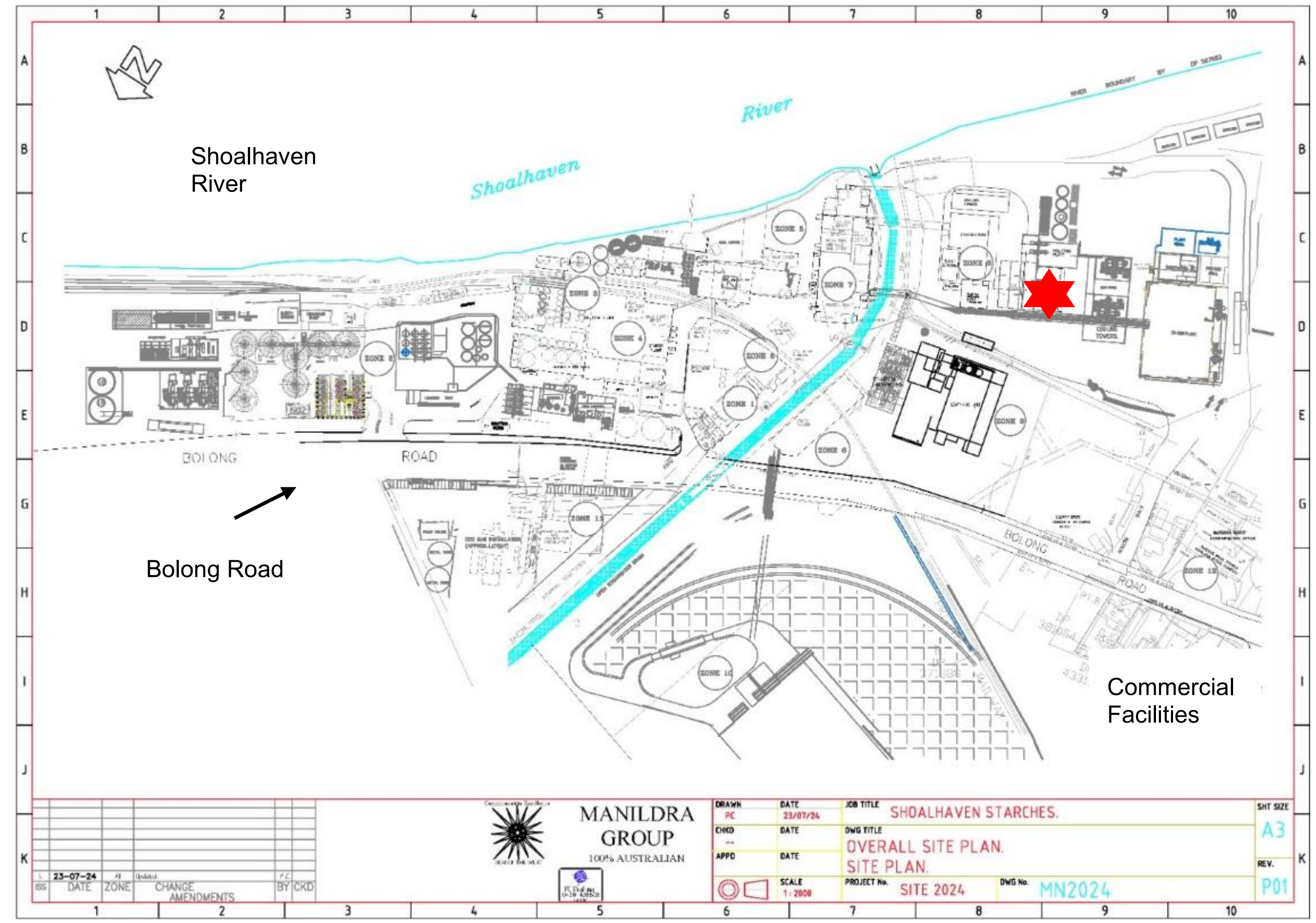
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 8 – DDG Storage Building:

Overpressure Contours:



Location on the Site:

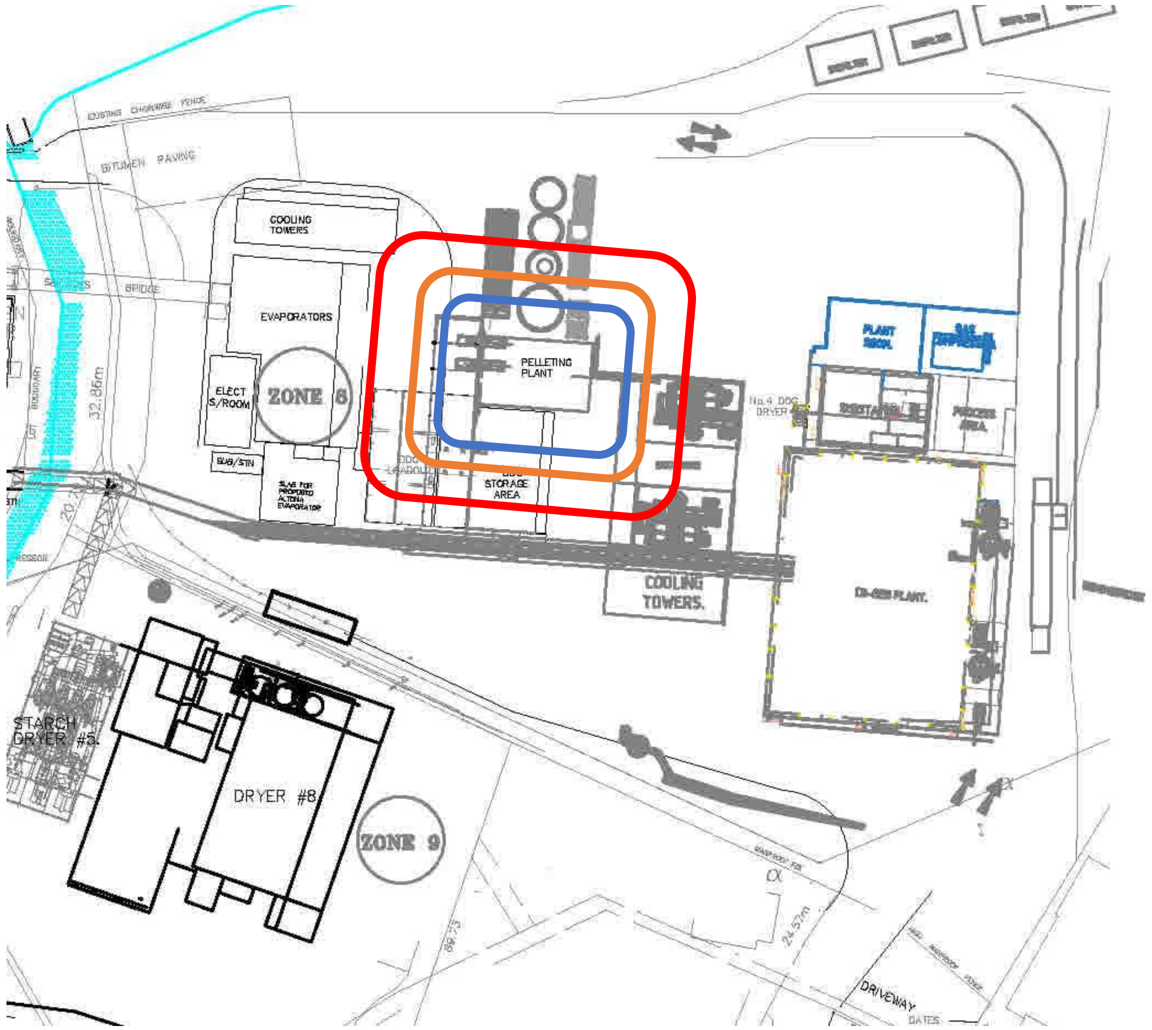


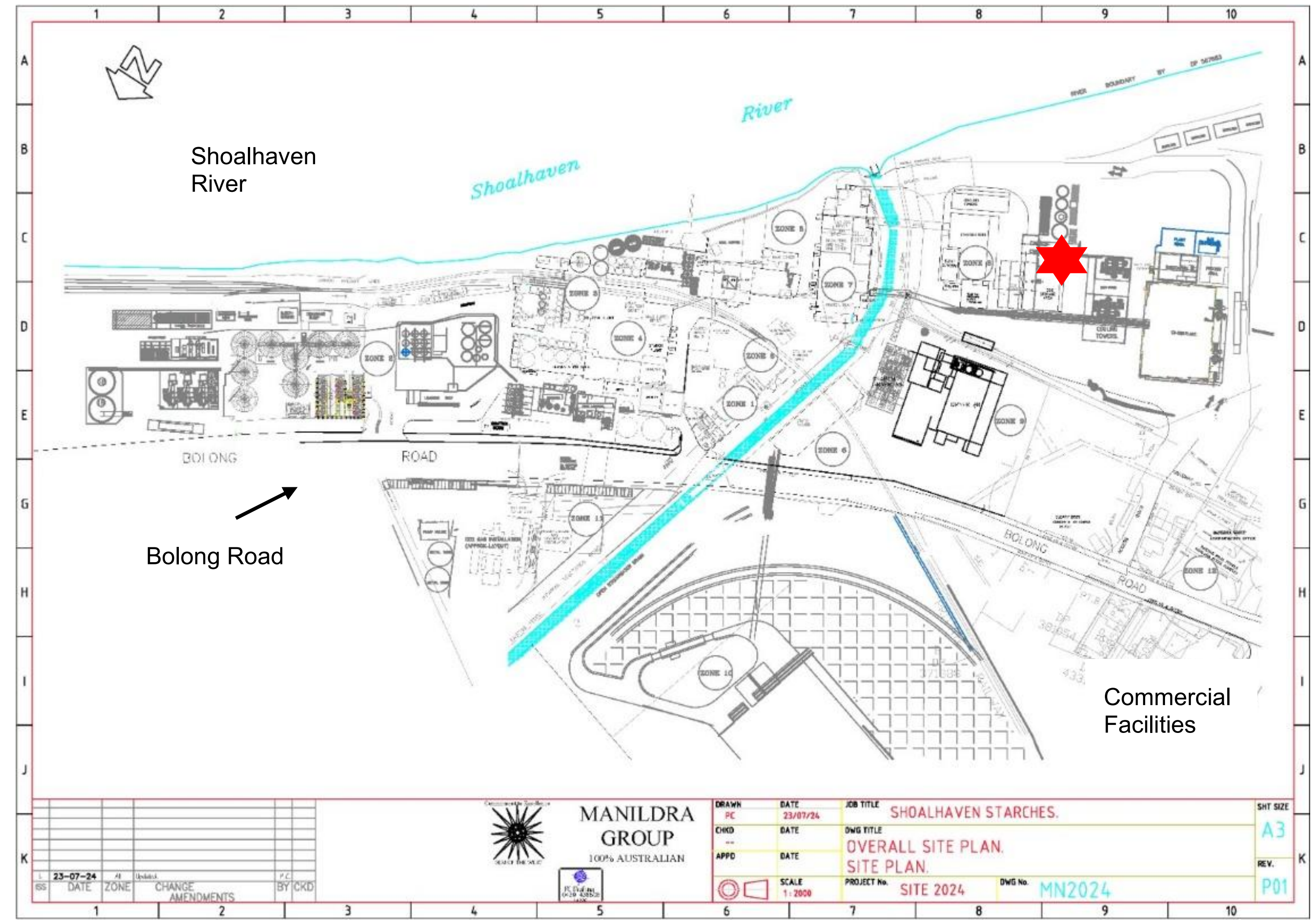
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 8 –Pellet Mill Building:

Overpressure Contours: ***Location on the Site:***



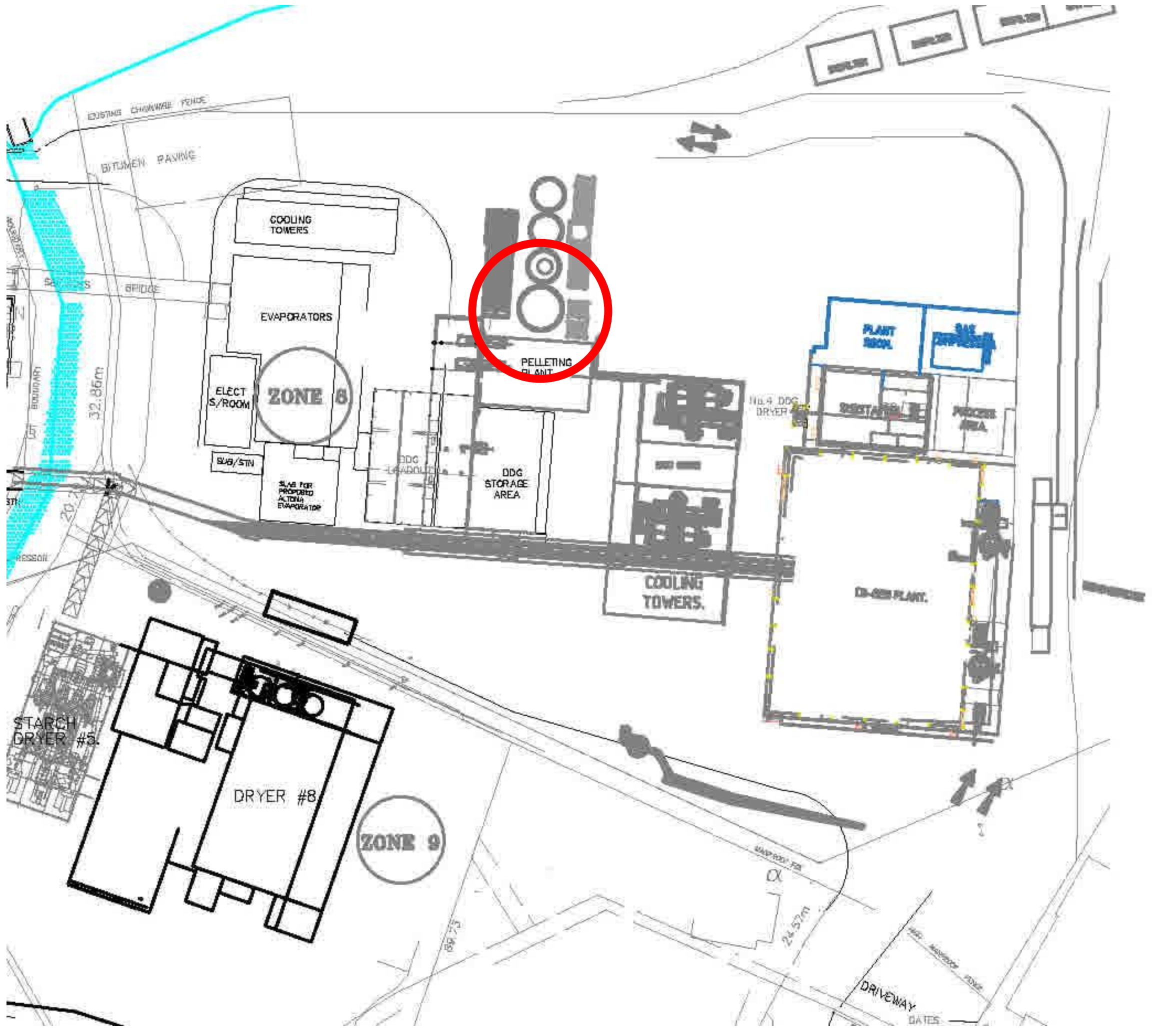


Overpressure Contours:

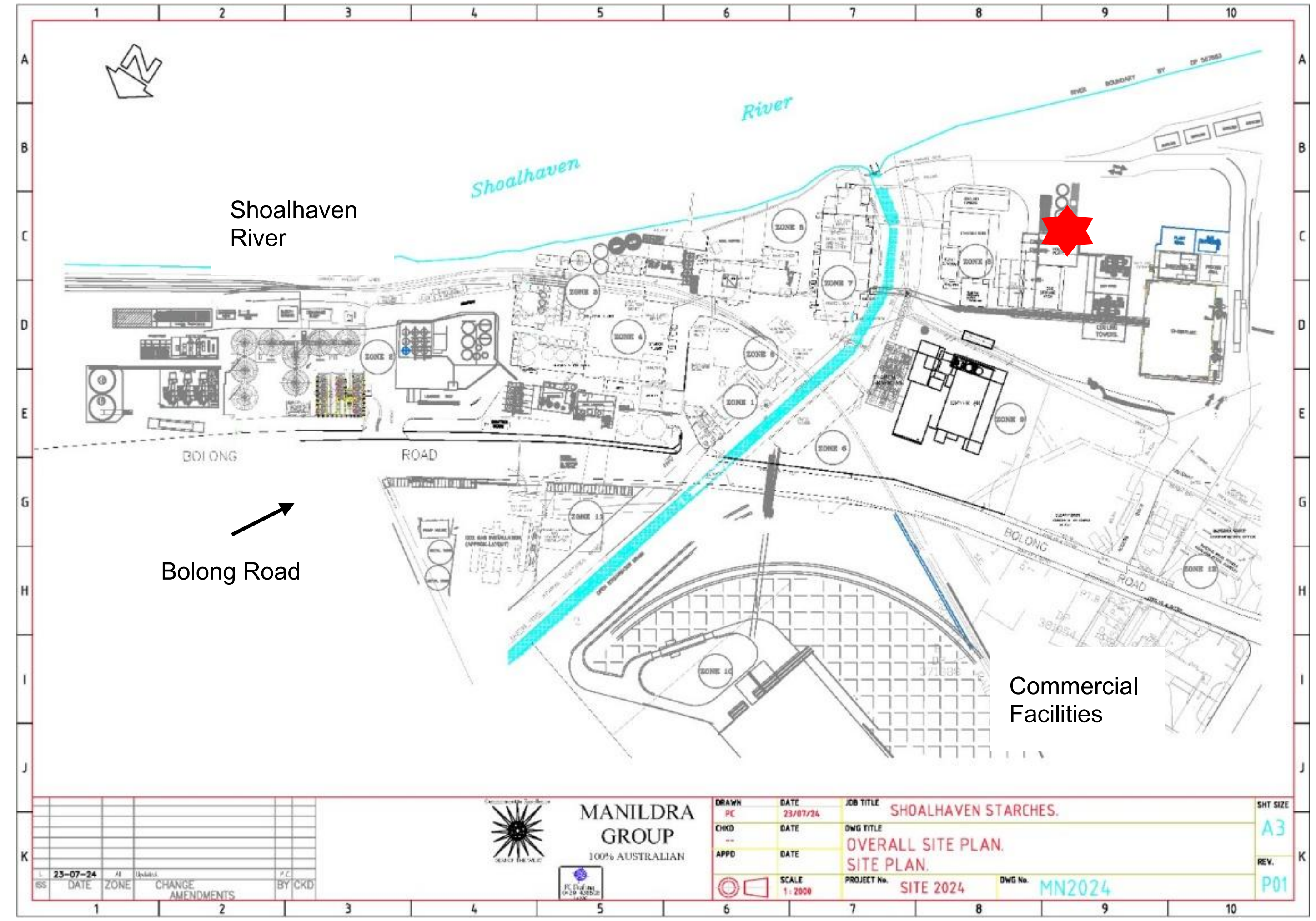
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 8 –Silo T201:

Overpressure Contours:



Location on the Site:

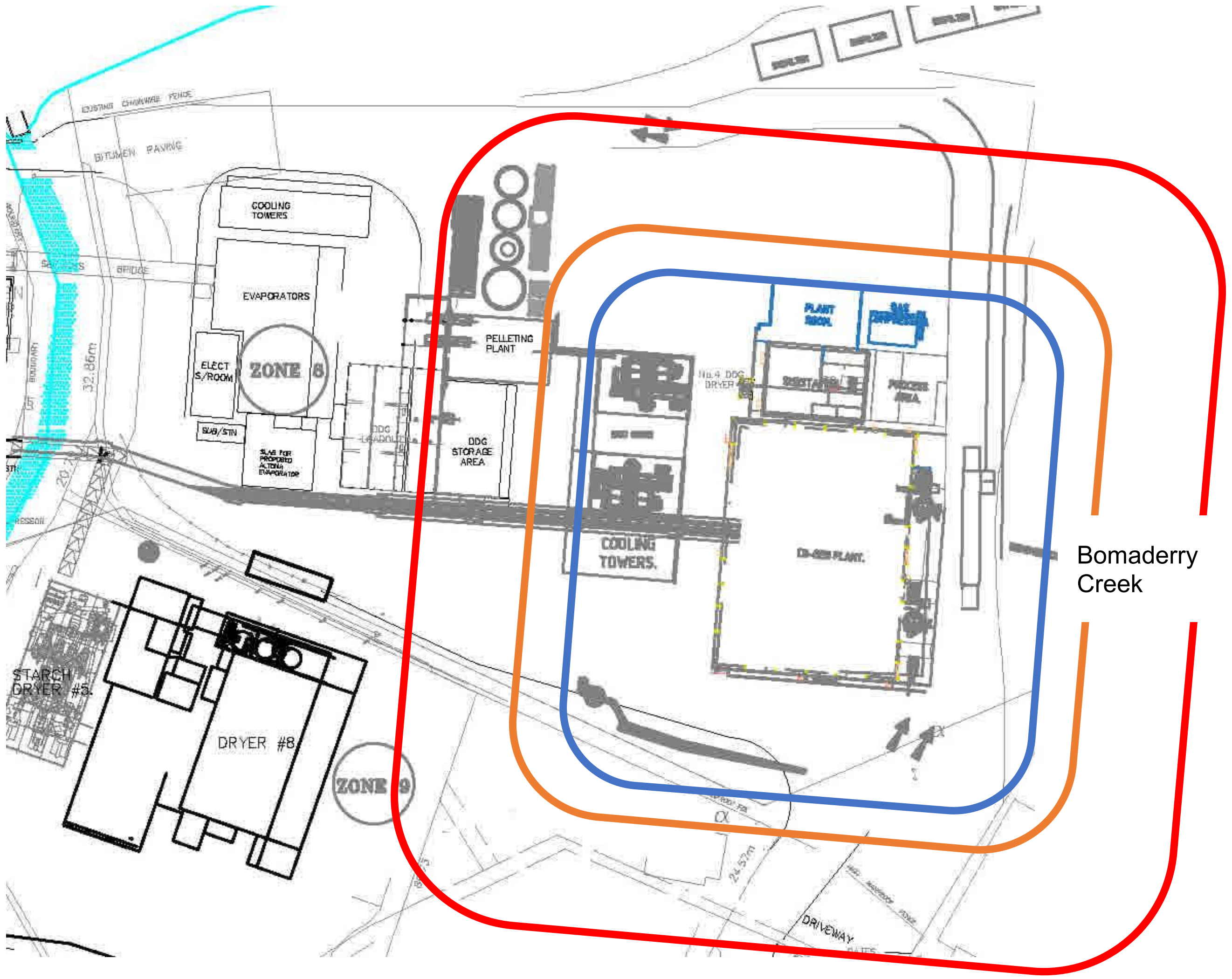


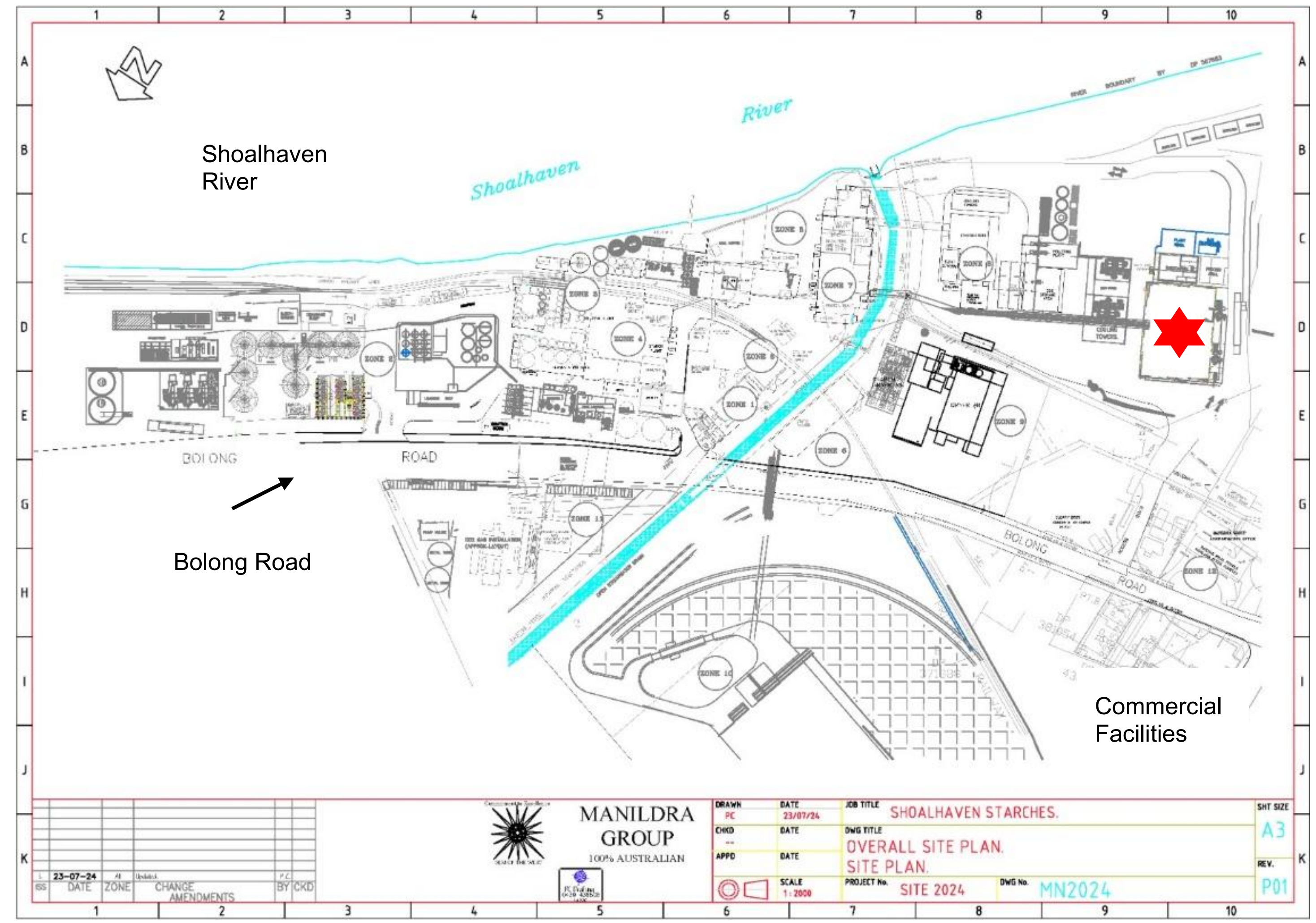
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa (no contour) **Blue** = 21 kPa (no contour)

Zone 8 – Cogeneration Plant Building:

Overpressure Contours: ***Location on the Site:***



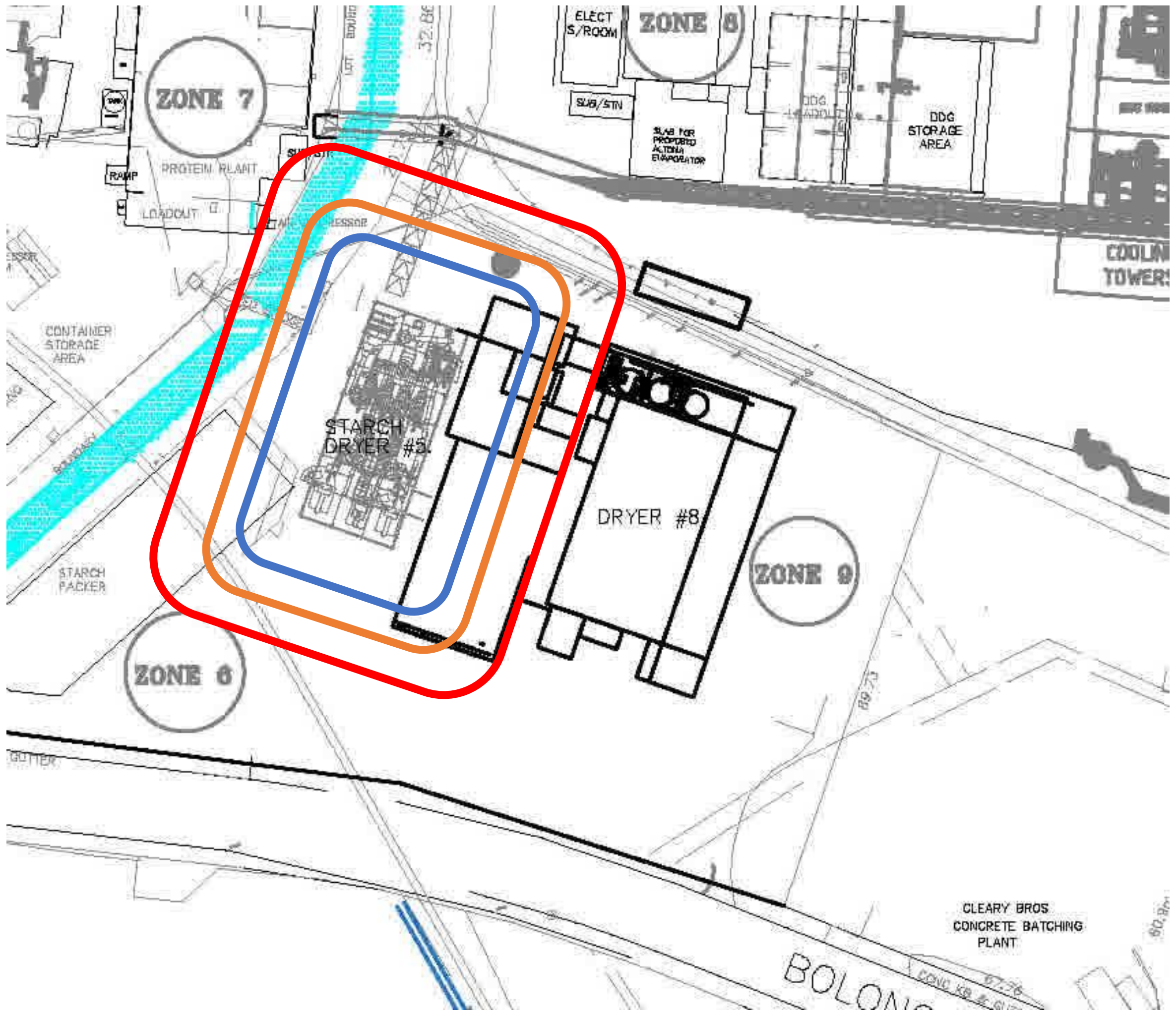


Overpressure Contours:

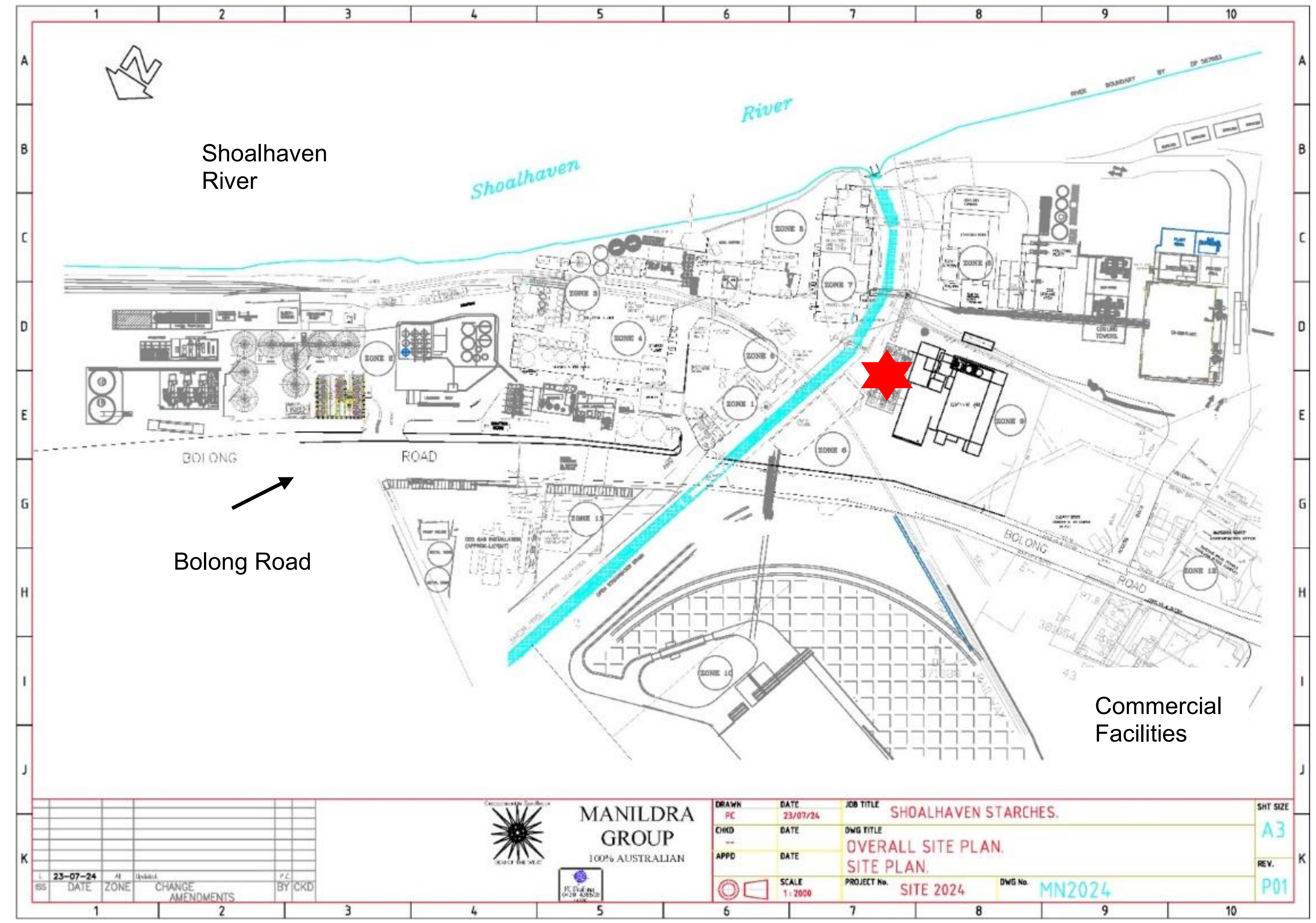
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 9 – SD5 Building:

Overpressure Contours:



Location on the Site:

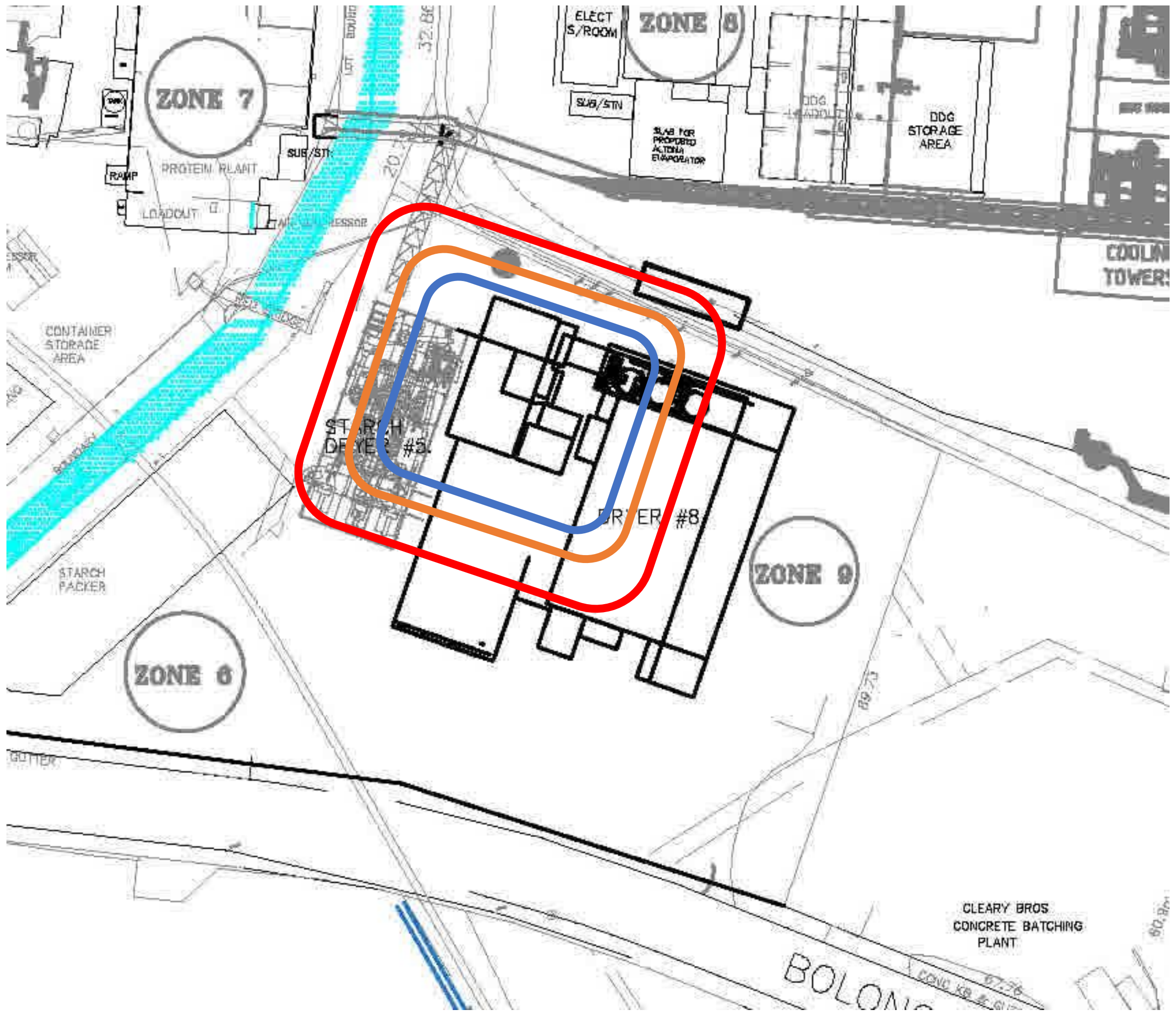


Overpressure Contours:

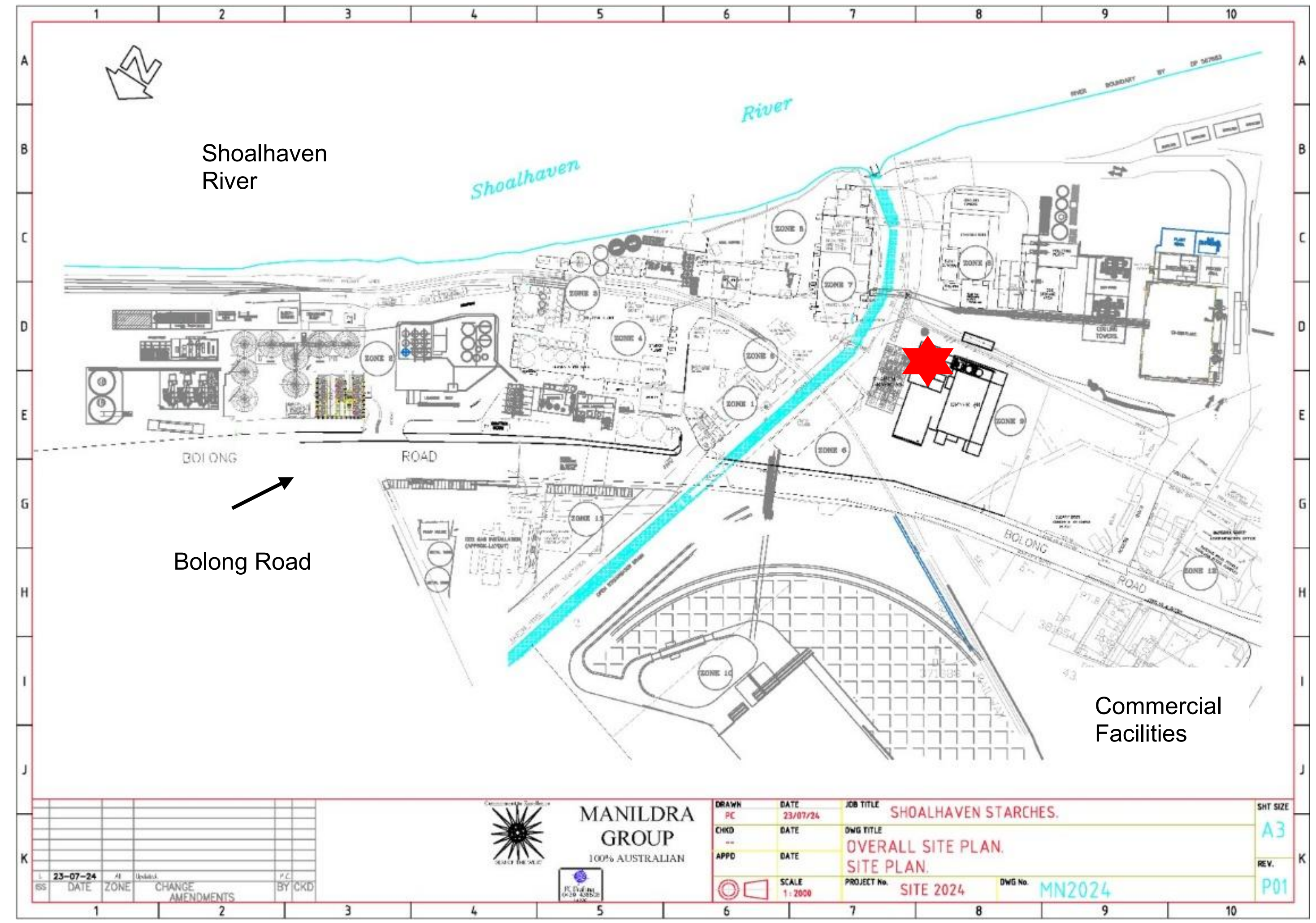
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 9 – Cationic Process Plant Building:

Overpressure Contours:



Location on the Site:

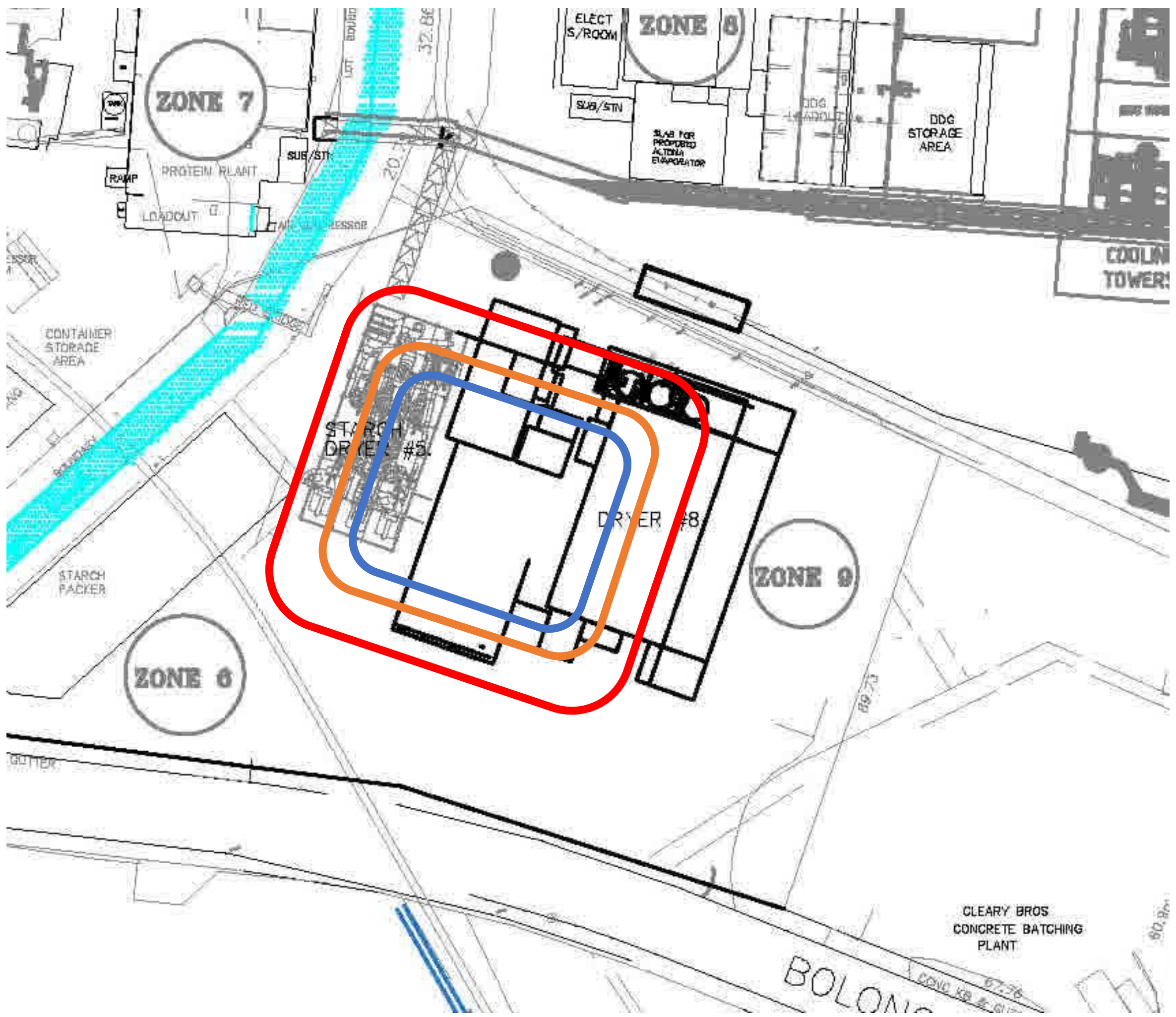


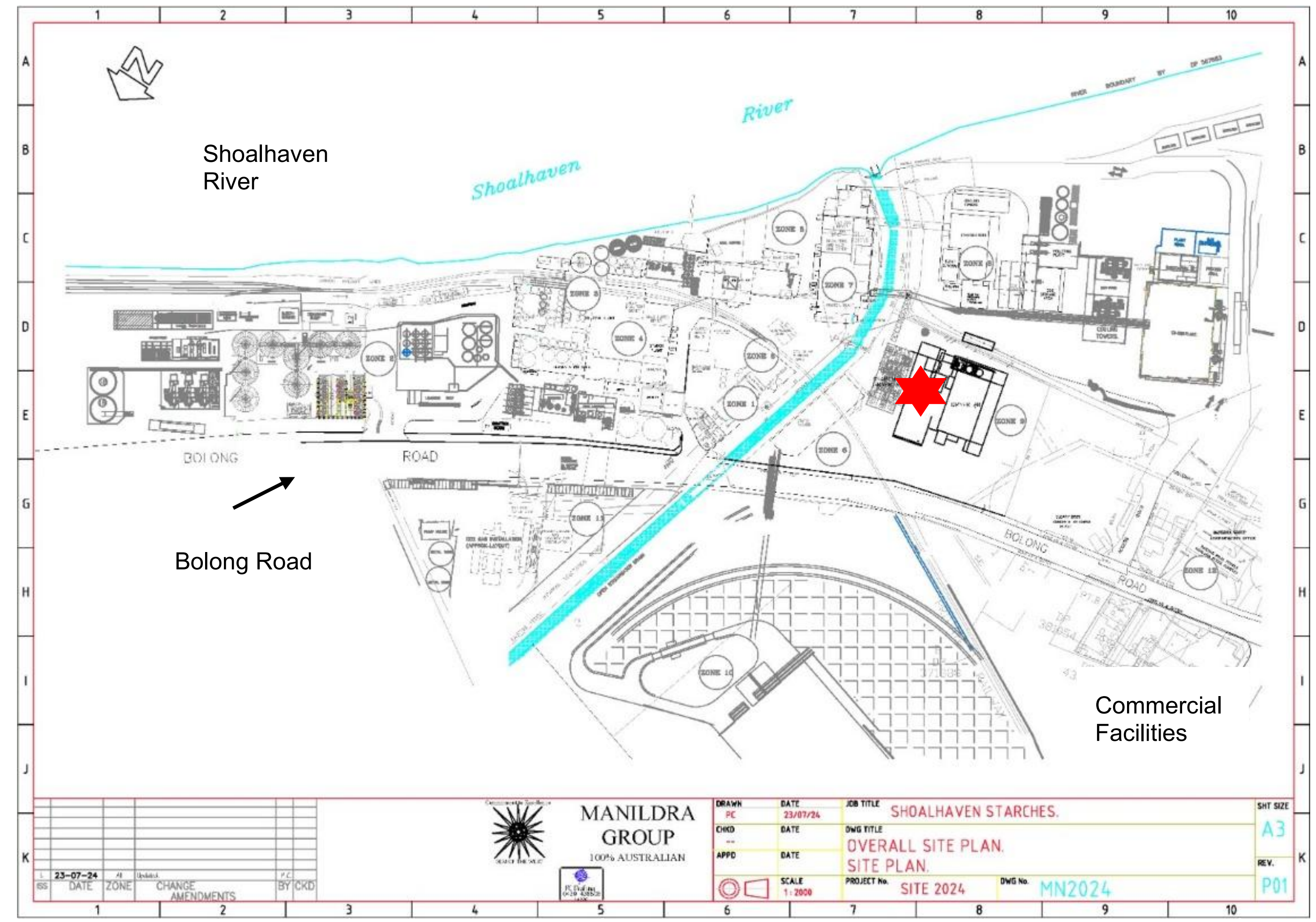
Overpressure Contours:

Red = 7 kPa　　**Orange** = 14 kPa　　**Blue** = 21 kPa

Zone 9 – Ring Dryer 9 Building:

Overpressure Contours: ***Location on the Site:***



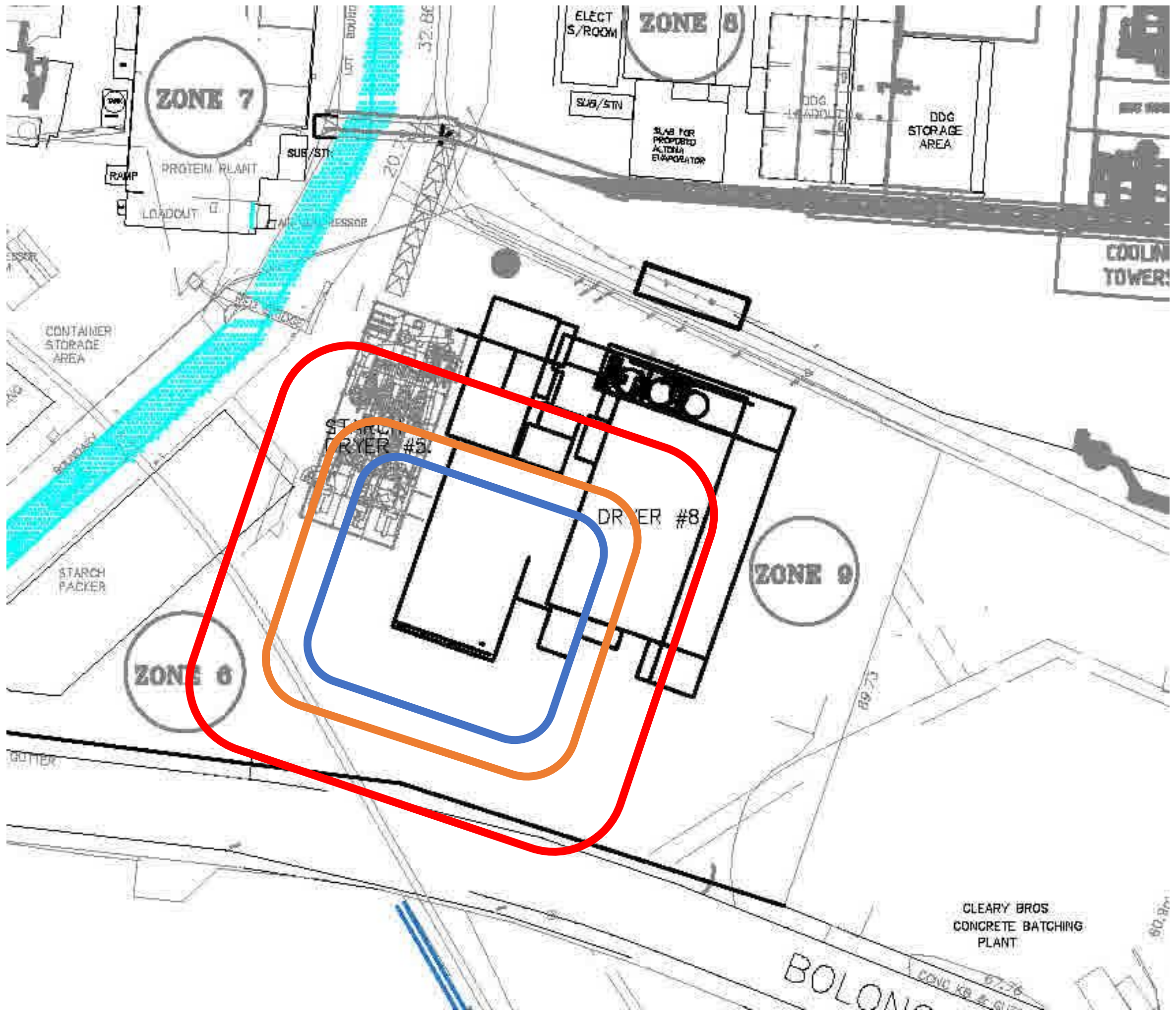


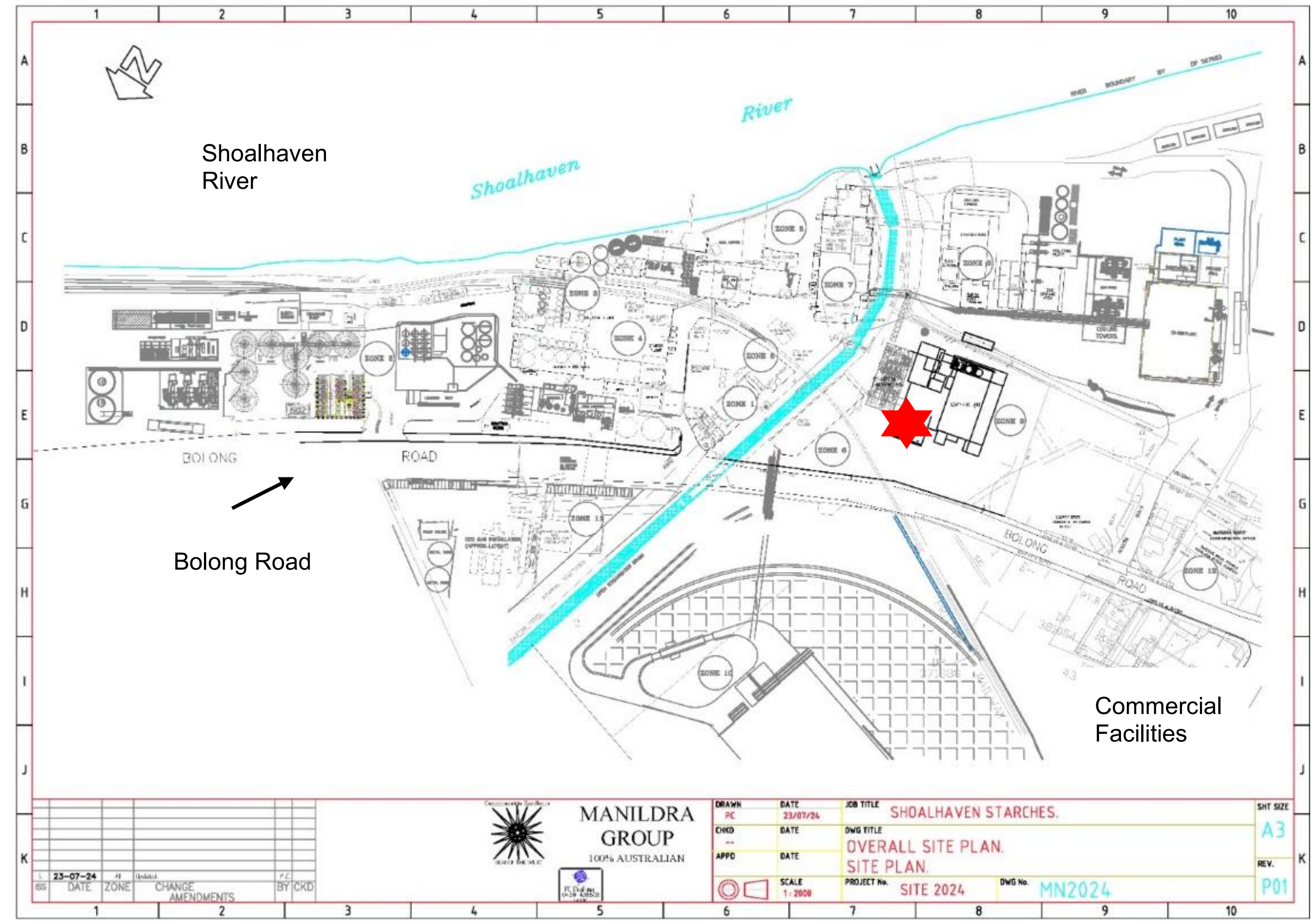
Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 9 – Cationic Packer Building:

Overpressure Contours: ***Location on the Site:***



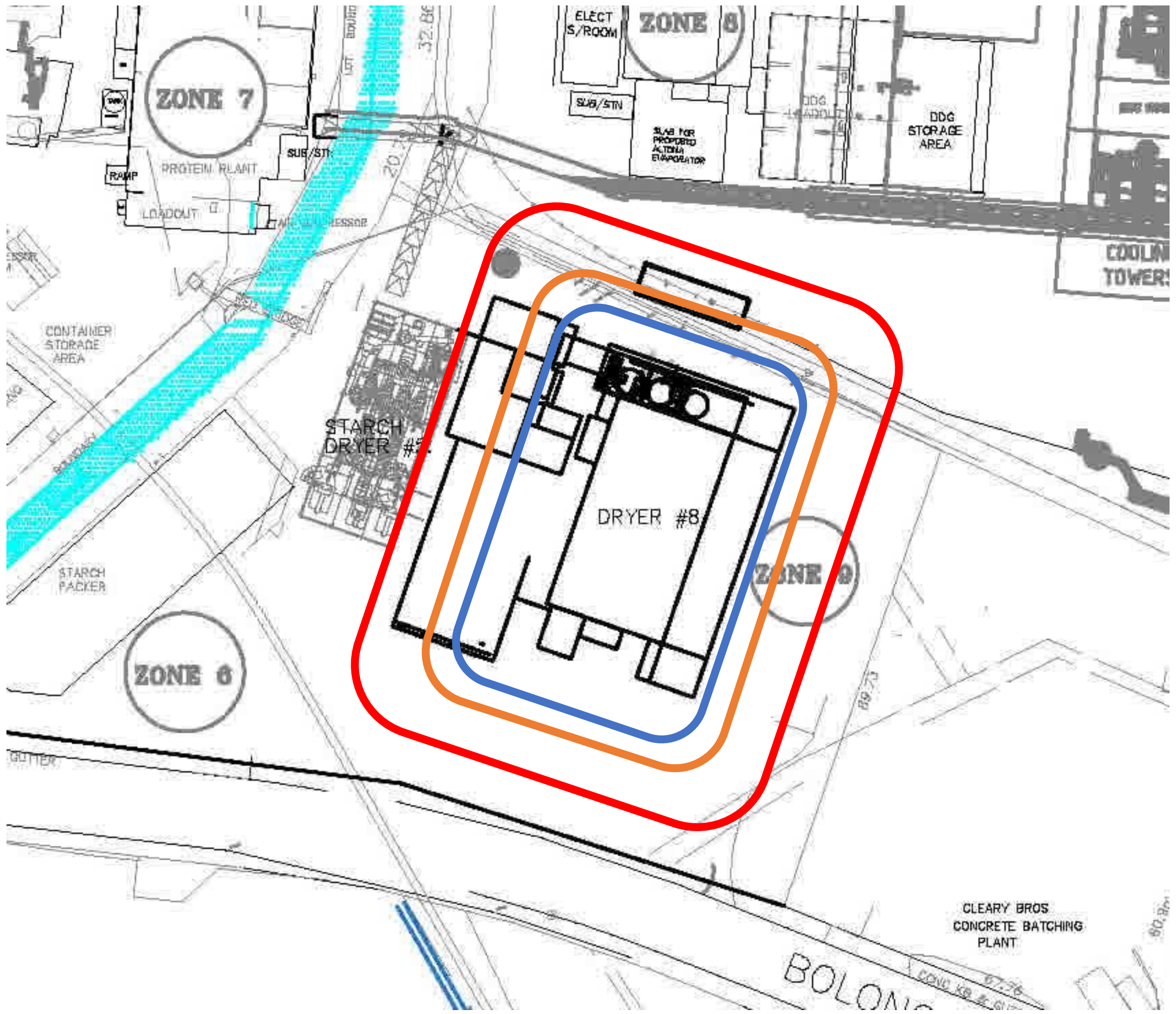


Overpressure Contours:

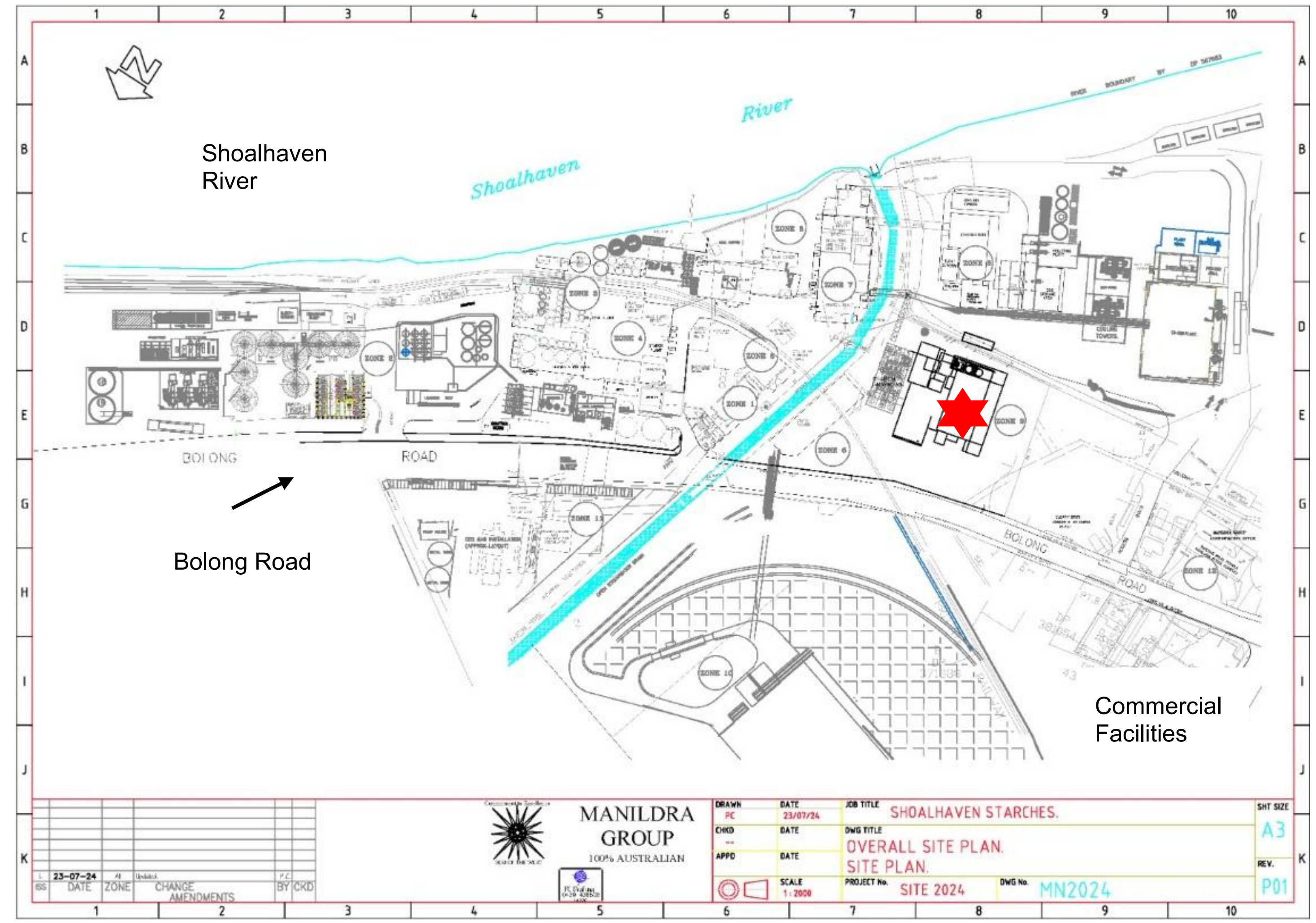
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 9 – GD8 Dry End Building:

Overpressure Contours:



Location on the Site:

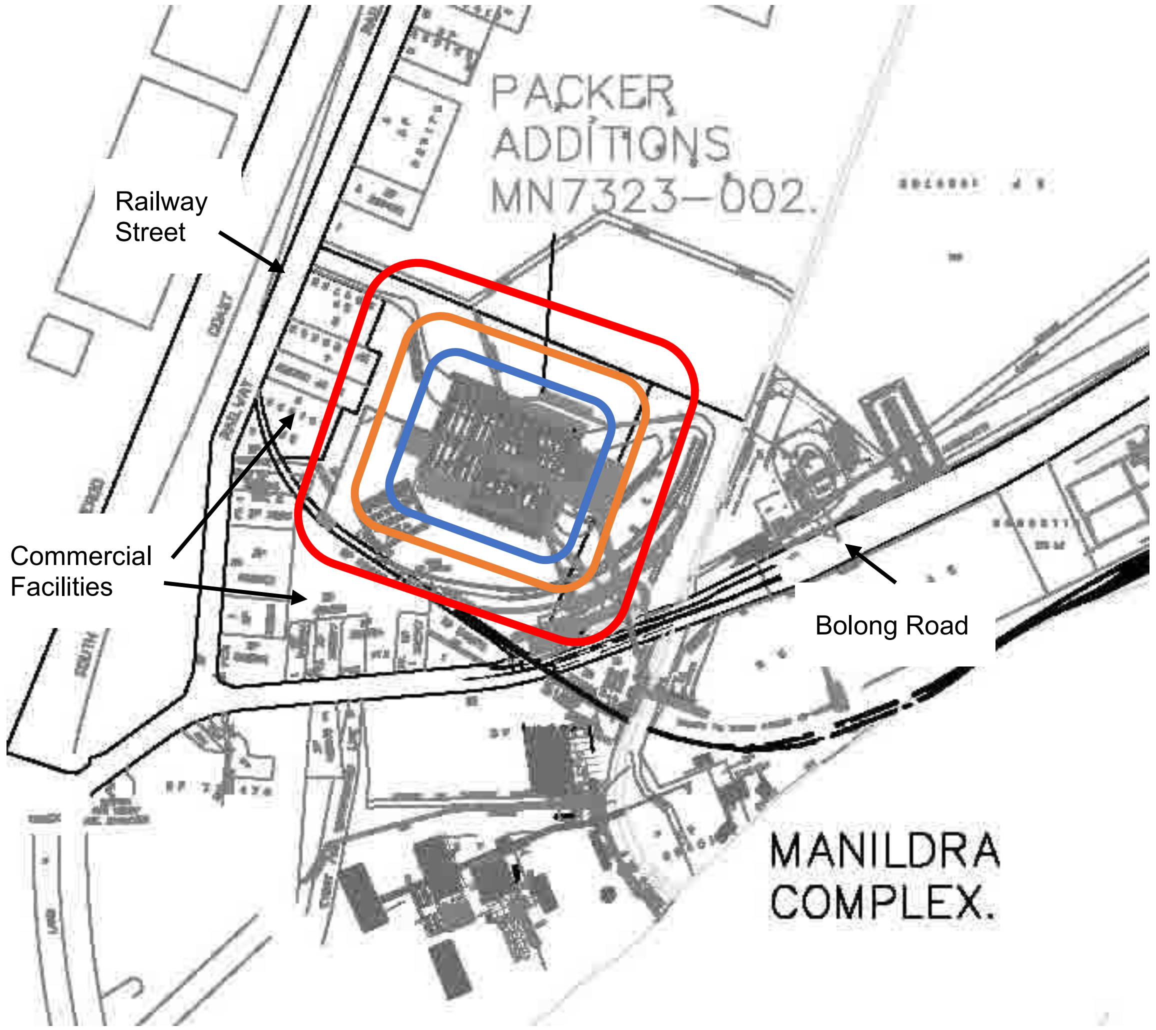


Overpressure Contours:

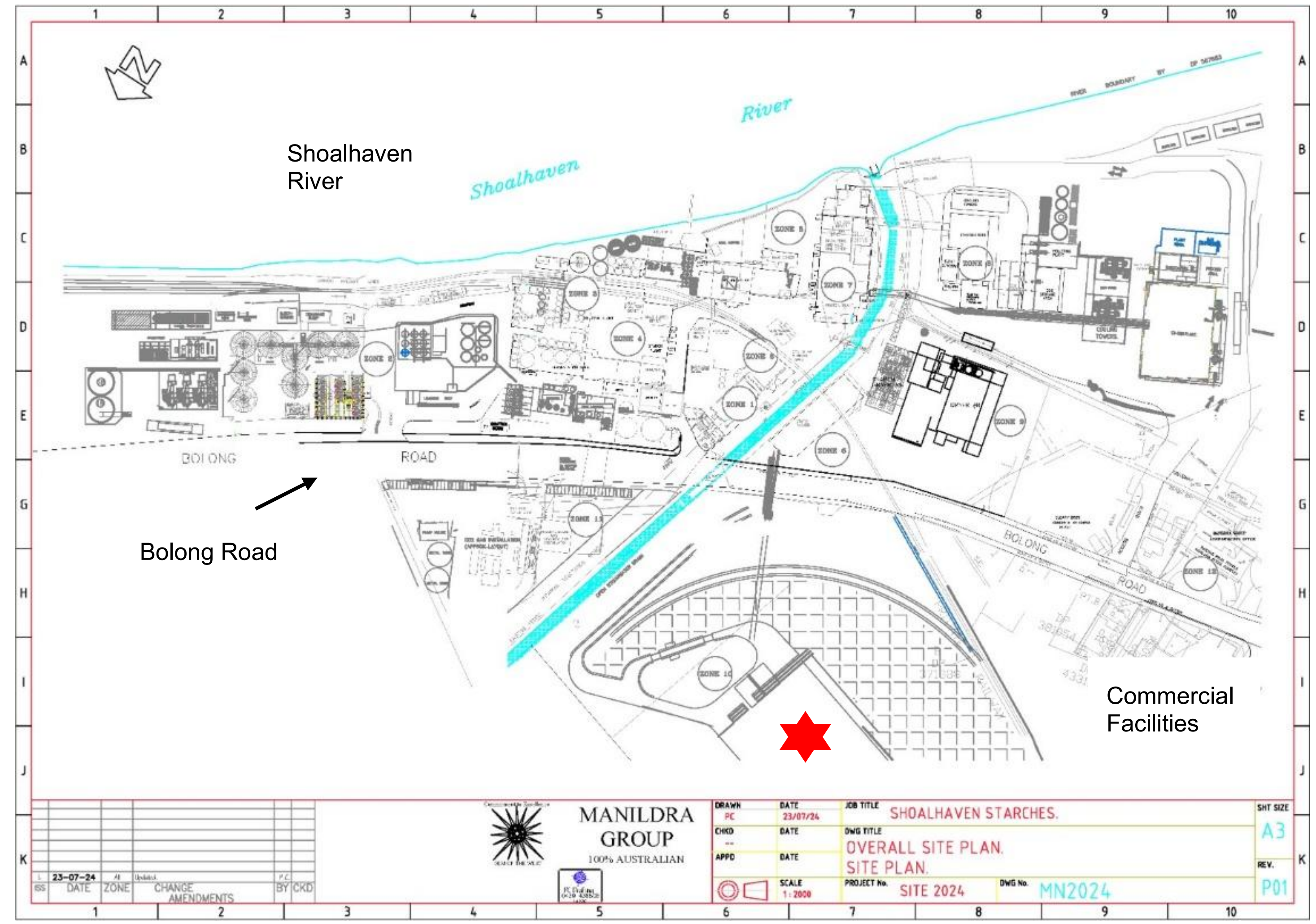
Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone 9 – North Packing Plant Building:

Overpressure Contours:



Location on the Site:

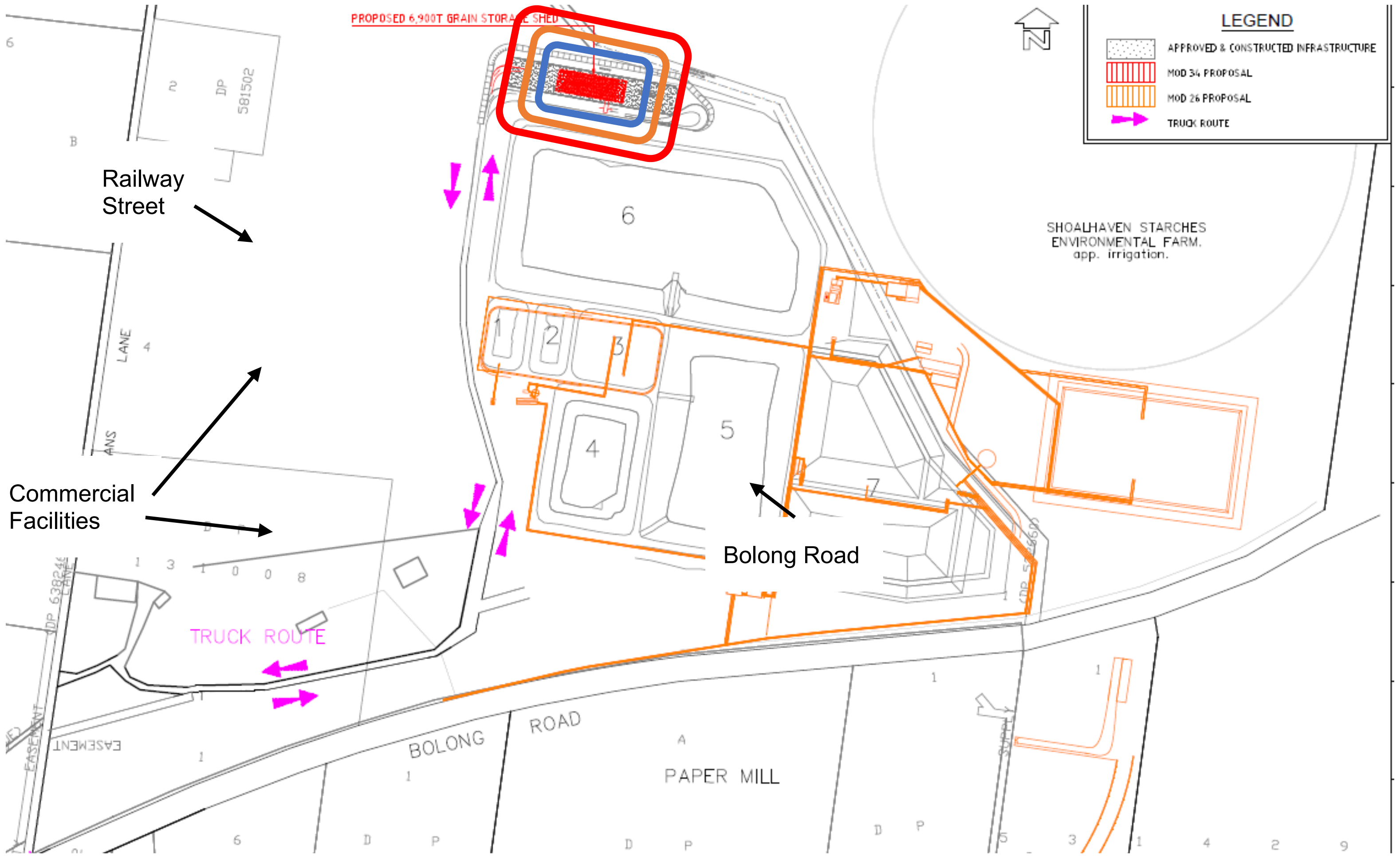


Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

Zone Waste Water Treatment Plant – Grain Storage Shed:

Overpressure Contours:



Commercial Facilities

Overpressure Contours:

Red = 7 kPa **Orange** = 14 kPa **Blue** = 21 kPa

18 APPENDIX E – CONFINED DUST EXPLOSIONS HAZARD ANALYSIS

Appendix E – Confined Dust Explosions Hazard Analysis

For each identified cause-consequence combination of interest for an identified hazardous event, the risk, i.e. consequence times likelihood, is assessed using the CCPS dust hazard analysis methodology (Ref 15) and Pinnacle Risk Management's risk matrix.

The Pinnacle Risk Management risk matrix is shown in Figure 9.

Figure 9 - Risk Matrix

	Severity of Consequences					
Likelihood	Minor 1	Significant 2	Severe 3	Serious 4	Extremely Serious 5	Catastrophic 6
Frequent > 1/yr	II	II	I	I	I	I
Probable $>10^{-1}$ to 1/yr	III	II	II	I	I	I
Possible $>10^{-2}$ to 10^{-1}/yr	III	III	II	II	I	I
Unlikely $>10^{-4}$ to 10^{-2}/yr	III	III	III	III	II	I
Very Unlikely $>10^{-6}$ to 10^{-4}/yr	III	III	III	III	III	II
Extremely Unlikely $<=10^{-6}$/yr	III	III	III	III	III	III

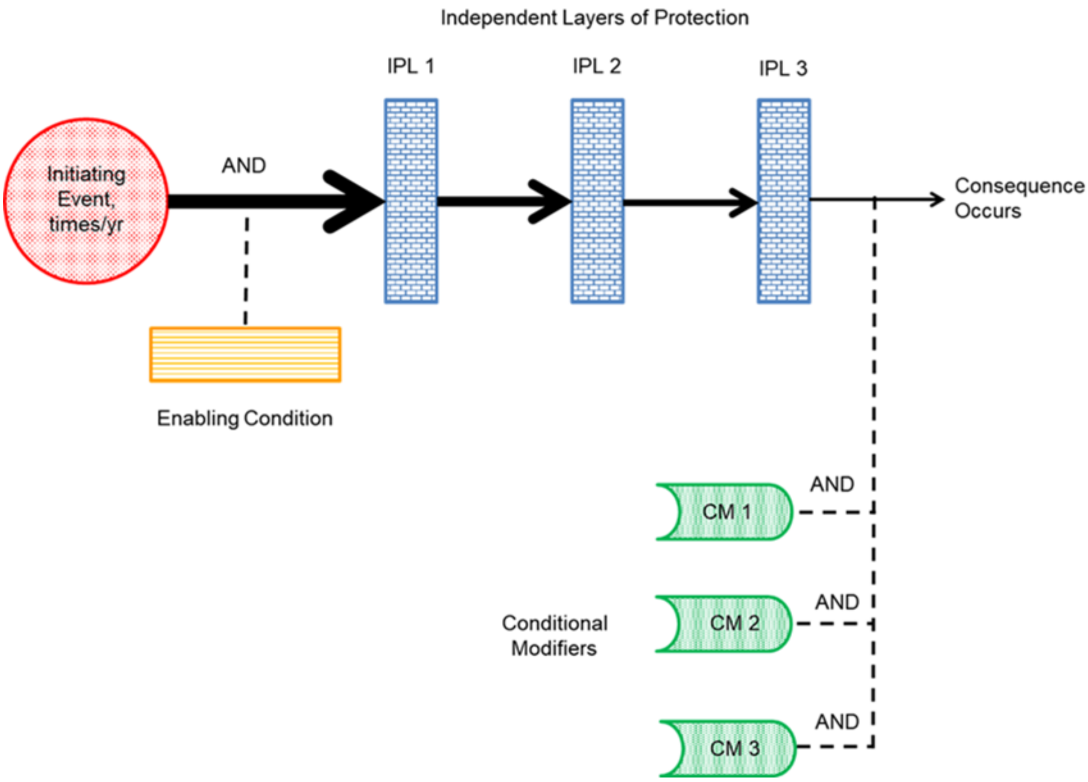
The consequences are determined qualitatively using the guidelines in Figure 10.

Figure 10 - Consequence Ratings

	Consequence Ratings					
	Minor 1	**Significant 2**	**Severe 3**	**Serious 4**	**Extremely Serious 5**	**Catastrophic 6**
Safety and Health	One minor injury, First Aid	Recordable or single MTI	Multiple MTI or one LTI	Permanent disability casualty or multiple LTI	Multiple permanent disabilities or one fatality	Multiple fatalities
Environment	Very minor pollution. No offsite escape of material (contained within the operational areas). Onsite nuisance value only	Minor local pollution. Nuisance offsite effect, typically of short duration, e.g. noise, odours, dust and/or visible plumes for less than one hour	Evident pollution, local concern. Minimal duration offsite effects (e.g. waterway slightly discoloured, turbid etc around the point of release with no or very few fish killed)	Significant local pollution. For example, waterways discoloured 10s of metres, fire or smoke affecting people near to the site	Major local pollution. Observable offsite effect (e.g. waterways discoloured 10s to 100s of metres for a few weeks with a significant number of aquatic life adversely affected)	Extremely severe pollution. Ecosystems at high risk of destruction. Only resolved via long term solutions (potentially taking years)
Public Relations	Minor issue, one complaint	Local issue, 10 complaints	Local media, 100 complaints	Regional or state media	Wide media national coverage	Headlines, corporate damage
Financial Impact	< $25,000	$25,000 to $100,000	> $100,000 to $1 million	> $1 million to $20 million	> $20 million to $100 million	> $100 million

The estimated likelihood of the cause of each potential hazardous event, i.e. the initiating event, is multiplied by the probabilities for the enabling condition (if relevant), the probabilities of failure on demand (PFD) for the IPLs and the probabilities for conditional modifiers (if any, e.g. the probability of 2 or more people being present). This is summarised in Figure 11.

Figure 11 - Event Likelihood



The resulting likelihood for each potential hazardous event is compared to the acceptable risk levels on the risk matrix. The risk should preferably be below the line between risks levels II and III for each consequence rating. The target and upper likelihoods for each consequence category are shown in the Table 19.

Table 19 - Likelihood Limits

Consequence Category	Target Likelihood for Tolerable Risk, times/year	Acceptable Likelihood Range if ALARP, times/year
Minor	1	1 to 10
Significant	0.1	0.1 to 10
Severe	0.01	0.01 to 1
Serious	0.01	0.01 to 0.1
Extremely Serious	0.0001 (or 10^{-4})	10^{-4} to 0.01
Catastrophic	0.000001 (or 10^{-6})	10^{-6} to 10^{-4}

The data presented in the CCPS methodology is used to determine the likelihood of the hazardous events. The data in the following tables summarise the allowable initiating events and IPLs for dust hazard analyses.

Table 20 - Dust Hazard Analysis Initiating Events

Item	Description	Frequency
BPCS Control Loop	The process parameter controlled by the BPCS (Basic Process Control System) control loop deviates without the ability to recover on its own, resulting in a consequence of concern	0.1/yr
Safety Controls, Alarms and Interlocks	The spurious operation of any safety control, alarm or interlock may lead to an upset or other consequences of concern	0.1 - 1/yr
Human Error (routine task performed once or more per week)	A human error occurs on a task that is performed at a frequency of once per week or more often. The consequences are dependent on the task being performed by the person	1/yr
Human Error (task performed 1/week to 1/month)	A human error occurs on a task that is performed at a frequency of once per week to once per month. The consequences are dependent on the task being performed by the person	0.1/yr
Human Error (task performed less than once per month)	A human error occurs on a task that is performed at a frequency of less than once per month. The consequences are dependent on the task being performed by the person	0.01/yr
Screw Conveyor Failure	The failure of the screw conveyor stops the process flow, resulting in an upstream and/or downstream upset or other consequence of concern	1 to 10/yr
Screw Conveyor Overheating of Materials	Overheating of the conveyed material potentially resulting in ignition or decomposition of material within the conveyor. This value can be used for other mechanical failures resulting in ignition (Table 8.19 in Ref 15)	0.1/yr
Fan or Blower Failure	This loss of operation could result in a process upset with a number of possible consequences as a result of the process deviation	0.1/yr
Mill	Explosion within a mill that has safeguards (Table 8.23 in Ref 15). This is within processing equipment	0.1/yr
Baghouse Filter Bags	Failure of the filters bags resulting in combustible dust entering the downstream blower (Table 8.25 in Ref 15)	0.1/yr
Packaging Unit	Existence of a combustible atmosphere at a bagging station	0.01/yr

Table 21 - Dust Hazard Analysis IPLs 1

Item	Description	Probability of Failure on Demand
Safety interlock or trip	Safety interlocks prevent progression of a scenario to the consequence of concern following an initiating event. This is in the BPCS (basic process control system). For example, a dryer high temperature or high carbon monoxide trip	0.1
SIS loop	A SIS loop prevents progression of a scenario following an initiating event, e.g. a high temperature or vibration trips on a hammer mill	SIL 1 - 0.1 SIL 2 - 0.01 SIL 3 - 0.001
Explosion isolation valve	An explosion isolation valve protects against the propagation of flame between interconnected equipment. This includes rotary valves PRM Comment: The PFD may be lower, e.g. 0.01, if the suppression system is well-designed (SIL rated)	0.1
Explosion panels on process equipment	Proper operation of explosion panels during an internal dust/vapour/gas explosion can protect a vessel or duct from excessive overpressure	0.01
Vent panels on enclosures	Vent panels prevent damage to an enclosure or room. However, activation of the panel does result in a pressure wave and loss of containment of dust/vapour/gas. If the vent panel relieves into an occupied area, a vent panel may not be an effective IPL against impact to nearby workers	0.01
Automatic fire suppression system	Within process equipment: An automated fire suppression system prevents propagation of a fire outside of the process equipment PRM Comment: The PFD may be lower, e.g. 0.01, if the suppression system is well-designed (SIL rated)	0.1
Automatic fire suppression system	For local applications: Fire suppression systems for local applications mitigate fires in small areas PRM Comment: The PFD may be lower, e.g. 0.01, if the suppression system is well-designed (SIL rated)	0.1
Automatic fire suppression system	For a room: Fire suppression systems mitigate fire in a room or small enclosure PRM Comment: The PFD may be lower, e.g. 0.01, if the suppression system is well-designed (SIL rated)	0.1
Human response to an abnormal condition	Human response to an abnormal condition can prevent a variety of possible consequences of concern. PRM Comment: It is also possible to use data that takes into account stress and time of response, e.g. the HEART (human error assessment and reduction technique) methodology	0.1

Item	Description	Probability of Failure on Demand
Automated explosion suppression system for process equipment	An explosion suppression system protects against explosions that could cause equipment damage including rupture. More quantitative analysis may support a lower PFD value for a specific system than the generic PFD provided PRM Comment: The PFD may be lower, e.g. 0.01, if the suppression system is well-designed (SIL rated)	0.1
Inerting	Inert a vessel or bin, e.g. with nitrogen, and install an oxygen detector with an interlock if the oxygen concentration exceeds a defined value (e.g. 2 vol% below the LEL). That is, a SIL 1 function	0.01
Personal Protective Equipment (PPE)	PPE prevents consequences associated with exposure of people within the area of potential impact to a hazard of concern. PRM Comment: This is not normally taken as an IPL in LOPAs but this approach for dust fires and explosions appears to allow such risk reductions	0.1
Bonding and earthing	Failure of the bonding and earthing (NFPA 654 - 9.3.2)	0.1

The following safeguards are used by the CCPS in their dust hazard analysis LOPA methodology even though they are not traditionally considered IPLs. This could be due to the definition of the methodology, i.e. a risk-based dust hazard analysis where safeguards (not IPLs) are taken into consideration. That is, the CCPS use the LOPA technique in a less formal way to allow safeguards to be included in the dust risk assessment. Independence rules for the Basic Process Control System (BPCS) and (Safety Instrumented System) SIS functions still apply though.

Table 22 - Dust Hazard Analysis IPLs 2

Item	Description	Probability of Failure on Demand
Bulk bag	Use of a standard design bulk bag (NFPA 654 - 9.3.4.3) reduces the probability of a release if dropped	0.1
PMs and training	PMs and training on a specific task (NFPA 654 - Sections 11 and 12)	0.1
Area classification	Proper area classification, e.g. to prevent hot surfaces on electrical equipment	0.1
PM for bonding	PM to maintain bonding and grounding of the equipment (NFPA - 12.1.2). PRM Comment: This is taken into account as well as an IPL for having bonding and earthing in the CCPS methodology, i.e. effectively a PFD of 0.01 (0.1 x 0.1)	0.1
Procedures	Dedicated, specific procedures with supervisory controls, e.g. emptying and cleaning a tank during a shutdown	0.1
Housekeep-ing	Written checklist for cleaning and ignition control procedures are in-place	0.1
Fugitive dust collection system	Installation of a fugitive dust collection system, e.g. extraction hood, ducting and fan (NFPA 654 - 8.1.1)	0.1
Fugitive dust collection system	Probability of a dust concentration above the MEC (minimum explosive concentration) within a fugitive dust collector only occurs during pulsing. Therefore, take a PFD = 0.1 (this is not applicable to a baghouse filter given the high dust concentrations in the feed streams)	0.1
Occupancy	Restrict the area around a hazardous equipment item, e.g. hammer mill, when it is running. Need a formal procedure	0.1
Occupancy	Restrict the area around a hazardous equipment item, e.g. hammer mill, when it is running. Need a formal procedure. Install a means to alert personnel that the equipment is running, e.g. flashing light	0.01
Hot sealing system for bag sealing	Ensure the temperature is below the auto-ignition temperature of the product. Note that a lower PFD can be used (e.g. 0.01) if the maximum temperature is physically limited (e.g. low power supply)	0.1

The following data (Ref 16) can be used to estimate the ignition probabilities.

Note: This data is used for LOPA studies and assumes there are no safeguards in-place, i.e. further risk reduction can be taken for the safeguards that do exist, e.g. area classification.

Table 23 - Ignition Probabilities

MIE	Probability of Ignition
0 < MIE < 10 mJ	1
10 < MIE < 100 mJ	0.1
MIE > 100 mJ	0.01
Hot work, failed bearing, dust entering a fan etc (unless other data exists)	1

MIE = Minimum Ignition Energy

The following table shows typical MIEs for dusts (Refs 17, 18, 19 and 20). As dust explosibility values will vary, e.g. different particle size distributions, the probability of ignition for the main agricultural dusts should be taken as 0.1.

Table 24 - Typical Minimum Ignition Energies

Material	MIE (mJ)
Wheat Dust	> 20
Flour	> 50
Starch	> 20
Gluten	30 - 100
Glucose	> 30

To calculate the risk, the likelihood is estimated by multiplying the initiating event likelihood by the probabilities for any enabling condition, IPLs failing and conditional modifiers. This value is then combined with the qualitatively determined consequence on the risk matrix to determine the acceptably of risk and hence whether any further controls are required.

19 APPENDIX F – PRM QRA METHODOLOGY

Appendix F – PRM QRA Methodology

The quantitative risk assessment (QRA) has been performed using Pinnacle Risk Management software. Various risk calculations are performed to check the compliance with the relevant risk criteria. The user enters consequence calculation results for defined hazardous release scenarios, estimates of the effects on people and combines these results with incident likelihood information, plant grid information and population data to determine risk. The risk results may be presented as individual risk contours, societal risk curves or risk curves for exceeding a predetermined likelihood of a defined consequence.

The following contains a general discussion of the risk analyst's consequence and likelihood modelling and estimation work (Ref 21).

1. Release Rates

The risk analyst models release behaviour for compressed gas, liquid or 2-phase releases from vessels, pipelines or total vessel rupture using appropriate software, e.g. EFFECTS, CCPS or PHAST. Data inputted into the release models will include the type of release, the location of release with respect to vessel geometry, pipe lengths and initial conditions of the fluid (i.e. before release).

A. Gas Releases

The equations for prediction of gas flowrates though orifices are well known and are not reproduced here. Two cases are typically modelled, i.e. sonic and subsonic flow. Sonic flow usually occurs when the ratio of the pressure of the gas to atmospheric pressure (assuming the release goes to atmosphere) is greater than 2.

Gas releases from either a vessel or pipe may be modelled. The initial release rate depends on the leak size, the discharge coefficient and the initial pressure inside the vessel or pipe. For pipes, frictional pipe pressure loss also affects the release rates. For the larger hole sizes where the initial release rates are in excess of the gas production rates, the system pressure will drop and therefore the release rate decreases with time. The rate of decrease depends mainly on the system volume and capacity.

The input mass rate to a dispersion model may be the average over the release duration (default choice) or chosen by the risk analyst.

B. Liquid Releases

Liquid release rates are typically calculated using the Bernoulli equation. The release rate depends on the leak size and the pressure of the liquid.

If confinement exists, e.g. a bund around a tank, then the pool size is restricted by the bund dimensions.

If no confinement exists and the material ignites then the pool area is calculated to match the pool spread given the material's burndown rate. If the material is not flammable then the pool size is typically calculated assuming a depth of 10 mm. Evaporation from the liquid pool formed can then be calculated using a pool evaporation model.

Released liquids that form pools can be either non-boiling or boiling.

For non-boiling liquids, the liquid temperature is below its normal boiling point and the boiling point also needs to be above the ambient temperature. The rate of evaporation from boiling pools will be higher and therefore the models need to take this into consideration.

For non-boiling pools, the evaporation rate depends on the partial vapour pressure of the liquid, the wind velocity and the surface area of the pool. As the liquid draws heat from its surroundings, the liquid will cool down until an equilibrium condition is reached. This decreases the partial vapour pressure, hence decreases the evaporation rate over time to a stable point dependent on wind velocity.

For boiling liquids, the evaporation rate from a liquid at its boiling point below ambient temperature depends on the heat flow from the surface to the liquid pool. The evaporation rate depends on the liquid properties and the type of surface. The heat required for the evaporation is taken from the subsoil / ground and from the liquid itself. This means that the liquid and the subsoil will cool-down, which results in a decrease of the evaporation rate.

C. Two-Phase Releases of Pressurised Liquefied Gases

Various models can be used to predict the release rate and therefore consequences of a two-phase release, e.g. the TPDIS model developed by the Finnish Meteorological Institute. The inputs to this and similar models are typically the vessel inventory, the vessel dimensions and the operating conditions of the vessel. The initial liquid release rate depends on the leak size and the pressure in the vessel. As the liquid level decreases, more vapour is formed by liquid boil off, decreasing the temperature and pressure in the vessel, hence decreasing the leak mass rate over time.

The input mass rate to a dispersion model may then be the initial mass flow rate, the average over the release duration (default choice) or set by the risk analyst.

The fraction of liquid that rains out of a two-phase release to fall onto the ground can be estimated using published models or via hand-calculations. The estimated rainout quantity is based on the conditions of the material after release, the height of the release and the ambient conditions. Materials that can lead to rainout include pressurised releases of liquid propane and ammonia. Evaporation from the pool can then be calculated using a pool evaporation model.

2. Dispersion

A. Atmospheric Conditions

Gas dispersion depends on the meteorology, in particular on atmospheric turbulence and wind speed. The meteorological conditions that are of prime importance are those in the near ground region where the releases take place. This region is known as the atmospheric boundary layer or mixed layer.

The wind flow in this layer is almost always turbulent. The turbulence is produced:

- Mechanically through the resistance of the earth's surface on the wind. This wind shear effect provides a downward turbulent momentum flux and depends mainly on the upper wind speed and the surface roughness

- Thermally through heating of the surface (primarily by the sun). This causes regions of hot air near the surface to rise, resulting in an upward turbulent momentum flux.

Atmospheric stability determines the degree of mixing. When regions of air move upwards from the earth's surface, expansion due to the pressure decrease will result in a decrease in temperature. When the air / plume has the same temperature as its surroundings during its travel upwards, no forces due to density differences are exerted on the air / plume and the atmospheric stability is referred to as neutral. Stable conditions occur when the air / plume is at a lower temperature than the surroundings and is thus forced downwards. Unstable conditions exist when the air / plume temperature is higher and is thus accelerated upwards. Dispersion is greatest in unstable conditions and least in stable conditions.

The stability of the of the mixed layer is determined by the ratio of turbulence generated by the temperature gradient and that generated mechanically by wind shear at the surface. Neutral or stable conditions tend to prevail at night and unstable conditions during the day, with a high degree of instability occurring on days of strong insolation and gentle winds.

Qualitative schemes are often used to characterise atmospheric stability. In dispersion modelling the most commonly used is the Pasquill scheme. This scheme ranks stability from class A (unstable) through D (neutral) to F (stable) and is based on observations of wind speed, cloud cover and time of day. The following (Ref 22) lists the stability classes relevant to various weather conditions.

Table 25 – Pasquill's Stability Categories

	Daytime			Night	
	Incoming Solar Radiation				
Surface wind speed (m/s) at 10m height	**Strong (> 600 kW/m^2)**	**Moderate 300-600 kW/m^2**	**Slight < 300 kW/m^2**	**Thinly overcast or ≥ 4/8 cloud**	**≤ 3/8 cloud**
< 2	A	A-B	B	F	F
2 – 3	A-B	B	C	E	F
3 – 5	B	B-C	C	D	E
5 – 6	C	C-D	D	D	D
> 6	C	D	D	D	D

The risk analyst will use the appropriate meteorological data for the site in the dispersion calculations. Typically the weather data is divided into (up to) 6 Pasquill stability classes and average windspeeds, with (up to) 12 directional probabilities for each stability class / wind speed combination. Pinnacle Risk Management normally uses the Pasquill stability classes for modelling work, i.e. hazard analysis and QRAs.

If the modelling results for one stability class / wind speed combination are close to the modelling results for another stability class / wind speed combination then the cumulative probabilities for both combinations can be determined using the more conservative results, i.e. for simplification purposes.

Depending on the data for the site, not all stability classes may be present for significant periods of time, e.g. it is common to not use "A" class stability as the percentage of the total time (as taken typically over one year) can be very low and therefore can be neglected from QRA calculations.

B. Dispersion Modelling

The dispersion model used by the risk analyst will depend on the release conditions and behaviour, e.g. velocity and density of the fluid.

Material that is released into the atmosphere will be dispersed by atmospheric turbulence. This process, known as dispersion, can be considered to start once the puff, jet or plume of material begins to interact with the ambient air. Instantaneous or short duration releases result in a puff of dispersing material. Continuous releases result in jets or plumes, depending upon whether the released material possesses significant initial momentum.

Turbulent eddies resulting from the momentum fluxes of atmospheric instability act to transport and dilute (disperse) material released into the atmosphere. These eddies cover a range of sizes from several hundred metres down to millimetres. Eddies whose dimensions are significantly larger than those of the cloud will displace the dispersing release without greatly altering its size or geometry. Eddies that are smaller will dilute the release and increase its size. Eddies of comparable size act to change the geometry of the cloud. Since the size of the cloud increases as it dilutes, the proportion of eddies contributing to displacement decreases while that contributing to dilution increases.

For continuous releases, large eddies act to displace the plume centre line. An appropriate averaging time must therefore be defined in order to determine concentration and plume width. The specification of the averaging time is relevant from a consequence point of view since consequences occur over a range of time scales, from almost instantaneously (e.g. combustion) to tens of minutes (e.g. toxicity effects). The risk analyst will typically select the averaging time based on the duration of the release as well as the weather combinations and the time of exposure to the plume.

i. Passive Dispersion

When the dispersion of a puff or plume of material is governed solely by atmospheric turbulence, the dispersion is said to be passive. The state of the atmosphere is not changed by the presence of the material in the air.

Assuming that the turbulence and wind speed are the same at all locations in the surroundings, it can be derived that the concentration distribution of an initial cloud will be Gaussian in shape. In practice, Gaussian distributions are observed in many situations and therefore the passive dispersion models are normally based on this type of distribution.

Gaussian dispersion calculations are based on three parameters, σ_x , σ_y and σ_z, which are used to predict longitudinal, horizontal and vertical dispersion behaviour. These parameters can be estimated using correlations. The variables used are typically surface roughness, averaging time and windspeed.

Simulations can be performed for continuous, instantaneous or semi-continuous releases. The following results can be achieved:

- Determination of gas concentration at a nominated position;
- Determination of a selected gas concentration contour;
- Determination of the amount of gas within the explosive range; and
- Determination of the toxic load ($C^n t$) at a nominated point.

In the PRM QRA Model, the downwind concentrations are determined via modelling and, using probits (as discussed below), the concentrations and time of exposure are used to determine the probability of an effect, e.g. individual fatality.

ii. Jets

Gases or vapours which are released with high velocity will cause jets. As long as the velocity inside the jet is high compared to velocities in the ambient air, the extent of mixing in the jet will only be affected by the properties of the jet itself. The velocity difference between the jet and the surrounding air generates fine scale turbulence, which causes the jet to spread sideways. The velocity in the jet decreases with distance from the release source. At a certain distance, the jet velocity will be reduced to such an extent that passive dispersion dominates.

Given the above data, the risk analyst will need to ensure the modelling takes into account the initial jet length and plume concentration decreases as well as the dispersion of the plume once the plume's velocity matches the wind speed.

For example, a typical turbulent jet model is valid up to the distance where the gas velocity reaches the wind velocity, e.g. this type of model can be used to determine the distance to the lower explosive limit. Beyond this point, passive or dense gas dispersion will be required to estimate the plume concentrations in the far-field.

iii. Plumes

Plume dispersion occurs when the material released into the atmosphere rises because it is either buoyant (less dense) than the ambient or because it possesses upward momentum. The released material will rise until it reaches a height where the momentum or buoyancy effects have been dissipated by dilution or where the material is in equilibrium with its surroundings. Once the material has reached this height, the dispersion may be assumed to be passive.

Various models that can be used for plumes are the Ooms Plume Path Model and the Briggs Plume Rise Model. These models typically calculate the plume path, gas velocity, density and/or concentration due to gases emitted by a stack or similar situations. The pressure at the point of release is assumed to be essentially atmospheric.

iv. Dense Gas Dispersion

When the released material is denser than the ambient air, the release will result in a laterally spreading cloud which remains in the lower part of the atmosphere. Material may be heavier than air because it has a higher molecular weight and/or because its temperature is lower than ambient. The latter may be due to a low release temperature which flashes and results in a mixture of aerosol and vapour, and/or the occurrence of reactions that are endothermic, and/or the gas or vapour may absorb atmospheric water vapour.

Upon its release, dense material will fall to the ground and spread radially under the influence of gravity. This self-induced flow produces a shallow, wide cloud. At the edge of the cloud, the effect of this gravity spreading (slumping) is to create strong vorticity that dominates random atmospheric turbulence and promotes mixing at the cloud edge. Once the slumping process is finished, the density gradient in the cloud causes localised stability, inhibiting dispersion in the vertical direction. Eventually these density effects will be dispersed and the dispersion will become passive.

Any model for dense gas dispersion should account for the following four consecutive phases:

- The initial phase where the fluid motion is dependent on the release conditions
- The gravity spreading phase where entrainment is mainly due to the turbulence generated by the gravity-induced motion of the cloud
- An intermediate phase where entrainment is due to the interplay between atmospheric turbulence and gravitational forces
- The passive dispersion phase.

Pinnacle Risk Management has found the SLAB Model, and the Britter and McQuaid Model to predict credible results for dense gas releases.

The SLAB model is capable of treating sources of the following types: horizontal or vertical jets, steady state surface area sources (e.g. evaporating pools) and instantaneous releases.

3. Fires

Heat radiation effects are normally calculated based on flame surface emissive power, SEP, (which is dependent on the quantity of material, its heat of combustion, flame dimensions and the fraction of heat radiated). The heat flux at a particular distance from a fire is then calculated using the view factor method. The view factor takes into account the distance from the flame to the target, the flame dimensions and the orientation angle between the flame and the target. It is defined as the fraction of the field of view at the receiving surface which is filled by the flame.

Note that the calculations of view factor and SEP are different for different types of fires but the general formula used to estimate the radiation intensity at a distance from the flame (i.e. at a receptor) is:

$I = SEP \times F \times \tau$

where	I	=	Heat radiation intensity at point of interest (kW/m^2)
	SEP	=	Surface emissive power of the flames (kW/m^2)
	F	=	View factor
	τ	=	Atmospheric transmissivity

The atmospheric transmissivity is calculated from the carbon dioxide and water content in the air.

A. Jet Fires

The risk analyst will model a jet fire with a selected model, e.g. the Chamberlain model. This type of model is based on simulating the flame shape as a frustrum of a cone. The flame stability, shape, orientation and total radiative flux are typically described by a set of semi-empirical correlations which have normally been developed from and validated against a wide range of laboratory wind tunnel tests and large scale field trials (both on-shore and off-shore).

The flame is defined as a solid body which emits radiation with uniform surface emissive power. Typical outputs from a jet fire model include:

- The heat radiation flux at a distance (x) away from the flame
- The surface emissive power of the jet
- The flare (jet) dimensions including flame tilt and lift-off.

Jet fires can be directed in many directions, e.g. from the horizontal to vertical, and in any directions such as North or East-South-East. Given the numerous permeations for a jet fire direction, Pinnacle Risk Management normally models a jet fire with the highest levels of radiant heat towards the nearest site boundary, e.g. a horizontal jet fire for an elevated pipe failure. For underground pipes, it is assumed the jet fire is 45 degrees from the vertical and pointing towards the site's nearest boundary (depending on the wind direction) and/or nearest receptors.

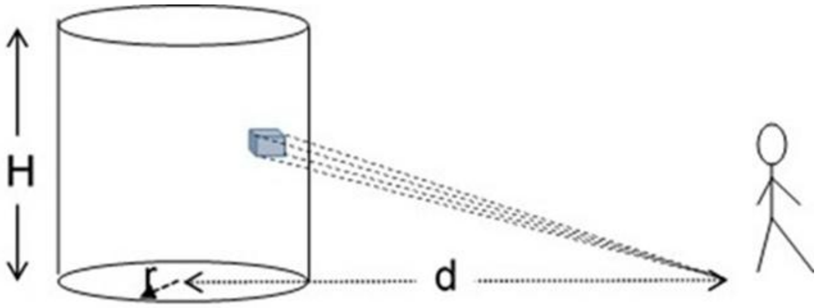
B. Pool Fires

Typical pool fire models use an average radiation intensity which depends on the liquid combustion rate. The combustion rate of the liquid can be manually set or calculated using the available combustion model. Other models exist, e.g. the two-zone model. The choice of model will depend on the nature of the fire, e.g. the diameter of the pool. Pinnacle Risk Management typically uses the average radiation intensity model (as this has proven to provide good agreement with experimental data) or a wall-of-flame model.

In a pool fire heat radiation model, account is taken of the diameter-to-height ratio of the fire, which also depends on the burning liquid and pool size. Also taken into account in a model can be the tilt of the pool fire flames. This tilt depends on the wind velocity and the vapour density difference between air and the burning liquid.

The following figure shows a pool fire modelled as a cylinder (which is a common shape for pool flames).

Figure 12 – Pool Fire Model



When inputting the results of a jet or pool fire into the PRM QRA Model, the distances to various probabilities of fatalities are entered. The probabilities of fatality are estimated using probit equations (as discussed below).

4. Explosions

If a released flammable material is not ignited directly, the gas / vapour cloud will spread in the surrounding area. The drifting gas cloud will mix with air. As long as the gas concentration is between the lower and upper explosion limits, the gas cloud may be ignited. The dimensions of the flammable gas cloud and its flammable content (explosive mass) are calculated by a dispersion model (as discussed in Section 2. Dispersion above). If the gas cloud ignites two situations can occur, namely non-explosive combustion (flash fire with no overpressure effects) and explosive combustion (vapour cloud explosion).

Various models are available for predicting the overpressures from an explosion, e.g. the Multi Energy method, the BST (the Baker-Strehlow-Tang) method and the TNT (trinitrotoluene) method. Pinnacle Risk Management typically uses the Multi Energy method for flammable vapour releases. One of the key features of the Multi-Energy method is that the explosion is not primarily defined by the fuel-air mixture but by the environment in which the vapour disperses.

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

The Multi Energy method uses the model for the blast produced by a hemispherical, steady flame speed and stoichiometric hydrocarbon-air explosion. The blast depends on the amount of combustion energy involved. The initial strength of the blast is a variable depending on the degree of confinement and the reactivity of the gas. The initial strength is indicated by a number ranging from 1 for insignificant strength to 10 for gaseous detonation, corresponding to the curve number of the method.

Guidance for choosing the blast strength is provided in various reference, e.g. TNO's The Yellow Book.

5. Effects on People

For production of a QRA, the risk, i.e. consequence x likelihood, needs to calculated for each scenario. The cumulative risk from all scenarios is then determined at all points within a grid around the facility being assessed to allow risk contours to be produced. The consequence for fatality risk contours is defined as the probability of fatality. The likelihood of an event is determined using in-house data, published data (that is applicable to the scenario of interest) and/or predictive techniques (e.g. Fault Trees and Layer of Protection Analysis).

The table below summarises the effects on people, i.e. how the probability of fatality is assessed, with additional comments following the table.

Table 26 – QRA Assumptions for the Effects on People

Event	Consequence	Risk Model
Gas cloud (from gaseous release or liquid / liquefied gas flash or pool evaporation)	Flash fire	100% fatality inside flaming gas cloud, no radiation effects outside cloud since the fire is of short duration
	Explosion	100% fatality inside flaming gas cloud, equation used for overpressure effects (fatality) outside gas cloud
	Jet fire	100% fatality within jet fire radius, probit equation for radiation effects outside the jet fire radius based on 20 seconds exposure
	Toxic exposure	Probit equation used to estimate probability of fatality, based on dose of toxic material
Liquid release	Pool fire	100% fatality within the pool fire. Probit equation used for radiation effects outside the jet fire radius based on 20 seconds exposure
BLEVE	Fireball	100% fatality within fireball, probit equation used for radiation effects outside the fireball radius. The exposure duration is the duration of the BLEVE. (calculated by the user, e.g. using the equations in TNO's The Yellow Book)

A. Toxic Impact

The effect of exposure to toxic materials is predicted using probit equations. The calculated probit can be mathematically transformed (using the error function) allowing a probability of fatality to be predicted for a particular dose. Probits for various materials are published, e.g. TNO's The Green Book and Lees, Loss Prevention in the Process Industries. The equations are of the form:

$Pr = A + B \ln(c^n t)$

Pr	probit value
A, B, n	constants specific to the toxic material
t	exposure time (minutes)
c	concentration (ppm)

The probit values are used to calculate the probability of fatality from the toxic dose by:

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

Dose is calculated by integrating the concentration at a particular location over the exposure duration. The concentration may vary over time. The duration is the lesser of the time taken for the cloud to pass or the maximum exposure duration (a parameter set by the risk analyst).

B. .Heat Radiation

The effect of heat radiation on a person is calculated from the following probit equation and the probability of fatality predicted by transforming the probit as for toxic impact calculations. The probit used by Pinnacle Risk Management is (Ref 22):

$Pr = -14.9 + 2.56 \ln(tQ^{1.33})$

t	exposure time (seconds)
Q	heat flux (W/m^2)

Note that this probit is only valid for very short exposure durations (less than 1 minute). For the purposes of risk assessments, it is assumed a person has 20 seconds to escape from heat radiation (i.e. an exposure duration of 20 seconds).

C. Flame Engulfment

For areas directly within the area of a flame, engulfment and fatality due to direct burns rather than heat radiation is the relevant effect. Within the flame area of pool fire, flash fires and jet fires, 100% fatality is assumed.

20 APPENDIX G - METEOROLOGICAL DATA

Appendix G - Meteorological Data

The following data is a summary of climate data obtained from the Bureau of Meteorology. The data summarises the local weather / wind conditions for various atmospheric stability classes and wind directions from 2010 to 2017.

Wind Direction	Stability Class / Wind Speed (m/s) Percentages:						
	A2	B3	C5	D5	E3	F1.5	Totals:
N	1.5	2.2	1.4	3.9	0.5	5.8	15.4
NE	0.5	0.7	1.4	2.7	0.2	0.2	5.6
E	0.4	0.7	2.4	3.4	0.2	0.3	7.4
SE	0.3	0.6	1.6	3.6	0.2	0.5	6.8
S	0.2	0.6	2.4	10.8	0.5	0.8	15.4
SW	0.1	0.2	0.7	4.5	0.8	1.2	7.6
W	0.2	0.8	3.8	9.9	2.0	3.8	20.6
NW	0.6	2.0	3.9	9.3	2.3	2.9	21.1
Totals:	3.9	8.0	17.7	48.1	6.9	15.5	

21 APPENDIX H - CONSEQUENCE MODELLING RESULTS

Appendix H - Consequence Modelling Results

1. Pool Fires:

There are a number of pool fire events that could result in adverse off-site impact. Some of these have already been modelled, e.g. Ref 23. The following is a description of the details of the input parameters to the View Factor Model that is used to estimate distances for selected radiant heat values.

A. Burndown Rates:

For burning liquid pools (Ref 24), heat is transferred to the liquid via conduction, radiation and convection.

Wind can also affect the burning rate (experiments have shown both an increase and decrease in burning rates due to the effects wind) but also can affect flame stability (and hence average flame emissive power) (Ref 25). Therefore, average reported values for burndown rates are used in this study.

For 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 26 and 22).

Typical burndown rates for hydrocarbons such as petrol (a denaturant for ethanol) are 4 to 6 mm/min (Refs 22 and 27). Therefore, an average value of 5 mm/min is used in this study.

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

B. Surface Emissive Power:

Surface emissive power (SEP) 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 can be 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 (Refs 28 and 29) indicates the following data:

> SEP's of 50 kW/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.

A surface emissive power correlation that fits experimental data well for products that produce smokey flames (as is the case for petrol) is as follows (Ref 24):

$$SEP\ (average) = 140 \times e^{(-0.12 \times D)} + 20 \times (1 - e^{(-0.12 \times D)})$$

Where D = the pool fire diameter.

The constant, 140 kW/m^2, is the maximum emissive power of luminous spots and the constant, 20 kW/m^2, is the emissive power of smoke.

The values in the following table are derived from this equation.

Table 27 – Predicted SEP

Diameter, m	SEP Average, kW/m^2
1	126
5	86
10	56
15	40
20	31
25	26
30	23
35	22
40	21
45	21
50	20

Note that low molecular weight materials do not produce sooty flames and therefore the above correlation cannot be used.

C. Wind Speed:

The dominant wind speeds listed in Appendix G for the area range from 1.5 to 5 m/s. Therefore, the modelling is performed at a wind speed of 5 m/s which yields a flame tilt of approximately 60 degrees. The results of the modelling will therefore show the extended radiant heat contours due to flame tilt and flame drag.

A wind speed of 5 m/s also allows the tilted cylinder flame model to better match the flame shape as at higher wind speeds, the flames can become irregular and “pancake”, i.e. the modelling accuracy may be affected at higher wind speeds.

The potential pool fire scenarios that can contribute to off-site risk are shown in the following table. As shown in Ref 23 (Table 3), the ground level radiant heat values from tank-top fires are not sufficient to lead to significant off-site impact. Therefore, these pool fire scenarios are not included in the off-site risk analysis.

Table 28 – Pool Fires Modelling Results

Item No.	Item Description	Width, m	Length, m	Eq. D, m	Liquid Density, kg/m^3	SEP, kW/m^2	Distance to Specified Radiant Heat Level, m (from the centre of the flames)					
							50 kW/m^2	40 kW/m2	30 kW/m2	23 kW/m^2	20 kW/m^2	12.6 kW/m2
Zone 1: Acetic Anhydride Tank												
1	Acetic anhydride tank bund fire	2.5	2.5	2.5	1,080	109	2	3	4	5	6	7
Zone 2: Ethanol Distillery												
2	Original Distillery (most western location in the ethanol plant) bund fire	19	26	22	790	60	12	16	18	19	20	22
3	Beverage Grade Distillery 2 bund fire	25	24	25	790	50	13	15	19	20	21	24
4	Beverage Grade Distillery 1 bund fire	13	19	15	790	60	8	11	13	14	14	16
4A	Modified Beverage Grade Distllery 1 bund fire with the 2025 Heat Recovery / Evaporators (area = 116 m^2)	-	-	21.5	790	60	11	15	17	19	19	22
5	Ethanol storage area bund fire	26	33	29	790	50	15	17	21	23	24	27
6	Ethanol day tank area bund fire	21	23	22	790	60	12	16	18	19	20	22
7	Fire at the road tanker loadout bay or at an Isocontainer	7	25	7	790	60	4	6	7	7	8	8
8	Fire in the denaturants' tanks bund	5	17	5	740	86	7	9	10	11	11	12
	Probability of Fatality:						0.87	0.64	0.27	0.06	0.02	0.00

The first event in Table 28 is for the acetic anhydride bund in Zone 1. This is not part of the ethanol distillery. It is modelled as it is relatively close to Bolong Road. The following figure shows the radiant heat contour for 12.6 kW/m^2 and 23 kW/m^2, i.e. for off-site fatality prediction and on-site propagation, respectively. This relatively small bund is surrounded by metal walls, i.e. these will also help to reduce the distance to adverse levels of radiant heat.

Figure 13 – Acetic Anhydride Bund Radiant Heat Contours

Legend:

Red Contour = 23 kW/m^2

Orange Contour = 12.6 kW/m^2

The contours are drawn assuming the wind is blowing from any direction.

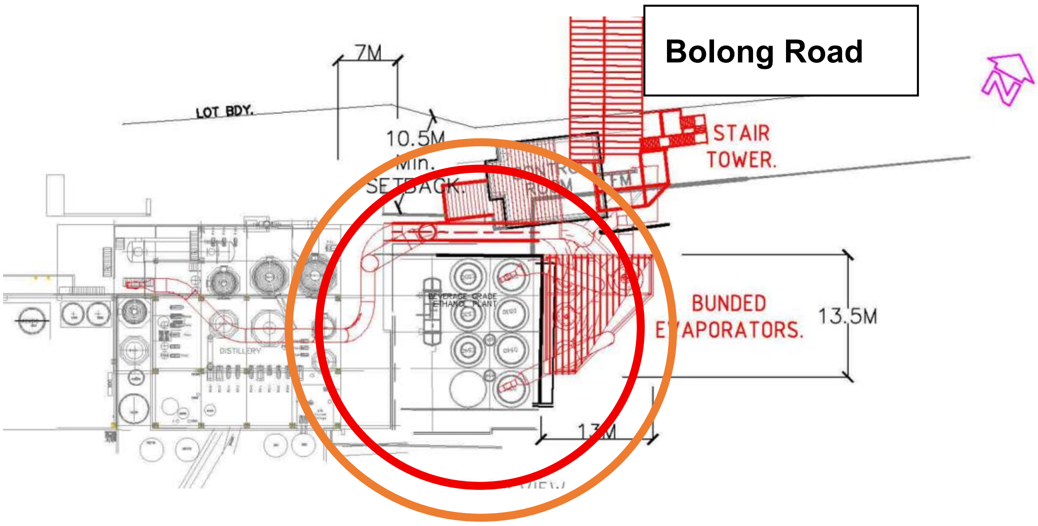
As can be seen from Figure 13, this event does not contribute to off-site fatality risk as the 12.6 kW/m^2 contour remains on the site.

The 23 kW/m^2 contour reaches Fermenter 1, i.e. heat damage may be sustained if the wind is blowing in this direction and the surrounding metal walls have failed. To gain an appreciation of the likelihood of this event, a typical bund fire frequency is 1.6 x 10^{-5} per year (Ref: LASTFIRE, 2003), i.e. a low likelihood event to a tank holding fermented solids in a water solution (essentially beer).

All other events in Table 28 are included in the QRA model for the ethanol distillery.

Event Number 4A is the model for a pool fire in the proposed combined heat recovery / evaporators and Beverage Grade Distillery 1 bund. When the evaporators are in use, there will be less equipment items in use in the existing Beverage Grade Ethanol Plants 1 and 2, e.g. the existing rectifier condensers and associated piping will not be in use when the four heat recovery evaporators are in use. Essentially, some of the QRA release scenarios (failed piping and pressure vessels) are shifted from the Beverage Grade Ethanol Plants 1 and 2 existing bunds to the heat recovery / evaporators bunded area. The combined heat recovery evaporators / Beverage Grade Distillery 1 bund fire is larger than existing. The radiant heat contours are shown in the following figure.

Figure 14 – Distillery Heat Recovery Bund Radiant Heat Contours



Legend:

Red Contour = 23 kW/m^2

Orange Contour = 12.6 kW/m^2

The contours are drawn assuming the wind is blowing from any direction. The contours are approximate given the irregular shape of the bund, e.g. the contours are expected to extend slightly further from the north-eastern end of the bund. This will be limited due to the radiant heat shielding provided by the proposed equipment items. However, the latter will not impact any receptors on or off site.

Based on the radiant heat contours, propagation is possible to the:

- Beverage Grade Distillery 2 to the west (and vice versa). Other than design standards such as the pressure vessels and piping being designed and installed to recognised standards (e.g. AS4041 for pressure piping), should a fire occur then the fixed firewater deluge system will be used to extinguish the fire

- Control Room. This risk is mitigated as per the above design standards and fixed firewater deluge system plus the Control Room is constructed of non-combustible materials and there are no windows facing the process areas.

Propagation to the existing storage areas and road tanker loadout facility is not expected.

In addition to the fixed firewater deluge system, there are also fixed and mobile fire monitors that can be used.

Importantly, the adverse levels of radiant heat do not impact any off-site areas. Therefore, this expanded pool fire event does not contribute to off-site risk. This includes potential flash fires from a pool of ethanol, in particular, due to the use of the fire deluge system.

2. Fireballs:

The main fireball or BLEVE (Boiling Liquid Expanding Vapour Explosion) event at Shoalhaven Starches is associated with the LPG (Liquefied Petroleum Gas) vessel at the WWTP.

A fire under a steel Isotank or road tanker at the ethanol distillery could also lead to a rupture and possible fireball. Note that most road tankers are aluminium and hence a BLEVE is not likely as the aluminium will melt.

The consequences of BLEVEs include:

- Heat damage from the fireball
- Fragments being thrown or rocketing of vessel pieces
- Pressure wave due to the expansion of vapour and flashing liquid – as a blast wave
- Release of the vessel contents leading to secondary effects such as a buoyant fireball, a vapour cloud explosion, a flash fire or dispersion of toxic substance depending on the contents in the vessel.

In hazard and risk analysis it is generally the heat damage from the fireball that is the considered the predominant damage mode and hence is used to assess the effect of BLEVEs as it is particularly harmful to people at a relatively large distance from the incident.

Other consequences may also be highly damaging, for example, missiles and the pressure wave may knock over nearby structures resulting in domino incidents.

Heat radiation from a BLEVE fireball can be calculated by approximating the shape of the fireball to a sphere.

A number of empirical correlations have been developed for predicting the results of a fireball based on data from BLEVE incidents (Ref 25):

$$D = 6.48M^{0.325}$$

$$t = 0.852M^{0.26}$$

$$H = D$$

Where:

- D is the diameter of the BLEVE fireball (m)
- *M* is the mass of flammable material in the fireball (kg)
- *t* is the duration of the fireball (s)
- *H* is height from centre of fireball to the ground (i.e. the lift-off which will change over time) (m)

It is assumed that 30% of the combustion energy is emitted as heat radiation.

The LPG vessel at the WWTP is 2 m^3 or approximately 1,00 kg.

A standard Isotank size is approximately 25 m^3. This equates to 20,000 te.

The above equations and the Point Source Method are used to estimate the radiant heat at ground level. To be conservative, it is assumed that the centre of the fireball is at a height equal to the fireball radius, i.e. no lift-off. The results from the modelling (Table 29) show the ground level distances to various levels of radiant heat. The corresponding probabilities of fatalities are used for these distances in the QRA.

As the WWTP LPG vessel is located approximately 410 m from the nearest off-site receptor, i.e. Bolong Road, then no adverse impacts from the fireball's radiant heat is expected (the distance along the ground from the fireball's centreline to 12.6 kW/m^2 is 123 m, i.e. less than 410 m).

As Isotanks are loaded at the ethanol distillery (at the road tanker loading bay) which is close to Bolong Road then adverse off-site impact from an Isotank fireball is possible. Therefore, this event is included in the QRA.

Table 29 – Fireball Modelling Results

Item No.	Item Description	Radius of Fireball (m)	Fireball Duration (s)	Distance to Specified Radiant Heat Level, m (at ground level, from the centreline of the fireball)					
				50 kW/m^2	40 kW/m2	30 kW/m2	23 kW/m^2	20 kW/m^2	12.6 kW/m2
1	WWTP 1 te LPG vessel	31	5	60	68	80	92	99	123
2	Isotank (containing 20 te ethanol)	81	11	127	146	173	200	215	276
	Probability of Fatality:			0.87	0.64	0.27	0.06	0.02	0.00

3. Jet Fires:

Piping and equipment failures within the ethanol distillery that can form a jet fire (if ignited) involve ethanol vapour releases.

Natural gas and biogas releases are assessed in the pipeline risk section of this FHA. There are potential jet fires from the 2 m^3 LPG vessel at the WWTP, however, as the distance from this vessel to the nearest site boundary is approximately 410 m then adverse off-site impact from an LPG jet fire is not credible and therefore not analysed.

There can be an infinite number of potential hole sizes that can occur in piping and equipment. Pinnacle Risk Management uses the suggested hole sizes from the Health and Safety Executive (HSE) UK 2017 (Ref 30).

Table 30 – HSE UK Pressure Vessel Release Types and Failure Rates

Type of Release:	Failure Rate (per vessel year)	Notes
Catastrophic	6×10^{-6}	Upper
Catastrophic	4×10^{-6}	Median
Catastrophic	2×10^{-6}	Lower
50 mm Diameter Hole	5×10^{-6}	
25 mm Diameter Hole	5×10^{-6}	
13 mm Diameter Hole	1×10^{-5}	
6 mm Diameter Hole	4×10^{-5}	

Table 31 – HSE UK Pipe Failure Rates

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	1×10^{-5}	2×10^{-6}			
4 mm			1×10^{-6}	8×10^{-7}	7×10^{-7}
25 mm	5×10^{-6}	1×10^{-6}	7×10^{-7}	5×10^{-7}	4×10^{-7}
1/3 pipe 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}

From a review of the ethanol equipment and operating conditions, there can be ethanol vapour releases from the following equipment items. For information, the majority of the distilleries are operated at vacuum conditions. Therefore, if a pipe or vessel failure occurs then air will be drawn into the process rather than ethanol vapour being released. The potential sources of pressurised ethanol vapour releases are:

Original distillery:

- Stages 2, 4 and 5 – The Molecular (Mol) Sieves Superheaters, piping (up to 200 mm DN), the Mol Sieves' vessels and the Mol Sieves' product condensers
- Stage 3 – Distillation column T680, piping (the overheads pipe is 350 mm DN) and the overheads condenser E514
- Stage 6 – Distillation column T540, piping (the overheads pipe is 450 mm DN) and the overheads condenser E814
- Stage 7 – The Mol Sieves Superheater, piping (up to 250 mm DN), the Mol Sieves' vessels and the Mol Sieves' product condensers E908 and E915.

Beverage Grade Ethanol 1 (BGE1):

- Rectification column D540, the overheads piping (400 mm DN) and the product condenser E530.

Beverage Grade Ethanol 2 (BGE2):

- Column D540, the overheads piping (600 mm DN) and the product condensers E530 and E510A
- Column D560, the overheads piping (350 mm DN) and the product condenser E510B.

The data for the analysis of the potential jet fires is shown in Table 32 and Table 33. The mass rates were estimated using TNO's EFFECTS program for both 50 mm diameter holes and a full bore pipe failure. The flame lengths and the corresponding radiant heat at various distances from the jet fires were also estimated using EFFECTS. Horizontal jets were modelled (worst case) at a height of 3 m above grade. Given the heights of the columns, e.g. 30 m high, then assuming a 3 m height release is conservative. The wind speed is 5 m/s.

As these are low pressure plants, there is insufficient vapour to support the instantaneous estimated vapour release rates for the full bore pipe failures. Also, as the column overheads streams are used to provide heat to reboilers within the plants then loss of the overheads flow will instantly reduce the reboiler heat load and therefore heat to its associated column, i.e. the plant rate will immediately reduce. Where the estimated release rates exceed the plant design rates then the latter were used for estimating the flame lengths.

Table 32 – Ethanol Vapour Jet Fire Data

Scenario:	Hole Size (mm)	Temp (C)	Pressure (barg)	Maximum Estimated Release Rate (kg/s)	Plant Rate (kg/s)	Design Jet Rate (kg/s)
Stage 2 Vessels or Piping	50	150	2.5	1.0	1.7	1
Stage 2 Piping	200	150	2.5	16	1.7	1.7
Stage 3 Vessels or Piping	50	125	3.7	1.4	0.07	0.7
Stage 3 Piping	350	125	3.7	68	0.07	0.7
Stage 4 Vessels or Piping	50	180	2.5	1.0	2.8	1
Stage 4 Piping	200	180	2.5	15	2.8	2.8
Stage 5 Vessels or Piping	50	150	2.9	1.1	3.3	1.1
Stage 5 Piping	200	150	2.9	18	3.3	3.3
Stage 6 Vessels or Piping	50	130	4.2	1.5	0.08	0.08
Stage 6 Piping	450	130	4.2	124	0.08	0.08
Stage 7 Vessels or Piping	50	160	3.2	1.2	5.6	1.2
Stage 7 Piping	250	160	3.2	29	5.6	5.6

Scenario:	Hole Size (mm)	Temp (C)	Pressure (barg)	Maximum Estimated Release Rate (kg/s)	Plant Rate (kg/s)	Design Jet Rate (kg/s)
BGE1 D540 Vessels or Piping	50	98	1.1	0.7	11.3	0.7
BGE1 D540 Piping	400	98	1.1	41	11.3	11.3
BGE2 D540 Vessels or Piping	50	98	1.1	0.7	13.6	0.7
BGE2 D540 Piping	600	98	1.1	93	13.6	13.6
BGE2 D560 Vessels or Piping	50	98	1.1	0.7	13.6	0.7
BGE2 D560 Piping	350	98	1.1	31	13.6	13.6

Table 33 – Jet Fires Radiant Heat

Scenario:	Design Jet Rate kg/s	Flame Length m	Distance to Specified Radiant Heat Level, m (from the point of release)						Distance from the Release Point to the Boundary m	Off-Site Impact (Y/N)
			50 kW/m^2	40 kW/m2	30 kW/m2	23 kW/m^2	20 kW/m^2	12.6 kW/m2		
Stage 2 Vessels or Piping	1	13	-	-	-	-	-	14	25	N
Stage 2 Piping	1.7	16	-	-	-	14	16	19	25	N
Stage 3 Vessels or Piping	0.7	11	-	-	-	-	-	10	25	N
Stage 3 Piping	0.7	11	-	-	-	-	-	10	25	N
Stage 4 Vessels or Piping	1	16	-	-	-	-	-	14	33	N
Stage 4 Piping	2.8	20	-	-	17	22	21	24	33	N
Stage 5 Vessels or Piping	1.1	13	-	-	-	-	9	15	31	N
Stage 5 Piping	3.3	21	-	-	22	24	25	26	31	N
Stage 6 Vessels or Piping	0.08	Note 1	-	-	-	-	-	-	16	N
Stage 6 Piping	0.08	Note 1	-	-	-	-	-	-	16	N
Stage 7 Vessels or Piping	1.2	14	-	-	-	-	11	16	25	N
Stage 7 Piping	5.6	27	-	29	30	31	32	33	25	Y
BGE1 D540 Vessels or Piping	0.7	11	-	-	-	-	-	10	24	N
BGE1 D540 Piping	11.3	37	39	40	41	42	42	44	24	Y
BGE2 D540 Vessels or Piping	0.7	11	-	-	-	-	-	10	17	N
BGE2 D540 Piping	13.6	40	42	43	44	45	46	48	17	Y
BGE2 D560 Vessels or Piping	0.7	11	-	-	-	-	-	10	23	N
BGE2 D560 Piping	13.6	40	42	43	44	45	46	48	23	Y
Probability of Fatality:			0.87	0.64	0.27	0.06	0.02	0.00		

Note 1: Flowrate too small to model. No off-site impact is credible.

For information, the closest distances between the original distillery, BGE1 and BGE2 to Bolong Road (the nearest site boundary) are 16 m, 18 m and 12 m. Given the lengths of some of the jet fires modelled shown in Table 32 then offsite impact is expected.

Off-site impact (Yes or No) in Table 33 was determined by measuring the distance from the release points to Bolong Road. If the 12.6 kW/m^2 radiant heat level does not reach the boundary then there is no contribution to off-site risk.

Based on the results in Table 33, there are four potential jet fire events that could result in off-site impact, i.e.:

- Original distillery – the Stage 7 piping
- BGE1 D540 piping
- BGE2 D540 piping
- BGE2 D560 piping.

For impact to the nearest boundary (Bolong Road), the failures need to result in full plant rates being released. That is, a 50 mm diameter hole is not expected to result in adverse off-site consequences. The above analysis also excludes the potential for screening by other piping and equipment items.

The above four events are included in the ethanol distillery QRA.

1. Explosions:

If a flammable gas or vapour is released and doesn't immediately ignite then delayed ignition could result is a flash fire or, if confinement exists, an explosion.

The same release scenarios as the above analysis on jet fires are considered for a vapour release leading to an explosion. Given the relatively small volumes of released flammable vapour then only catastrophic and one-third of the pipe diameter failures can contribute to an explosion risk, i.e. the released quantity will occur either instantaneously or within one minute. This is the same basis for an "instantaneous" release used in the US EPA ALOHA modelling package.

The flowrates from smaller diameter hole sizes do not pose off-site explosion risks. They may, however, pose off-site flash fire effects as analysed in the following section.

The original distillery, Beverage Grade Ethanol 1 (BGE1) and Beverage Grade Ethanol 2 (BGE2) provide partial confinement of potential ethanol vapours. The most likely to provide a level of confinement is BGE2, i.e. it has the largest footprint. The original distillery and BGE1 are relatively narrow, i.e. approximately two columns wide. However, it is assumed that partial confinement exists in all three distilleries in this QRA.

A vapour cloud explosion is the deflagration / detonation of a flammable vapour cloud resulting in blast waves with damaging overpressure effects. Partial confinement is regarded as a major cause of blast in vapour cloud deflagrations. Where there is no confinement, a flash fire would occur rather than explosion, i.e. no overpressure effects.

For this study, the TNO Multi-Energy Method was used to estimate the impact of vapour cloud explosions, i.e. overpressure levels. The method assumes that a strong blast is generated only by that part of the cloud that is subjected to congestion and confinement, and the remaining part of the cloud will have no significant contribution to the blast.

The Multi-Energy Method models the blast produced by a hemispherical, steady flame speed, stoichiometric hydrocarbon-air explosion. The blast depends on the amount of combustion energy involved.

The Multi-Energy Method uses the following three parameters:

- Explosive mass
- Degree of confinement
- Blast Strength.

Explosive mass: This parameter sets the amount of explosive mass used the calculation. The total explosive amount in the cloud was obtained from the dispersion calculation.

Degree of confinement: This parameter essentially sets the proportion of the total mass in the cloud that contributes to the explosion calculation. For example, if the total mass and degree of confinement is set to 100 kg and 50% respectively, this is equivalent to 50 kg as the maximum amount that can be included in the explosion calculation. The following is typically used for guidance in selecting the degree of confinement:

- 10% for pipelines and isolated storages
- 25% for open plant areas and most storages
- 75% for the congested plant areas.

For this hazard analysis, the percentage confinement value used is 50% as the distilleries are relatively open structures.

Blast strength: The blast strength is represented by a series of curves relating overpressure to distance, where curve 1 means a slow deflagration and curve 10 means detonation.

Within the model, ignition is assumed to occur at the centre of the gas cloud formed.

The blast strength curve numbers and definitions are as follows:

1. Very weak deflagration
2. Very weak deflagration
3. Weak deflagration
4. Weak deflagration
5. Medium deflagration
6. Strong deflagration
7. Strong deflagration
8. Very strong deflagration
9. Very strong deflagration
10. Detonation

Based on a review of a number of references, some rules of thumb are proposed below for selecting the blast strength (developed from analysing the guidelines of Kinsella and Roberts / Crowley):

- Charge strengths of 9-10 are applicable for a high level of confinement involving a high reactivity gas (such as hydrogen) ignited by a high energy ignition source

- Lower charge strength in the range of 6-7 may be justified for a medium level congested outdoor plant with a medium reactive gas-air mixture such as LPG
- In a medium level congested outdoor plant with a low reactive gas-air mixture such as methane, charge strength values of 5-6 may be justifiable
- In a very low density obstacle area, the charge strength may be even lower and the Kinsella and Roberts / Crowley guidelines recommend curves 1-3.

Based on the following guidance (Table 5.3 in The Yellow Book, Ref 25) then a blast strength (curve) of 4 to 6 is recommended. Therefore, take the average value of 5 for this QRA, i.e.:

> Low ignition strength, e.g. static, hot surface or flame.
> High obstruction, e.g. spacing between equipment items less than 3 m.
> Unconfined by 2 or 3 walls.
> Note: The minimum ignition energy for ethanol is 0.28 mJ, i.e. the same as methane.

The released vapour quantities from catastrophic and large diameter piping failures are shown in Table 34. These quantities include the vapour within the columns as well as boiling ethanol flashing to vapour. It is assumed that these quantities of ethanol are partially confined (50%), e.g. within the distillery piping and equipment, and ignited. The corresponding overpressures are also given in Table 34.

Table 34 – Distilleries Explosion Modelling Results

Scenario:	Total Mass of Vapour Released (kg)	Distance (m) from the Point of Release to the Following Overpressures:					Distance from the Release Point to the Boundary m	Off-Site Impact (Y/N)
		50 kPa	35 kPa	21 kPa	14 kPa	7 kPa		
Stage 2 Vessels and Piping	75	-	-	12	19	38	25	N
Stage 3 Vessels and Piping	322	-	-	20	31	63	25	Y
Stage 4 Vessels and Piping	95	-	-	13	21	41	33	N
Stage 5 Vessels and Piping	148	-	-	15	24	48	31	N
Stage 6 Vessels and Piping	427	-	-	21	34	69	16	Y
Stage 7 Vessels and Piping	165	-	-	15	25	50	25	Y
BGE1 D540 Vessels and Piping	643	-	-	24	39	79	24	Y
BGE2 D540 Vessels and Piping	969	-	-	28	45	90	17	Y
BGE2 D560 Vessels and Piping	252	-	-	18	29	58	23	Y
Probability of Fatality (person in the open):		**0.36**	**0.13**	**0.04**	**0.01**	**0.00**		

Given the above analysis, off-site fatality impact is possible for the following event:

- Stage 3 Vessels and Piping
- Stage 6 Vessels and Piping
- Stage 7 Vessels and Piping
- BGE1 D540 Vessels and Piping
- BGE2 D540 Vessels and Piping
- BGE2 D560 Vessels and Piping.

These events are included in the QRA.

2. Flash Fires:

A flash can occur if delayed ignition of a flammable mixture occurs. The flash fire length is taken to be the maximum distance from the point of release to the downwind lower explosive limit (LEL).

Analysis of the potential flash fire diameters are shown in the following tables.

It is assumed that the probability of fatality is 1.0 for anyone within the flammable region, i.e. to LEL. Anyone outside this flammable region is assumed to survive.

Given the similar operating temperatures and pressures throughout the various distilleries, the range of releases from a 50 mm diameter hole is relatively small, i.e. 0.7 to 1.2 kg/s. To simplify the calculations, all release rates from a 50 mm hole are assumed to be 1.2 kg/s. The only weather / wind condition that result in off-site impact for a 50 mm hole release is F1.5. The other weather / wind combinations do not have any ground level impacts, The F1.5 scenarios are included in the QRA.

As shown in Table 36, most of the elevated releases do not have an impact at ground level. The corresponding scenarios are therefore not included in the QRA.

Table 35 – Flash Fire Distances – 50 mm Holes

Scenario:	Weather / Wind Condition:	Distance to LEL, m (from the point of release)	Distance from the Release Point to the Boundary m	Off-Site Impact (Y/N)
50 mm Hole - Vessels or Piping	A2 B3 C5 D5 E3 F1.5	6 6 6 10 21 60	See Table 33	N N N N N Y

Table 36 – Flash Fire Distances – Large Releases

Scenario:	Weather / Wind Condition:	Distance to LEL, m (from the point of release)	Distance from the Release Point to the Boundary m	Off-Site Impact (Y/N)
Stage 2 Vessels or Piping 75 kg release	A2 B3 C5 D5 E3 F1.5	32 41 53 70 90 127	25	Y
Stage 3 Vessels or Piping 322 kg release Note 1: The release height is 12 m and higher. The LEL does not reach ground level / head height	A2 B3 C5 D5 E3 F1.5	40 Note 1 Note 1 Note 1 Note 1 Note 1	25	Y
Stage 4 Vessels or Piping 95 kg release	A2 B3 C5 D5 E3 F1.5	35 45 59 76 99 139	33	Y
Stage 5 Vessels or Piping 148 kg release	A2 B3 C5 D5 E3 F1.5	41 54 69 90 118 166	31	Y

Scenario:	Weather / Wind Condition:	Distance to LEL, m (from the point of release)	Distance from the Release Point to the Boundary m	Off-Site Impact (Y/N)
Stage 6 Vessels or Piping 427 kg release Note 1: The release height is 12 m and higher. The LEL does not reach ground level / head height for all weather / wind conditions	A2 B3 C5 D5 E3 F1.5	Note 1	16	N
Stage 7 Vessels or Piping 165 kg release	A2 B3 C5 D5 E3 F1.5	43 56 72 94 123 173	25	Y
BGE1 D540 Vessels or Piping 643 kg release Note 1: The release height is 27 m and higher. The LEL does not reach ground level / head height for all weather / wind conditions	A2 B3 C5 D5 E3 F1.5	Note 1	24	N
BGE2 D540 Vessels or Piping 969 kg release Note 1: The release height is 23 m and higher. The LEL does not reach ground level / head height for all weather / wind conditions	A2 B3 C5 D5 E3 F1.5	Note 1	17	N
BGE2 D560 Vessels or Piping 252 kg release Note 1: The release height is 26 m and higher. The LEL does not reach ground level / head height for all weather / wind conditions	A2 B3 C5 D5 E3 F1.5	Note 1	23	N

Flash Fires from Ethanol Pools:

It is possible that large spills of flammable liquids can create a correspondingly large flammable vapour cloud that can travel off-site. If ignited then any person within the vapour cloud (typically measured to the lower explosive limit or LEL) is assumed to suffer a fatal injury.

Experimental data (Ref 31) for evaporation from flammable liquids pools shows the distance to LEL in the horizontal direction is in the order of one pool diameter (for worst-case weather and wind conditions such as F Stability Class and a low wind speed of 1.5 to 2 m/s). The same reference shows that the vertical distance to LEL is up to one half the pool diameter.

The main events that can result in a large contained pool are significant releases of ethanol into the bulk storage tanks bund (29 m equivalent diameter) and the ethanol day tanks bund (22 m equivalent diameter). The distances to the boundary for these bunded areas are 42 m and 46 m, respectively. Therefore, no adverse off-site impact is expected for potential flash fires from significant releases into these bunds.

This event is less likely in the plant areas or road tanker loadout area as they are drained areas, e.g. to an underground tank.

22 APPENDIX I – DISTILLERIES QRA LIKELIHOODS

Appendix I – Distilleries QRA Likelihoods

The table at the end of this Appendix contains the likelihoods used in the ethanol distillery QRA. The table includes the references for the likelihood values used plus additional comments as appropriate.

For each of the potential pressurised ethanol vapour releases, the following are all possible:

- No ignition occurs and the ethanol disperses
- Immediate ignition occurs leading to a jet fire
- Delayed ignition occurs leading to a flash fire or an explosion. These events may also lead to a jet fire if the release continues to flow.

Ignition probabilities are derived from the following sources.

Table 37 - Vapour and Liquid Ignition Probabilities

Leak	Probability of Ignition	Probability of Explosion Given Ignition	Probability of Explosion Given Leak	Probability of Ignition
	Gas			Liquid
Minor (<1 kg/s)	0.01	0.04	0.0004	0.01
Major (1 to 50 kg/s)	0.07	0.12	0.008	0.03
Massive (>50 kg/s)	0.3	0.3	0.09	0.08

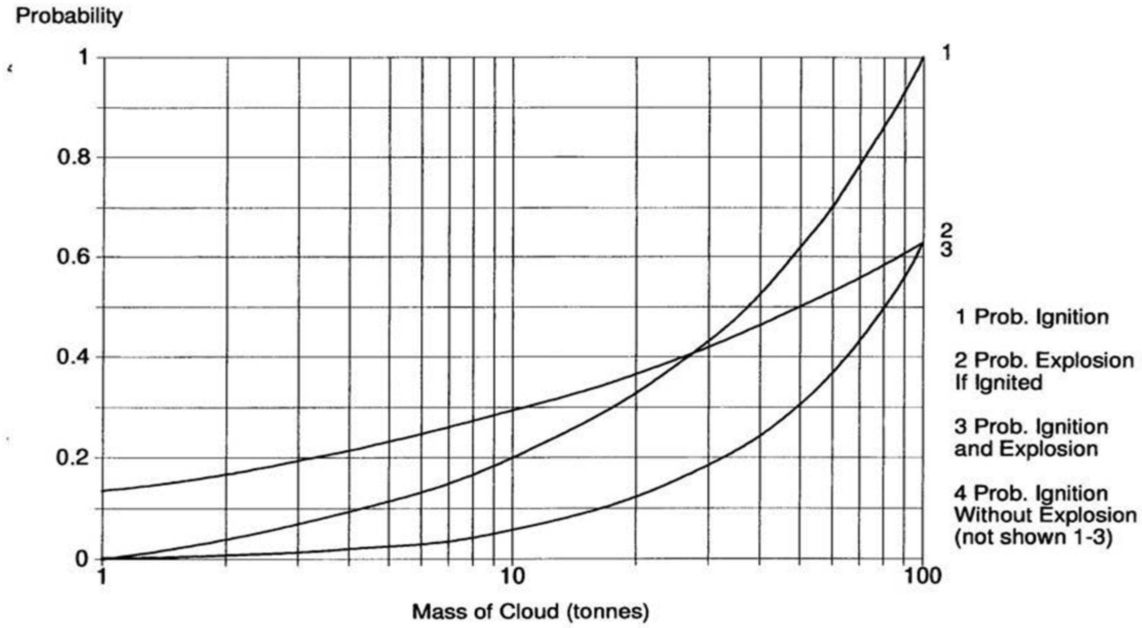
Reference 32: Cox, Lees and Ang, Classification of Hazardous Locations, January 2000

Given the relatively low release rates and quantities, the ethanol vapour ignition probability is taken to be 0.07.

Therefore, the probability of no ignition is 0.93.

The following graph (Ref 27) is used to determine the probabilities of a jet fire, flash fire or explosion given ignition. This graph is used as the quantities of the estimated releases are all relatively low, i.e. less than 1 te.

Table 38 – Jet and Flash Fites, and Explosions Probabilities



From the above graph, the probability of an explosion if ignited for a 1 te release is approximately 0.13. Therefore, the combined probability of a jet or flash fire is 0.87.

There are controls in place at the distilleries to avoid immediate ignition, e.g. hazardous area compliant instrument and electrics. Therefore, the probability of a jet fire (if ignited) is taken to be 0.2. Correspondingly, the probability of a flash fire (if ignited) is then 1 – 0.13 – 0.2 = 0.67.

The overall outcome probabilities are then:

- Probability of no ignition = 0.93
- Probability of ignition leading to a jet fire = 0.07 x 0.2 = 0.014
- Probability of ignition leading to a flash fire = 0.07 x 0.67 = 0.047
- Probability of ignition leading to an explosion = 0.07 x 0.13 = 0.009.

These probabilities are used in the calculations to determine the various event outcomes.

Table 39 – QRA Likelihoods

	Scenario	Grid Reference, Easting, Northing	Number of Vessels	Vessel Failure Likelihood, times/yr	Vessel Hole Failure Likelihood, times/yr	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Hose Failure Probability per Transfer	Number of Road Tanker Transfers per Year	Likelihood Reference	Total Failure Likelihood, times/yr	Ignition Probability	Probability of Automatic Deluge Failing	Ignition Probability Reference	Event Likelihood, times/yr	Comments:
	Pool Fires:															
1	**Original Distillery (most western location in the ethanol plant) full bund fire**	170, 160	18	5.00E-06		500	2.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17)	1.90E-04	0.1		Cox, Lees and Ang, Classification of Hazardous Locations, 2000	1.90E-05	The distillery pool fires likelihoods are estimated using the number of pressure vessels where above atmospheric pressure exists plus the length of piping that contains liquid ethanol. The latter is initially estimated based on site measurements and then doubled. The probability of ignition is from Cox, Lees and Ang, i.e. 0.1. This is on the basis that there are controls on ignition sources, e.g. hazardous area compliance, and the equipment is designed and built to the relevant standards and codes. Full bund fires will be a low likelihood event as the bund floors are sloped to drains and the drains would need to be blocked. Only large failures are considered as these are required to potentially lead to a large bund fire. All three distilleries have deluge sprays to dilute and extinguish a release leading to a fire
2	**Beverage Grade Distillery 2 full bund fire**	200, 150	5	5.00E-06		300	2.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17)	8.50E-05	0.1		Cox, Lees and Ang, Classification of Hazardous Locations, 2000	8.50E-06	
3	**Beverage Grade Distillery 1 full bund fire**	220, 140	3	5.00E-06		250	2.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17)	6.50E-05	0.1		Cox, Lees and Ang, Classification of Hazardous Locations, 2000	6.50E-06	
4	**Ethanol storage area bund fire**	260, 160									1.00E-03				1.00E-03	The bund fire likelihood is increased by approximately two orders of magnitude (compared to the LASTFIRE, 2003, likelihood in the next scenario) as the tanks do not have nitrogen padding and the tanks are not known to be designed to a recognised standard
5	**Ethanol day tank area bund fire**	290, 140								LASTFIRE, 2003	1.60E-05				1.60E-05	
6	**Fire at the road tanker loadout bay or at an Isocontainer**	270, 110						2.00E-07	5408	HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17). There are loading arms in use	1.08E-03	0.1		Cox, Lees and Ang, Classification of Hazardous Locations, 2000	1.08E-04	Using plant data, there are 104 trucks per week
7	**Fire in the denaturants' tanks bund**	300, 110									1.00E-03				1.00E-03	The likelihood of this smaller bund fire is approximated to be the same as the storage tanks bunds as the tanks do not have nitrogen padding and there is basic tank overfill protection
	BLEVE															
8	**Isotank BLEVE**	270, 110						4.00E-06	30	HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17). Hoses are used	1.20E-04	0.1	0.04	Cox, Lees and Ang, Classification of Hazardous Locations, 2000. NFPA, U.S. Experience with Sprinklers, May 2017	4.80E-07	

	Scenario	Grid Reference, Easting, Northing	Number of Vessels	Vessel Failure Likelihood, times/yr	Vessel Hole Failure Likelihood, times/yr	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Hose Failure Probability per Transfer	Number of Road Tanker Transfers per Year	Likelihood Reference	Total Failure Likelihood, times/yr	Ignition Probability	Probability of Automatic Deluge Failing	Ignition Probability Reference	Event Likelihood, times/yr	Comments:
	Jet Fires															
9	**Stage 7 Piping (250 mm hole)**	160, 170				44	2.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	8.80E-06	0.014		See the start of Appendix 7 in this report	1.23E-07	
10	**BGE1 D540 Piping (400 mm hole)**	230, 140				30	7.00E-08			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	2.10E-06	0.014		See the start of Appendix 7 in this report	2.94E-08	
11	**BGE2 D540 Piping (600 mm hole)**	200, 140				30	4.00E-08			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	1.20E-06	0.014		See the start of Appendix 7 in this report	1.68E-08	
12	**BGE2 D560 Piping (350 mm hole)**	200, 140				30	7.00E-08			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	2.10E-06	0.014		See the start of Appendix 7 in this report	2.94E-08	
	Explosions															
13	**Stage 3 Vessel and Piping**	170, 150	2	5.00E-06		25	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	1.68E-05	0.009		See the start of Appendix 7 in this report	1.51E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
14	**Stage 6 Vessel and Piping**	160, 160	2	5.00E-06		25	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	1.68E-05	0.009		See the start of Appendix 7 in this report	1.51E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
15	**Stage 7 Vessel and Piping**	160, 170	2	5.00E-06		44	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.64E-05	0.009		See the start of Appendix 7 in this report	3.28E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
16	**BGE1 D540 Vessel and Piping**	230, 140	2	5.00E-06		30	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	1.81E-05	0.009		See the start of Appendix 7 in this report	1.63E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
17	**BGE2 D540 Vessel and Piping**	200, 140	3	5.00E-06		30	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	2.31E-05	0.009		See the start of Appendix 7 in this report	2.08E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
18	**BGE2 D560 Vessel and Piping**	200, 140	3	5.00E-06		30	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	2.31E-05	0.009		See the start of Appendix 7 in this report	2.08E-07	The release likelihood is estimated using a catastrophic vessel failure rate with the combined rates for catastrophic and 1/3 hole size in the piping systems
	Flash Fires															
19	**Stage 2 Vessels or Piping, 50mm Hole, F1.5**	180, 160	3	5.00E-06		40	5.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.50E-05	0.047		See the start of Appendix 7 in this report	1.65E-06	
20	**Stage 3 Vessels or Piping, 50mm Hole, F1.5**	170, 150	2	5.00E-06		25	5.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	2.25E-05	0.047		See the start of Appendix 7 in this report	1.06E-06	

	Scenario	Grid Reference, Easting, Northing	Number of Vessels	Vessel Failure Likelihood, times/yr	Vessel Hole Failure Likelihood, times/yr	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Hose Failure Probability per Transfer	Number of Road Tanker Transfers per Year	Likelihood Reference	Total Failure Likelihood, times/yr	Ignition Probability	Probability of Automatic Deluge Failing	Ignition Probability Reference	Event Likelihood, times/yr	Comments:
21	**Stage 4 Vessels or Piping, 50mm Hole, F1.5**	210, 160	3	5.00E-06		67	5.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	4.85E-05	0.047		See the start of Appendix 7 in this report	2.28E-06	
22	**Stage 5 Vessels or Piping, 50mm Hole, F1.5**	190, 160	4	5.00E-06		54	5.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	4.70E-05	0.047		See the start of Appendix 7 in this report	2.21E-06	
23	**Stage 7 Vessels or Piping, 50mm Hole, F1.5**	160, 170	2	5.00E-06		44	5.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.20E-05	0.047		See the start of Appendix 7 in this report	1.50E-06	
24	**Stage 2 Vessels or Piping, Large Release, Unstable Conditions (A & B)**	180, 160	3	5.00E-06		40	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.90E-05	0.047		See the start of Appendix 7 in this report	1.8E-06	For all large releases, the unstable conditions (A and B) are added together and the modelling results for the B condition are used, i.e. a conservative simplification. This applies to the neutral conditions (C and D) and the stable conditions (E and F) as well
25	**Stage 2 Vessels or Piping, Large Release, Neutral Conditions (C & D)**	180, 160	3	5.00E-06		40	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.90E-05	0.047		See the start of Appendix 7 in this report	1.8E-06	
26	**Stage 2 Vessels or Piping, Large Release, Stable Conditions (E & F)**	180, 160	3	5.00E-06		40	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.90E-05	0.047		See the start of Appendix 7 in this report	1.8E-06	
27	**Stage 3 Vessels or Piping, Large Release, Unstable Conditions (A)**	170, 150	2	5.00E-06		25	2.70E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	1.68E-05	0.047		See the start of Appendix 7 in this report	7.9E-07	
28	**Stage 4 Vessels or Piping, Large Release, Unstable Conditions (A & B)**	210, 160	3	5.00E-06		67	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.52E-05	0.047		See the start of Appendix 7 in this report	2.6E-06	
29	**Stage 4 Vessels or Piping, Large Release, Neutral Conditions (C & D)**	210, 160	3	5.00E-06		67	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.52E-05	0.047		See the start of Appendix 7 in this report	2.6E-06	
30	**Stage 4 Vessels or Piping, Large Release, Stable Conditions (E & F)**	210, 160	3	5.00E-06		67	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.52E-05	0.047		See the start of Appendix 7 in this report	2.6E-06	
31	**Stage 5 Vessels or Piping, Large Release, Unstable Conditions (A & B)**	190, 160	4	5.00E-06		54	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.24E-05	0.047		See the start of Appendix 7 in this report	2.5E-06	
32	**Stage 5 Vessels or Piping, Large Release, Neutral Conditions (C & D)**	190, 160	4	5.00E-06		54	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.24E-05	0.047		See the start of Appendix 7 in this report	2.5E-06	

	Scenario	Grid Reference, Easting, Northing	Number of Vessels	Vessel Failure Likelihood, times/yr	Vessel Hole Failure Likelihood, times/yr	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Hose Failure Probability per Transfer	Number of Road Tanker Transfers per Year	Likelihood Reference	Total Failure Likelihood, times/yr	Ignition Probability	Probability of Automatic Deluge Failing	Ignition Probability Reference	Event Likelihood, times/yr	Comments:
33	**Stage 5 Vessels or Piping, Large Release, Stable Conditions (E & F)**	190, 160	4	5.00E-06		54	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	5.24E-05	0.047		See the start of Appendix 7 in this report	2.5E-06	
34	**Stage 7 Vessels or Piping, Large Release, Unstable Conditions (A & B)**	160, 170	2	5.00E-06		44	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.64E-05	0.047		See the start of Appendix 7 in this report	1.7E-06	
35	**Stage 7 Vessels or Piping, Large Release, Neutral Conditions (C & D)**	160, 170	2	5.00E-06		44	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.64E-05	0.047		See the start of Appendix 7 in this report	1.7E-06	
36	**Stage 7 Vessels or Piping, Large Release, Stable Conditions (E & F)**	160, 170	2	5.00E-06		44	6.00E-07			HSE UK, Failure Rate and Event Data for use within Risk Assessments (06/11/17).	3.64E-05	0.047		See the start of Appendix 7 in this report	1.7E-06	

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