HAZARD AND RISK ASSESSMENT FOR THE DEVELOPMENT OF THE WICKHAM WOOL STORES ADJACENT TO THE EXISTING CALTEX FUEL DEPOT

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Hazard and Risk Assessment for the Development of the Wickham Wool Stores Adjacent to the Existing Caltex Fuel Depot

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EXECUTIVE SUMMARY

E1 - Introduction

Investec Australia Loans Management Pty Ltd (Investec) propose to develop the Wool Stores at Wickham (*the Wickham Wool Stores*) and another building adjacent to the east of these Wool Stores (*building 4)* as well as to build a new building (*building 5*) adjacent to the north. The Wool Stores and buildings 4 and 5 are located in the vicinity of an existing fuel depot operated by Caltex as their *Newcastle site* (referred to in this report as *the Caltex fuel depot*).

Investec has appointed Planager Pty Ltd (Planager) to prepare this hazard and risk analysis (HRA) to form part of the development application for the Wickham Wool Stores.

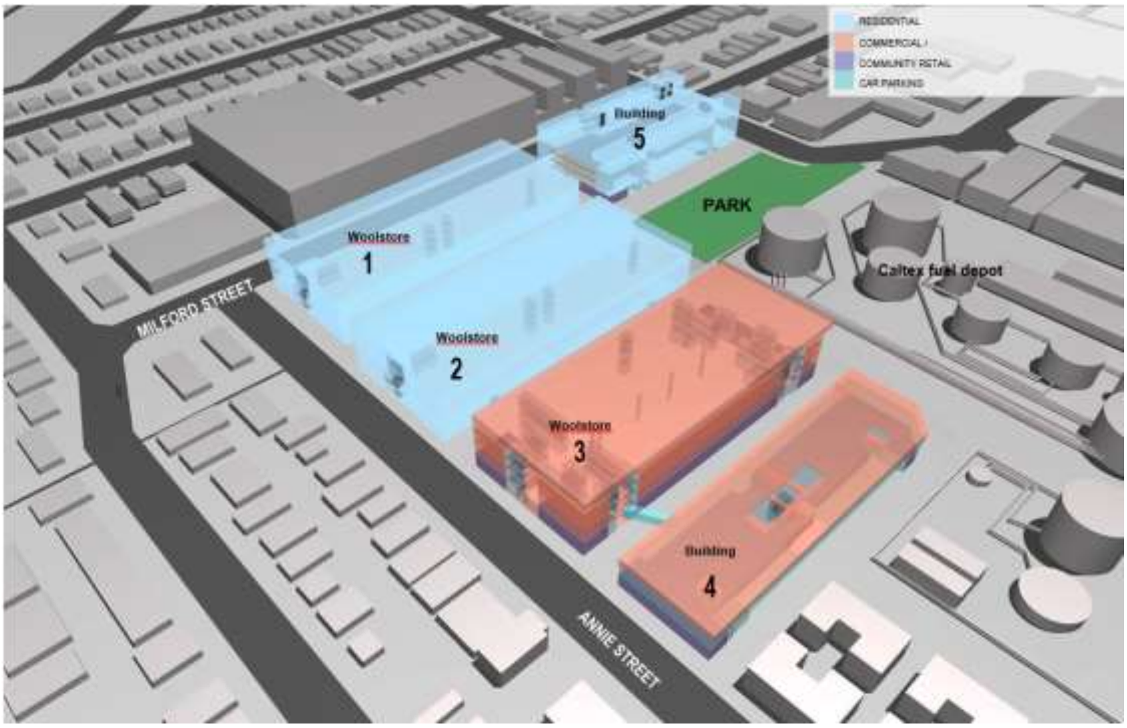
Planager is an independent Australian Risk Engineering Consultancy with over 15 years' experience as a leading risk engineering service provider with extensive experience in the oil and gas, energy and mining sector. As a specialist in risk management and risk minimisation, Planager's consultants have provided risk engineering advice to Global corporations and SMEs, Government departments and Universities in Australia, South East Asia, Europe, North America, and North Africa.

The aim of the HRA is to assess the risk to human safety for occupants of the Wool Stores, as posed by Caltex's fuel depot. To be considered as *acceptable* risk, the risk from the Caltex fuel depot must be demonstrated to be in compliance with the risk criteria set by the NSW Department of Planning and Environment (NSW DPIE) in their Hazardous Industry Planning Advisory Paper No 10 *Land use Safety Planning* (HIPAP10, 2011).

The development area is located at Annie Street, corner Milford Street, Wickham, in NSW. The development area includes three (3) Wool Stores (*Wool Stores 1, 2 and 3*) and two adjacent buildings (*buildings 4 and 5*).

The Investigation Area and the adjacent Caltex site infrastructure are shown in Figure E1, with the development area shown as *Woolstores 1, 2* and *3, Building 4* and *5,* and *Park* and Caltex fuel depot.

Figure E1 – Investigation Area



E2 - Major HRA assumptions

Rev 1 With the exception of overfill protection (discussed below), the information available to describe the Caltex fuel depot is limited to information available from public sources by way of the Internet.

As such, the assumptions made in this HRA need to be highly conservative, in particular with respect to the controls in place at the fuel depot (i.e. to prevent an incident from occurring and to protect against the hazardous effects from such an event) as the implementation of such controls cannot be verified with the operator of the depot.

Rev 1 Paragraph deleted

No risk reduction has been assumed from any fire repression system (fire water, foam system) or any fire proof wall available at the Caltex fuel depot, even though information sourced shows an extensive system of reticulated water and foam system at the storage tanks and a fire proof wall on the fuel depot.

The Caltex fuel depot is assumed to operate 100% of the time with the storage tank being filled to capacity 100% of the time.

Other conservative assumptions are those that are standard in HRAs in NSW, including an assumed person is present 100% of the time day or night; and the person is assumed not to be able to take shelter or to step away from the fire. The buildings are not included in the risk calculations as possible shelter to people from heat radiation from fires or vapour cloud explosions.

With these conservative assumptions, it then follows that the risk results determined in this HRA are conservative and most likely overstate the risk associated with the Caltex fuel depot.

Rev 1 The exception noted above, relating to the availability of information for this HRA, concerns the overfill protection at the depot, which became available to inform the Revision 1 update of this HRA, as provided in a report prepared in 2019 by Sherpa on behalf of Caltex (*Risk Equivalence Review for AS1940:2017 Separation Distance Non Compliance*).

E3 - Methodology

The HRA uses a risk-based methodology in accordance with HIPAP10, through a combination of qualitative analyses and assessments and a quantitative calculation of risks (the latter referred to as a *Quantitative a Risk Assessment*, or *QRA*). The methodology includes:

- Identification of the worst case credible hazardous events associated with the potential for a loss of containment of flammable or combustible material at the Caltex fuel depot which may affect the safety of any future occupiers of the Wickham Wool Stores or the adjacent buildings 4 and 5;
- Evaluation of the level of risk associated with the potential hazardous events to people occupying the Wickham Wool Stores and buildings 4 and 5, and comparison of the calculated risk levels with the risk criteria published by the NSW DPIE;
- Review of the adequacy of the known safeguards at the Caltex fuel depot and at Wickham Wool Stores and buildings 4 and 5 to prevent and mitigate the potential hazardous events at the Caltex fuel depot (including the buffer distances between the two developments); and
- Where necessary, submitting recommendations to Investec to allow the Wickham Wool Stores and the adjacent buildings 4 and 5 to be developed at acceptable levels of safety to occupiers of the Wool Stores.

E4 - Scope

The HRA assesses the credible potential loss of containment of flammable or combustible liquids from the Caltex fuel depot that may pose a hazard and risk to future occupants of the Wickham Wool Stores and buildings 4 and 5.

Hazards and risks are assessed in terms of an ignited release of material which could result in heat radiation and/or explosion overpressures with acute effects, relating to fatality or injury to occupants of the buildings and/or propagation (escalation) incidents at the buildings.

Rev 1 The HRA was conducted using historical failure data from Risk Assessment Data Directory- *Storage incident frequencies, International Association of Oil & Gas Producers, Report No. 434* (March 2010) and other reliable sources available for HRAs. Credible potential major incident scenarios identified included generic equipment failures, e.g. failures of tanks, pipes etc., and these are supplemented by process incidents due to other abnormal modes of operation, control system failure and human error, e.g. overfill of a storage tank. In each case, the result of the incident involved a large spillage of flammable or combustible materials into a bund or onto ground, evaporation of flammable vapours, and fire (pool or flash) if ignited.

Rev 1 Revision 1 of this report, as per comments by Caltex during the review of earlier revisions, also includes the so called *Buncefield* type overfill scenarios.

In line with HIPAP10, the following are outside of the scope of this HRA:

- any possible nuisance effects generally associated with industrial activity (possibly associated with noise, odour, etc.);
- any possible long term effects from exposure to vapours or contaminated land due to activities from the Caltex fuel depot or the Wool Stores themselves, experienced at the Wool Stores;
- off-site transport incidents (e.g. of fuel).

E5 Results

E5.1 General

- Some fire scenarios at the Caltex fuel depot have the potential to affect the Wickham Wool Stores and the area (currently unused) to the west of the depot;

Rev 1
- Vapour cloud explosions are considered extremely rare events for the types of facilities and materials associated with the Caltex Wool Stores. The computer modelling carried out for the worst case scenarios, except for the barely credible Buncefield scenarios[1], under the worst case wind weather conditions, found very little flammable vapours in the vapour cloud, indicating that a vapour cloud explosion is extremely unlikely.

- The buildings in themselves are likely to provide a level of protection against the potential fires at the fuel depot.

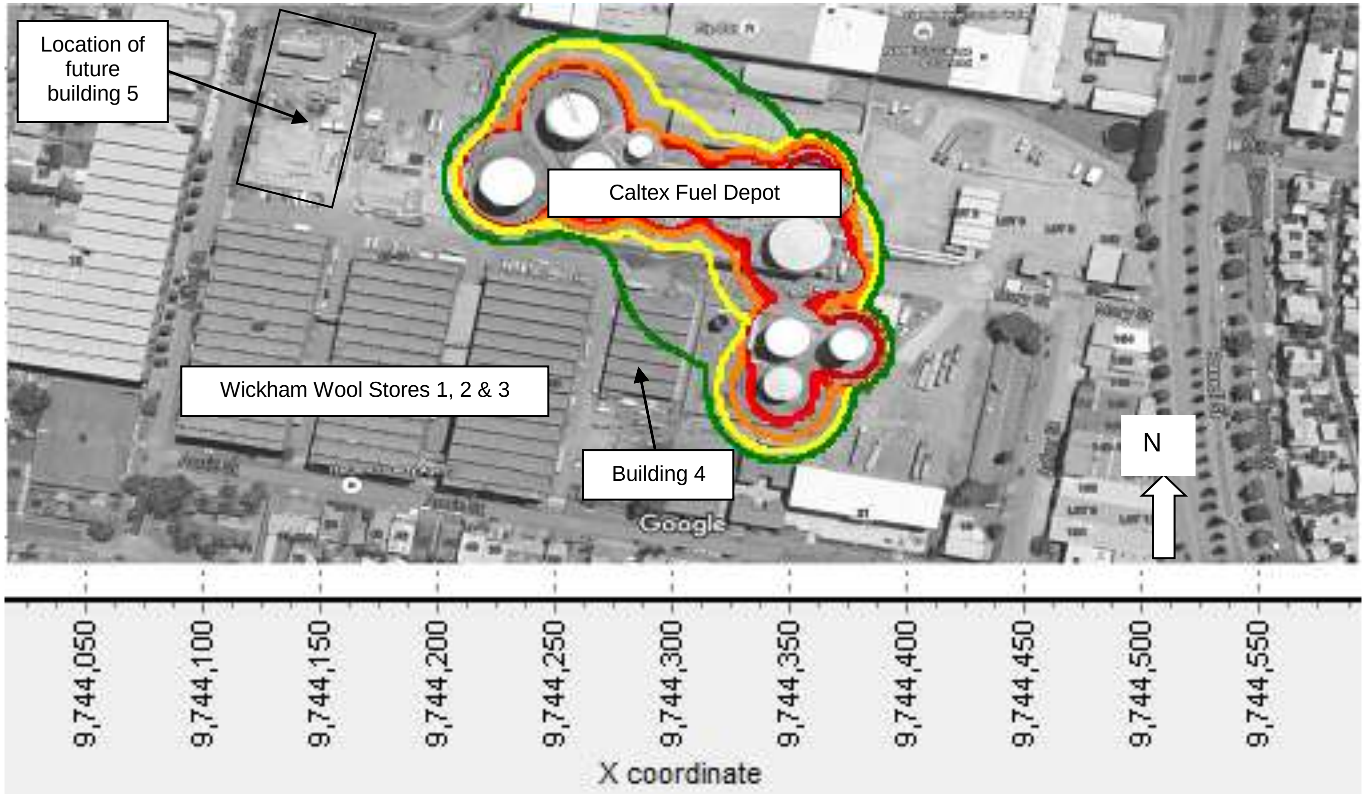
E5.2 Adherence to risk criteria

The NSW DPIE uses a risk-based methodology as the basis of a framework for locational guidance for developments in the vicinity of existing potentially hazardous industry. In a risk based approach, the likelihoods of major incidents are combined with the potential consequences to determine the risk of exposure.

Rev 1 The results are presented graphically in Figures E2 (individual fatality risk) and E3 (societal risk).

Rev 1 [1] These scenarios can occur in extreme circumstances involving prolonged overfilling of a gasoline tank at nil wind speed; and the formation of a large flammable vapour cloud which, in the case of a delayed ignition, may generate overpressure with effects outside of the site boundary. This is an extremely uncommon circumstance and only three (3) incidents are known to have occurred worldwide (Buncefield in 2005 and Jaipur and San Juan, both in 2009), where they occurred at larger terminals compared to the relatively small Wickham fuel depot (believed to be about 15% of the capacity of Buncefield) and was initially not believed to be a credible type of event for this depot. However, there is a risk, albeit small, and hence it has been included in Revision 1 of this report.

Figure E2 - Individual Fatality Risk Contours



Legend:			
	(dark red line)	50pmpy	Industrial development buffer
	(red line)	10pmpy	Active open space buffer
	(orange line)	5pmpy	Commercial development buffer
	(yellow line)	1pmpy	Residential buffer
	(green line)	0.5pmpy	Sensitive development buffer

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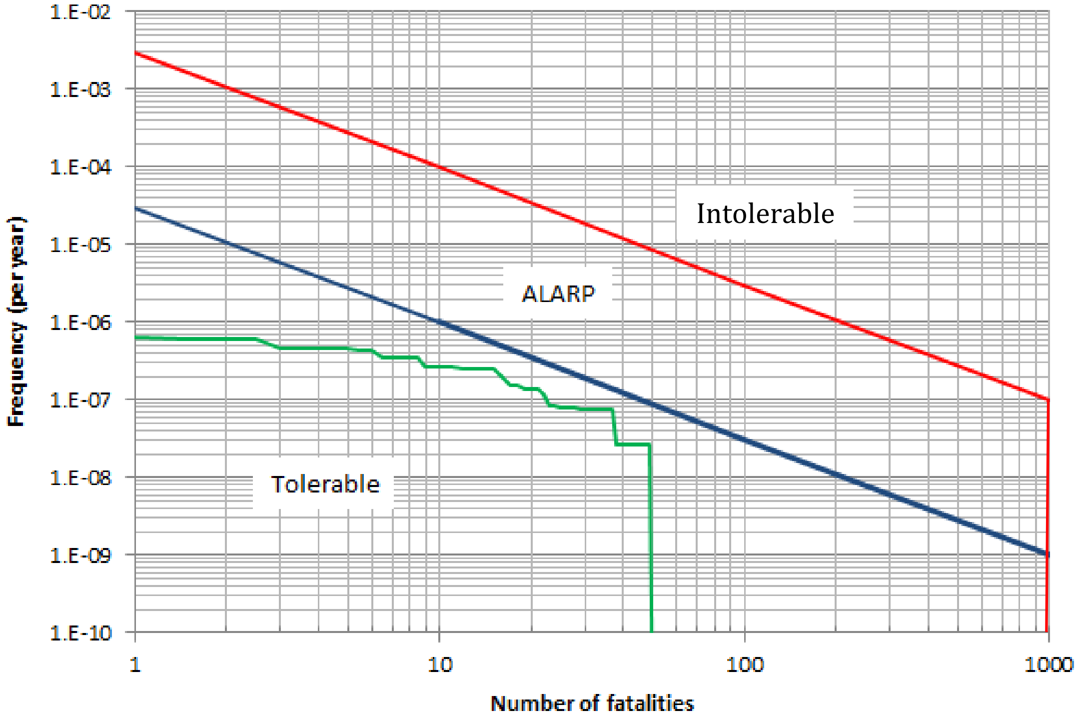
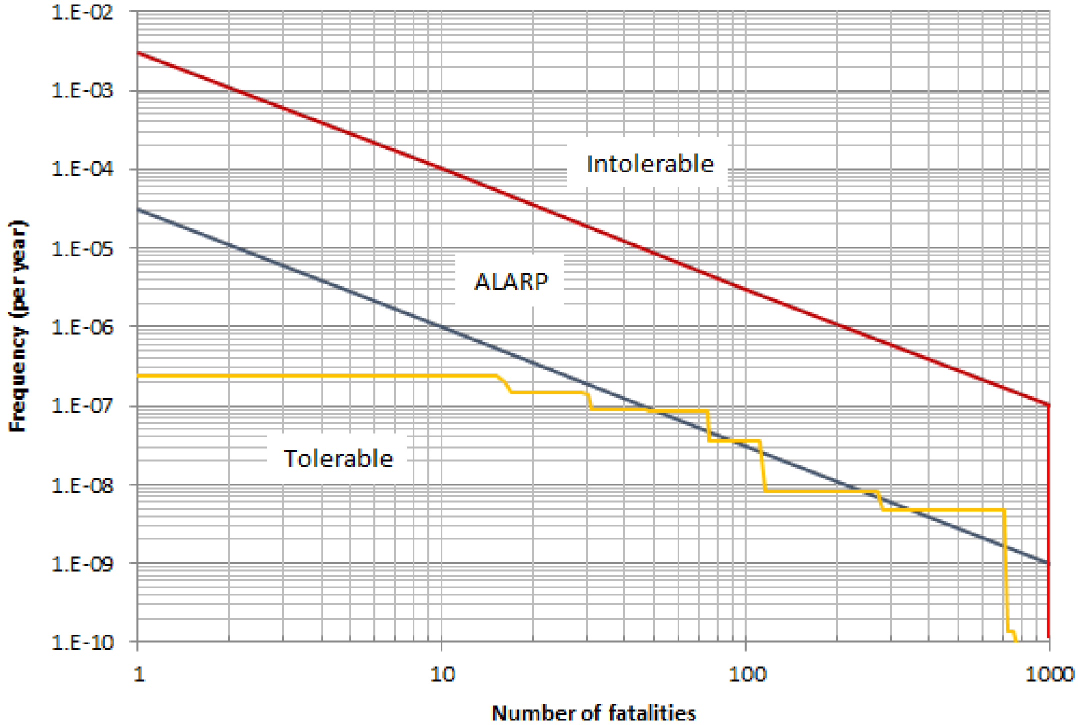
Figure E3 – Incremental Societal Risk Increase

Rev 1 Major overfill (Buncefield) scenarios not included



Rev 1 Major overfill (Buncefield) scenarios included



The adherence to the NSW DPIE risk criteria (HIPAP10, 2011) is presented in table E1 below.

E1 – Adherence to Risk Criteria

Risk criteria	Results	Impact on development
Industrial development criterion 50 pmpy risk (dark red contour)	Fully contained within the site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot. It does not reach the Wickham Wool Stores nor buildings 4 and 5	Industrial development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Industrial development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Active open space criterion 10 pmpy risk (light red risk contour)	Fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations). It does not encroach onto the Wool Stores nor buildings 4 and 5	Active open space development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Active open space development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Commercial development criterion 5 pmpy risk (orange risk contour)	Fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations). It does not encroach onto the Wool Stores nor buildings 4 and 5	Commercial development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Commercial development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Residential development criterion 1 pmpy risk (yellow risk contour)	Largely contained within the Caltex site boundary except for an excursion into the (currently) unused area to the west of the fuel depot. It does not encroach onto the Wool Stores nor buildings 4 and 5	Residential development at the Wickham Wool Stores is acceptable. The maximum individual fatality risk at any location of the Wool Stores is 0.8 pmpy which is below the NSW DPIE criterion for residential development of 1 pmpy. Residential development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Sensitive development criterion	The sensitive development risk contour is mainly contained within the Caltex	The risk from the Caltex fuel depot does not preclude sensitive development at

Risk criteria	Results	Impact on development
0.5 pmpy risk (green risk contour)	site boundary except for an excursion into the (currently) unused area to the west of the fuel depot and another excursion into the Caltex easement to the south of the site. It does not encroach onto the Wool Stores but it does encroach onto building 4	Wool Stores 1, 2 and 3. The maximum individual fatality risk at Wool Stores 1, 2 and 3 is 0.1pmpy which is less than the criterion for sensitive development of 0.5pmpy. The risk from the Caltex fuel depot precludes sensitive development of: • Building 4 - the maximum individual fatality risk at building 4 is 0.8pmpy which is above than the criterion for sensitive development of 0.5pmpy; • The small area defined by the excursion into the (currently) unused area to the west of the depot; and • The area defined by the excursion into the Caltex easement to the south of the site.
Irritation risk 50 pmpy	The maximum risk of injury at the Wickham Wool Stores is calculated as 1.6 per million per year (pmpy).	The individual risk of injury at the Wool Stores 1, 2 and 3 and at buildings 4 and 5 is well below the maximum risk criterion of 50 pmpy.
Propagation risk 50 pmpy	The maximum risk of propagation at any location of the Wickham Wool Stores is calculated as 1.1 per million per year (pmpy).	The individual risk of propagation at the Wool Stores 1, 2 and 3 and at buildings 4 and 5 is well below the maximum risk criterion of 50 pmpy.

	Risk criteria	Results	Impact on development
Rev 1	Societal risk	The incremental increase associated with societal risk from the increase in population of the Wool Stores never enters the intolerable risk zone. - In the case where the Buncefield overfill scenarios are not included, the societal risk is within the tolerable risk zone for the full range. - If the so called *Buncefield* overfill scenarios are included the incremental increase in societal risk from the increase in population at the Wool Stores remains mainly within the tolerable zone but enters the lower region of the ALARP zone at a number of points.	The proposed development at the Wickham Wool Stores has very little impact on the cumulative societal risk for the Wickham area. The small entry into the lower region of the ALARP zone for the case where the Buncefield style overfill scenarios are taken into account does not appear significant given the fact that these scenarios are barely credible for the Wickham fuel depot and given the number of highly conservative assumptions made throughout this HRA.

Rev 1 The levels of risks to public safety from a proposed residential and/or commercial development of the Wickham Wool Stores and the adjacent buildings 4 and 5 are within the most stringent accepted risk criteria for land use safety. The small excursion into the lower region of the societal risk ALARP zone in the case where the Buncefield scenarios are included can, given that the other quantitative criteria and other qualitative criteria are met, be considered tolerable (refer HIPAP10, Ref 1). Further discussion below.

Any potential use of building 4 for sensitive development (child care, elderly care etc.) is restricted.

Some restriction applies to the area immediately to the west of the fuel depot (within the development area) and from the easement between the Wool Stores and the depot.

Rev 1 E6 Conclusion

In NSW, land use safety is determined based on risk, and in risk terms the Wickham Wool Stores are acceptable for the proposed development because the likelihoods of major incidents at the Caltex fuel depot are very low.

Rev 1 The levels of risks to public safety from a proposed residential and/or commercial development of the Wickham Wool Stores and the adjacent buildings 4 and 5 are within the most stringent accepted risk criteria for land use safety (individual and societal risk considerations).

Rev 1 Individual risk criteria are for residential areas is adhered to for this development. While the result show that building 4 cannot be used for sensitive development, this usage is not within the proposed development plan. The use of the area immediately to the west of the fuel depot as parkland or playground confirms with the land use restriction in this area.

Rev 1 The incremental increase in societal risk in the area resulting from the proposed development is very low and the societal risk associated with the increase in population is well within the tolerable zone for the full range with a small excursion into the lower region of the ALARP zone for the case where the barely credible Buncefield scenarios are included. It never enters the intolerable region.

Rev 1 This small excursion into the ALARP region does not appear significant and the risk associated with the development can be considered tolerable following the guidance in HIPAP10 Section 5.4.2 given that scenarios of the type which occurred in Buncefield in 2005 are extremely uncommon and that it is not expected to be a credible type of event for the relatively small fuel depot at Wickham[2]; given the extensive additional mitigation measures designed into the buildings closest to the fuel depot (refer discussion in the body of the report and recommendations below), and lastly given that all other quantitative risk criteria are met.

Rev 1 The provision of fire proofing against radiant heat levels from major fire incidents at the fuel depot at Wool Store 3 and building 5, while not quantified, is expected to reduce the actual risk at the proposed development. Such fire proofing would also significantly reduce the risk of flammable vapours entering the buildings, and therefore would also mitigate from effects resulting from the extreme case Buncefield scenario.

E7 Recommendation

Radiant heat levels from major incidents do impinge on Wool Store 3 and building 4 and damage to windows, building and walls may occur, if included in the design of these buildings.

Rev 1 This has been taken into account in the design of Wool Store 3, with a buffer provided between the wall facing the fuel depot and the wall of the building and with the building wall having been designed with fire rating (to be confirmed). **It**

[2] Given that the Buncefield style scenarios have only occurred three (3) times worldwide at much larger fuel terminals than the one at Wickham, they were not considered credible for a fuel depot the size of the one at Wickham and were therefore not included in the earlier versions of this HRA report. As a response to comments by Caltex on the earlier version of the HRA and as they cannot completely be ruled out (i.e. cannot be given a nil risk), they were included in Revision 1 of this HRA.

is recommended that the fire rating of the northern wall facing the fuel depot be determined as part of the detailed design of Wool Store 3.

Rev 1 The North side of building 4 facing the fuel depot and the Northeast corner of building 4 facing the larger tank may be impacted by heat radiation from major incidents at the fuel depot. **It is recommended that fire rating on the north side and north eastern corner of building 4 be considered in detailed design.**

Rev 1 Paragraph removed

Such design solutions are likely to reduce the risk to the occupants of the building. These solutions have not been assessed quantitatively in the HRA.

GLOSSARY

ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
AS	Australian Standard
CCTV	Closed Circuit Television
Diesel	Automotive Diesel Oil
DG	Dangerous Good
DPIE	NSW Department of Planning (and Environment)
f-N (curve)	Type of diagram used to represent societal risk from a facility. Obtained by plotting the frequency f at which such events might kill N or more people, against N.
HRA	Hazard and Risk Assessment
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
Investec	Investec Australia Loans Management Pty Ltd
LEL	Lower explosion limit
LOC	Loss of containment
NFPA	National Fire Protection Association
PG	Packaging Group
PHI	Potentially hazardous Industry
PIRMP	Newcastle Terminal Pollution Incident Response Management Plan
Planager	Planager Pty Ltd
PMPY	Per million per year
PULP	Premium unleaded petrol
QRA	Quantitative risk assessment
SFAIRP	So Far As Is Reasonably Practicable
TNO	Netherlands Organisation for Applied Scientific Research
UEL	Upper explosive limit
ULP	Unleaded petrol
WHS	Work Health and Safety

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Investec Australia Loans Management Pty Ltd (Investec) are in the process of preparing a development application for the adaptive re-use of the Wool Stores at Wickham (*the Wickham Wool Stores*) and two adjacent buildings (*buildings 4 and 5*) which are located adjacent to an existing fuel depot operated by Caltex as their *Newcastle site* (referred to in this report as *the Caltex fuel depot*).

A hazard and risk analysis (HRA) has been requested by the Newcastle City Council to form part of the development application for the Wickham Wool Stores and buildings 4 and 5, to assess the risk to human safety for occupants of the buildings posed by Caltex's fuel depot. To be considered as *acceptable* risk, the risk from the Caltex fuel depot must be demonstrated to be in compliance with the risk criteria set by the NSW Department of Planning and Environment (NSW DPIE).

Investec has appointed Planager Pty Ltd (Planager) to prepare this HRA report. Planager is an independent Australian Risk Engineering Consultancy with over 15 years' experience as a leading risk engineering service provider with extensive experience in the oil and gas, energy and mining sector. Planager's consultants have provided risk engineering advice to Global corporations and SMEs, Government departments and Universities in Australia, South East Asia, Europe, North America, and North Africa.

This HRA has been prepared in accordance with the guidelines described by the NSW DPIE in their Hazardous Industry Planning Advisory Paper No 10 *Land use Safety Planning* (HIPAP10, Ref 1) detailing the hazard and risk analysis and assessment process for developments in the vicinity of potentially hazardous industry.

The information available to describe Caltex fuel depot is limited to information that has been picked up from public sources by way of the Internet. As such, the assumptions made in this HRA are necessarily conservative, in particular with respect to controls in place at the depot to prevent an incident from occurring and to protect against the hazardous effects from such an event. It then follows that the risk results determined in this HRA are conservative and most likely overstate the risk associated with the Caltex fuel depot.

1.2 AIM OF STUDY

The aim of the HRA is to assess the risk to occupants of the Wickham Wool Stores and the adjacent buildings 4 and 5 from the adjacent fuel depot operated by Caltex, and to compare this risk with the risk criteria for land use planning in use in NSW as described in the their HIPAP10 (Ref 1). The HRA:

- Identifies the worst case credible hazardous events associated with the potential for a loss of containment of flammable or combustible material at the Caltex fuel depot which may affect the safety of any future occupiers of the Wickham Wool Stores and buildings 4 and 5;
- Evaluates the level of risk associated with the identified potential hazardous events to people occupying the Wickham Wool Stores and buildings 4 and 5, and compares the calculated risk levels with the risk criteria published by the NSW DPIE;
- Reviews the adequacy of the known safeguards at the Caltex fuel depot and at Wickham Wool Stores and buildings 4 and 5 to prevent and mitigate the potential hazardous events; and
- Where necessary, submits recommendations to Investec to allow the Wickham Wool Stores and buildings 4 and 5 to be developed at acceptable levels of safety to occupiers of the Wool Stores.

1.3 SCOPE

This HRA assesses the credible potential loss of containment of flammable or combustible liquids, and in-situ ignition, and the corresponding risks, associated with the Caltex fuel depot that may pose a hazard and risk to future occupants of the Wickham Wool Stores and buildings 4 and 5.

The hazard and risk are assessed in terms of an ignited release of material resulting in heat radiation and/or explosion overpressures. Risks that are assessed are those relating to fatality, injury and propagation (escalation) at the Wickham Wool Stores and the adjacent buildings 4 and 5 from ignition of fuels at the Caltex fuel depot resulting in fires and explosions. The following plant equipment on the Caltex fuel depot are included:

- The fuel storage tanks;
- On-site pipelines;
- The associated product transfer pumps;
- The road tanker loading bay, used for product export.

1.4 OUTSIDE SCOPE

In line with HIPAP10, the following are outside of the scope of this HRA:

- any possible nuisance effects generally associated with industrial activity (possibly associated with noise, odour, etc.);
- any possible long term effects from exposure to vapours or contaminated land due to activities from the fuel depot experienced at the Wool Stores or buildings 4 and 5;
- off-site (outside of the Caltex fuel depot site boundaries) transport incidents.

2 SITE DESCRIPTION

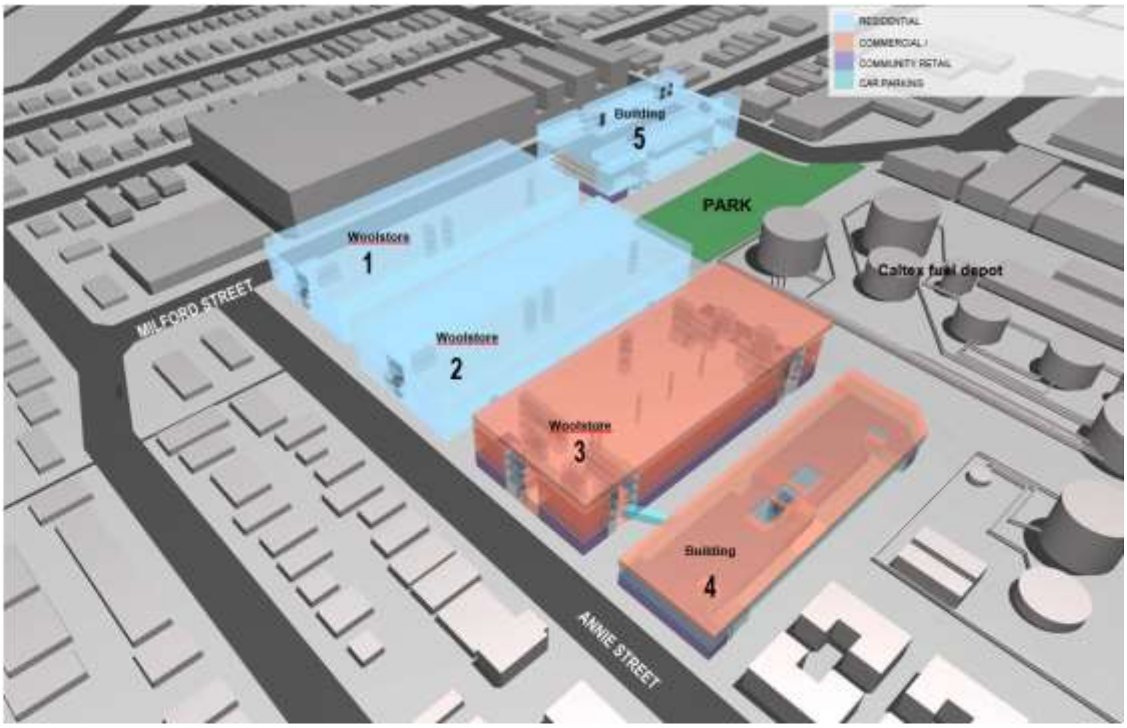
2.1 LOCATION

The Caltex fuel depot is located on Lot 1 DP 715007 and Lot 1 DP 80877 (Site ID 1158) at 156 Hannell Street, Wickham. Annie Street borders the site to the south.

The Wickham Wool Stores (i.e. the Investec site - Wickham Self-Storage) are located at 33 Annie Street (Lot 13 DP 830026), 41 Annie Street (Lot 3 DP 346352), 49 Annie Street (Lot 2 DP 346352) and 57 Annie Street (Lot 1 DP 346352), with further development area north of the Wool Stores, corner Milford Street. The buildings are referred to as Wool Stores 1, 2 and 3 and buildings 4 and 5.

The Investigation Area (*Woolstores 1, 2* and *3; Buildings 4* and *5*; and *Park*) and Caltex fuel depot infrastructure (shown in dotted dark blue line) are shown in Figure 1 together with adjacent development (in grey outside of the fuel depot).

Figure 1 – Investigation Area



The owners, existing Council zoning and proposed new site use associated with the Investigation Area are summarised in Table 1.

Table 1 – Investigation Area and Land Use

Lot and DP	Owner	Council zoning (refer LEP 2014)	Proposed new site use
Lot 1 DP 715007 & Lot 1 DP 80877	Caltex Australia Petroleum Pty Ltd	IN2 (light industrial)	No change
Lot 1, 2 and 3 DP 346352 & Lot 13 DP 830026	Asset Strata Investments managed by Investec and currently occupied by Wickham self-storage	IN2 (light industrial)	Adaptive re-use of existing Wool Stores to Multi storey, mixed use development.

2.2 Development Neighbouring the Caltex Fuel Depot

Immediately to the south and west of the Caltex fuel depot is the Investec site (i.e. Wickham Wool Stores and buildings 4 and 5) with Milford Street beyond. Commercial properties are located immediately to the north, south and west of the Caltex fuel depot. Hannell Street borders the Caltex fuel depot to the east. Residential properties are located on the eastern side of Hannell Street and Throsby Creek lies to the east of these properties.

2.3 Occupancy of the Wickham Wool Stores

The Wickham Wool Stores consist of three buildings (labelled 1, 2, 3) with building 4 located adjacent (east) to Wool Store 3 and building 5 located adjacent (north) to Wool Store 1, as shown in Figure 1. It is proposed that the buildings will be refurbished to contain a number of 1, 2 and 3 bedroom apartments and 3 bedroom townhouses as well as commercial offices and retail stores. Parking space for cars will also be included in the development.

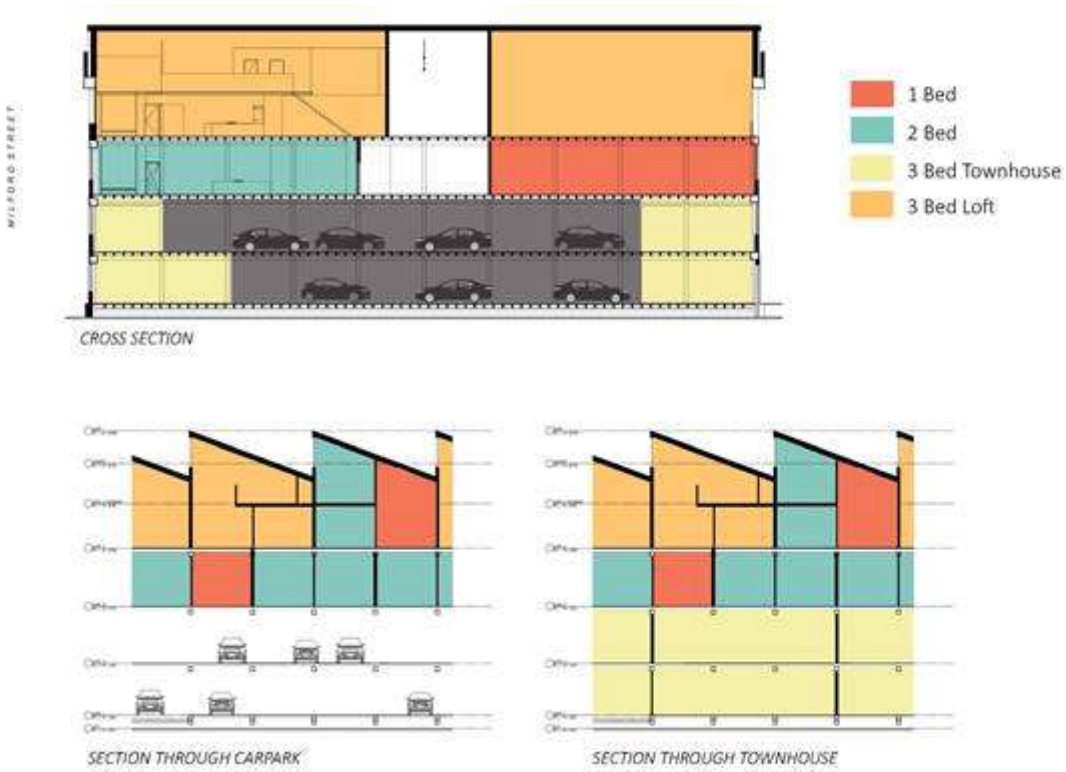
Rev 1
- Buildings 1 and 2: The development of buildings 1 and 2 will to contain a total of about 100 residential dwellings per Wool Store.

Rev 1
- Building 3 will be a mixed use development 10,517sqm of commercial office space and 785sqm of retail space.
- Building 4 will be replaced with a mixed use development of approximately 1,700sqm of retail & 2858sqm of commercial space as well as car parking.
- Building 5 is to be a new built residential building with a total of 71 residential dwellings and 116 car parks for the apartments. There will be retail on the northern front (facing the Caltex fuel depot) as well as on the eastern side of this building. The southern side of the building will have commercial / community use.

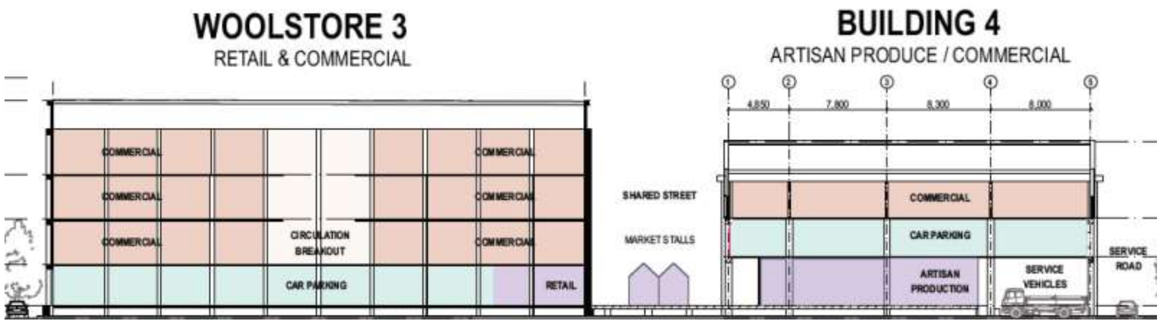
A typical cross section of the buildings is shown in Figure 2.

Figure 2 – Typical Cross Sections

Through Wool Stores 1 & 2:

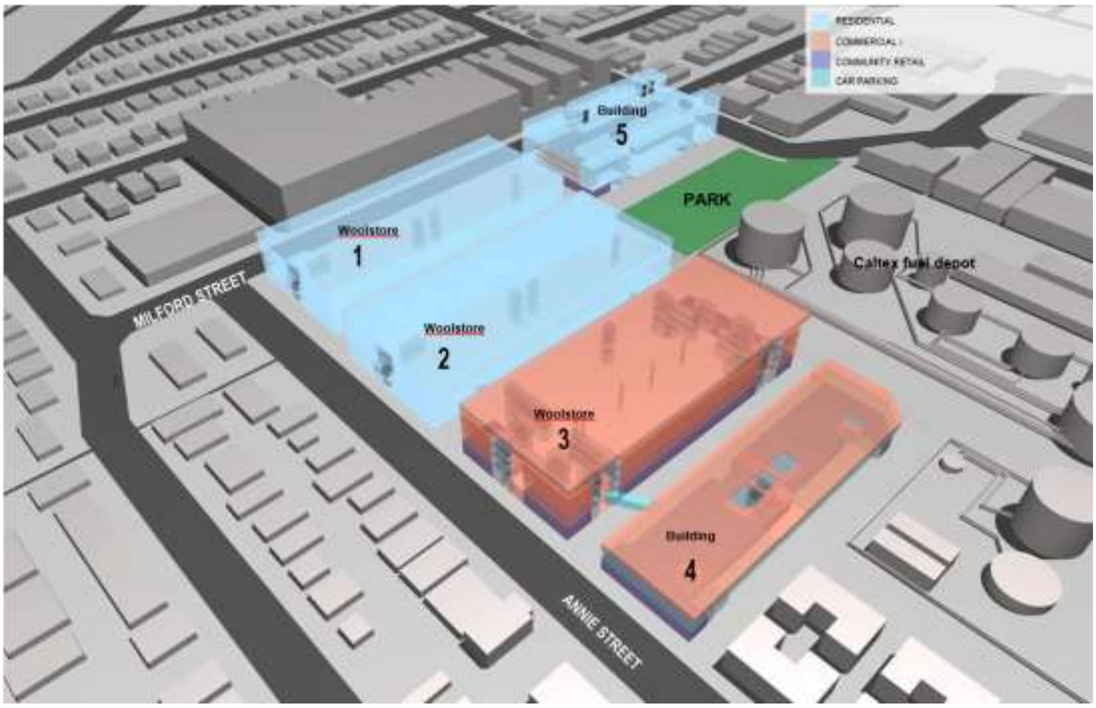


Through Wool Store 3 and Building 4:



The building usage is shown in Figure 3.

Figure 3 – Building Usage



Rev 1 The design of the Northern side of Wool Store 3 has been strengthened to protect against incidents at the fuel depot by addition of a fire rated wall along the full length of the building facing (fire rating to be confirmed, refer recommendations in this report) and a buffer between the depot and the Wool Store.

Rev 1 Further, Wool Store 3 was originally intended to have a residential component, and was due to utilise the full extent of the Wool Store. The building has subsequently been truncated in order to increase the separation distance between people working in the building and the Caltex site, and the residential component has been deleted.

Rev 1 The design of the northern side (full length) and the north eastern corner of Building 4 will also include some type of fire proofing, whether it be at the windows or the wall – to be confirmed in detailed design).

Rev 1 These mitigating features have not been included in the risk assessment calculations but would improve safety and reduce the risk for the occupants of the buildings.

2.4 CALTEX SITE INFRASTRUCTURE

2.4.1 Fuel Storage

Fuel is stored at ambient temperature in either fixed roof tanks or floating roof type tanks. From Newcastle Terminal Pollution Incident Response Management Plan (*PIRMP*, Ref 2 and 3), the total volume of each type of material is detailed in Table 2 together with the type of tank.

Table 2 – Fuel Storage

Contents	DG Class (Packaging Group)	Total volume stored on site (kilo litres, kL)	Tank type
Petrol (including PULP / SPULP / additive ULTRAZOL)	DG3 (PGII)	13,150	Internal floating roof
Ethanol	DG3 (PGII)	340	Internal floating roof / Fixed roof (horizontal)
Jet fuel (including jet additive, ICINOL and stadis)	DG3 (PGIII)	6,340	Fixed roof (cone)
Slop and bio-slops	DG3 (PGII)	660	Internal floating roof / Fixed roof (horizontal)
Diesel (including biodiesel, diesel additive and LUBRIZOL)	C1 (DG9 PGIII)	13,740	Fixed roof (cone / horizontal)

This HRA assumes that a spill at a storage tank would be contained within one of the bunds that are visible from satellite images of the site, and that these bunds are capable of handling at least 100% of the capacity of the largest tank (to Australian Standard AS1940-2004 *Storage and handling of flammable and combustible liquids* Ref 4 requirements). The AS1940 bunding requirement is standard for fuel depots of this type and has been in place for many years, before construction of the depot. It is considered unlikely that the fuel depot would be operating without adhering to this basic requirement, supporting this assumption.

2.4.2 Piping

The fuel is supplied to the depot from the Sydney-to-Newcastle pipeline which runs belowground up to the depot and then aboveground up to the manifold where it branches off into smaller diameter pipes through to each individual fuel tank. Liquids spilled from aboveground piping or pumps outside of curbed / bunded areas would drain away into an oily water separator.

2.4.3 Road Tanker Loading

Fuel is dispatched from the depot by road tankers which are filled on site (at the road tanker loading bay at gantry). Liquids spilled from aboveground piping or pumps outside of curbed / bunded areas would drain away into an oily water separator.

2.4.4 Fire System

The PIRMP for the fuel depot (Ref 2) details the firefighting system available for the site.

The system includes a fire water tank located at the north eastern corner of the site, supplying water across the site via a fire water ring main to fire water monitors (some with foam capability) located at strategic positions across the site.

The plan shows two water monitors located along the boundary of the fuel depot across the road to the northern front of Wool Store 3 and building 4. There are hydrants along the western boundary (facing building 5) and along the boundary to the eastern side of building 4. These water monitors and hydrants can be set up to provide a water curtain between the fuel depot and the Wool Stores and buildings 4 and 5, thus reducing the effect of a fire on the buildings[3].

Water is also supplied via risers up to the top of the tanks, used to cool the tank in the case of a nearby fire and to provide water for the foam system which is injected into floating roof tanks to quench a roof fire. There is also a foam sprinkler system above the road tanker loading gantry. Foam is stored in a

[3] Note that the operation of the fire and emergency protective equipment is at the discretion of the operations representatives at Caltex fuel depot in conjunction with the emergency services. Planager has no control of this operation and no risk reduction has been assumed for the fire water or foam for cooling or quenching purposes.

number of fixed storage tanks across the site, dedicated for various parts of the site, and there is also mobile foam equipment.

As the effectiveness of these fire repression systems cannot be verified for this HRA, the operation of the fire water curtain, cooling water system and foam system, and the effective reduction in risk from the fuel depot has conservatively not been included in this HRA.

2.5 SAFETY MANAGEMENT SYSTEMS

In hazard and risk assessments, incidents are assessed in terms of consequences and likelihoods leading to a measure of risk. Where possible, frequency data comes from actual experience. However, in many cases, situations evaluated are so unusual and infrequent that local experience is not available. In such cases, the frequencies used are generic, based on historical information from a variety of plants and processes with different standards and designs.

The quality of the management systems (known as *safety software*) in place in these historical plants will vary. Some will have little or no software, such as work permits and modification procedures, in place. Others will have exemplary systems covering all issues of safe operation. Clearly, the generic frequencies derived from a wide sample represent the failure rates of an *average plant*. This hypothetical average plant would have average hardware and software safety systems in place.

If an installation with below average safety software is assessed using generic frequencies, it is likely that risk will be underestimated. Conversely, if a plant is above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of software on plant safety.

Therefore, Planager adopts a policy which does not attempt to quantitatively account for the presence, and quality, of software safety systems. It is assumed that the generic failure frequencies used in the analysis apply to installations which have safety software corresponding to accepted industry practice. It is believed that this assumption will be conservative in that it will overstate the risk from well managed installations such as Caltex's site.

2.6 REQUIREMENTS FOR BUFFER ZONES AROUND FUEL DEPOTS

2.6.1 Code Requirements

The following Codes provide technical guidance for designers and operators of facilities storing and handling flammable and combustible liquids:

- (US) National Fire Protection Association NFPA30 *Flammable and Combustible Liquids Code* (Ref 5)

- Australian Standard AS1940 *Storage and handling of flammable and combustible liquids* (Ref 4)

The Codes include safety requirements for storage, operating procedures, emergency planning and fire protection as well as minimum separation distances to facilities on and off the industrial site.

NFPA30

The NFPA Code Table 22.4.1.1.(a) and (B) provide the minimum distance between fuel storage tanks and the *property line that is or can be built upon, including the opposite side of a public way* (refer paragraph 22.4 *Location of Storage Tanks*).

For floating roof tanks, the minimum distance is equal to the tank diameter. For horizontal and vertical tanks the distance depends on the tank capacity, e.g. a tank with a capacity 1,900m^3 - 3,800m^3 requires a 30m separation to the neighbouring *property line that can be built upon* (as per the NFPA30 definition).

The Code allows for both distances to be reduced by half in this instance as they would be protected by NSW Fire & Rescue in the case of a fire.

(Note that there is also the fire system at the Caltex fuel depot, in particular the fire water monitors at the boundary, as discussed in Section 2.4.4).

The minimum NFPA separation distances between the tanks at the fuel depot and the Wool Stores are adhered to in all circumstances.

AS1940

Table 5.4 in AS1940 sets the minimum separation between aboveground storage tanks to *protected places*[4] depending on the quantity, the class and the packaging group of the liquid stored. The minimum separation distance between the tanks at the Caltex fuel depot to the Wickham Wool Stores are adhered to in most circumstances with the Wool Stores being encroached upon in the case of the following three tanks on the depot:

[4] A protected place is defined as any of the following (AS1940-2004, paragraph 1.4.55):
(a) A dwelling, residential building, place of worship, public building, school or college, hospital, theatre, and any building or open area in which persons are accustomed to assemble whether it is within or outside the property boundary of the installation.
(b) A factory, workshop, office, store, warehouse, shop, or building where persons are employed, that is outside the property boundary of the installation.
(c) A ship lying at permanent berthing facilities.
(d) Any storage facility for dangerous goods outside the property boundary of the installation, except for those defined as minor storages in this or other Standards or regulations.

- Wool Store 3: Tank T214, storing petrol, encroaches onto the north side of the store.
- Building 4: Tank T7972 (petrol) encroaches onto the north side of the store and Tank T6 (jet fuel) encroaches onto the east side of the store.

Under WHS legislation, Caltex is obliged to comply with AS1940 separation distances or to demonstrate an alternative with equivalent or better risk control. Note that these separation distances are based on experience and history of fuel depots and other similar installations and do not directly relate to a degree of injury at the Wool Stores. Separation distances are generally used by operators of fuel depots and other similar facilities to ensure that the layout of their facilities is appropriate to their surroundings. For land use planning, the NSW DPIE instead uses a risk based approach for developments in the vicinity of potentially hazardous facilities, as discussed in Section 2.6.2 below.

2.6.2 Approach Used by NSW for Developments in the Vicinity of Potentially Hazardous Industry

As mentioned above the NSW DPIE uses a *risk-based* methodology as the basis of a framework for locational guidance for developments in the vicinity of existing Potentially Hazardous Industry (PHI, refer HIPAP10 (Ref 1)).

The risk based methodology defines a set of buffer distances between a PHI and surrounding land use depending on the potential consequences of hazardous incidents and their respective likelihood of occurrence. The risk of the PHI is compared against a defined set of risk criteria to determine whether a development adjacent to a PHI can be deemed acceptable.

The present HRA assesses the risk associated with the Caltex fuel depot as the approach in use in NSW land use planning to determine whether this risk is acceptable for the proposed new use of the Wickham Wool Stores.

3 STUDY METHODOLOGY

3.1 INTRODUCTION

The HRA has been conducted as follows:

- Initially, the existing tanks, equipment and operations associated with the Caltex fuel depot and their locations on site were reviewed to identify credible, potential hazardous events, their causes and consequences;
- The consequences of each potential hazardous event were then estimated to determine if there are any possible unacceptable (adverse) impacts on the Wickham Wool Stores and buildings 4 and 5;
- Where a potential hazardous event might produce adverse impacts on the Wool Stores or buildings 4 and 5, the likelihood of the event was determined, using appropriate techniques and methods as per HIPAP10;
- For such events, the hazardous consequences to occupants of the Wool Stores or buildings 4 and 5 were combined with their respective likelihood of occurrence to determine the risk of the event. The risks of each event were then combined and assessed at each location of the Wool Stores and buildings 4 and 5 and for each possible wind-weather category to determine the risk levels from potentially hazardous events imposed by the fuel depot on occupants of the Wickham Wool Stores and buildings 4 and 5;
- The risk associated with the Caltex fuel depot on the Wool Stores and buildings 4 and 5 was then compared with the acceptable land use risk criteria provided by the NSW DPIE in HIPAP10, to determine the acceptability of the proposed development of the Wickham Wool Stores.

3.2 RISK CRITERIA

3.2.1 Individual Risk

Table 3 summarises the risk criteria applying to developments in NSW (HIPAP10, Ref 1).

Table 3 - Risk Criteria

Land Use	Individual Risk Criteria (per million per year)
Sensitive development (hospitals, schools, child-care facilities, old age housing)	0.5
Residential (and hotels, motels, tourist resorts)	1
Business (commercial developments including retail centres, offices and entertainment areas)	5

Land Use	Individual Risk Criteria (per million per year)
Active open space (including sporting complexes)	10
Boundary of an industrial site (facility generating risk) (max risk at boundary of the site which generates the risk)	50
Injury risk criteria (heat radiation 4.7kW/m^2 or overpressure 7kPa)	50
Injury risk criteria Serious injury Irritation	 10 50
Propagation risk criteria (heat radiation 23kW/m^2 or overpressure 14kPa)	50

3.2.2 Societal Risk

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

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

The indicative societal risk criteria (HIPAP10, Ref 1) are presented in Table 4.

Table 4 – Indicative Societal Risk Criteria

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

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

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

In addition to quantitative criteria, qualitative guidelines are also given to ensure that off-site risk is prevented and where that is not possible, controlled.

The use of the term ALARP used by the DPIE in their HIPAP10 is approached in the same manner as the SFAIRP (so far as s reasonably practicable) criteria defined in the NSW Work Health and Safety (WHS) Regulations (Ref 6).

4 Hazard and Risk Analysis

4.1 Hazard Identification

4.1.1 Hazardous Materials

The Caltex fuel depot handles and stores the following chemicals (Ref 2):

- Petrol;
- Diesel / biodiesel;
- Jet fuel;
- Ethanol;
- Slops (a mixture of the preceding chemicals).

Table 5 lists the identified hazardous materials, their respective properties and the maximum total amounts stored at the Caltex fuel depot (Ref 2).

Table 5 – Materials Properties

Material name	Dangerous Goods (DG) Class (Packaging Group (PG))	UN No.	HAZCHEM Code	Flash Point (°C)	Flammability limits in air
Petrol	DG3 (PGII)	1203	3YE	-40ºC	1.4 - 7.6%
Ethanol	DG3 (PGII)	1170	2YE	13	3.3 – 19%
Jet fuel	DG3 (PGIII)	1863	3Y	38-40ºC (or above)	0.6 – 6%
Diesel / biodiesel (as Automotive Diesel Fuel)	DG9 (PGIII) (C1 combustible)	3082	Not applicable	>61.5ºC	Not applicable
Slops (as petrol)	DG3 (PGII)	N/A	3YE	-40ºC	1.4 - 7.4%
Trade-waste (as petrol)	DG3 (PGII)	N/A	3YE	-40ºC	1.4 - 7.4%

DG3: Flammable liquid
DG9: Environmentally polluting liquid
PGII: Flashpoint <23°C; Boiling point >35°C
PGIII: Flashpoint ≥23°C ≤60.5°C; Boiling point >35°C

Petrol, jet fuel and ethanol are Dangerous Goods Class 3 (DG3) flammable liquids. The control measures regarding safe handling and storage of DG3 materials include construction and ongoing maintenance and inspection of integrity of tanks, pipes, pumps and hoses associated with plant items; containment of a release in bunds or draining to containment areas in a safe location; and elimination of ignition sources. The vapour from DG3 materials is heavier than air and can accumulate in low points where explosions of confined vapours are possible. Combustion of DG3 materials at the Caltex fuel depot would produce carbon dioxide and carbon monoxide and the fire would produce soot. Fires are normally extinguished with alcohol resistant foam.

Diesel and biodiesel are classified as combustible liquids (C1), which could cause environmental pollution if spilled into the environment without being contained (DG9). These liquids are not readily ignitable at atmospheric temperatures and pressures (relevant for the Caltex fuel depot). The control measures regarding safe handling and storage of C1 materials at facilities such as the Caltex depot include construction and ongoing maintenance and inspection of integrity of tanks, pipes, pumps and hoses associated with plant items; and containment of a release in bunds or draining to containment areas.

Slops tanks and trade waste can contain a mixture of the materials stored and handled on site and are therefore treated as the material with the lowest flashpoint, in this case as DG3s.

The packaging group (PG) defines the hazard level of the flammable or combustible liquid, with PGII defining a liquid which has a low flashpoint, such as petrol and ethanol, and PGIII defining one with a higher flashpoint, such as diesel and jet fuel. The probability of ignition of a flammable or combustible liquid depends on its flashpoint – in general terms, the lower that flashpoint the higher the probability of ignition.

All petroleum products are potentially injurious to humans, e.g. as potential carcinogens, and environmental pollutants if released, e.g. to aquatic organisms. Storage tank details at the fuel depot are provided in Table 6 (Ref 2).

Table 6 – Details of Caltex Storage Tanks

Contents of tank	DG Class	Tank number	Tank volume (m^3)	Tank type
Gasoline / PULP / SPULP / additives	DG3 (PGII)	1911	9.8	Cone
		2082	0	Not in use
		214	2359	Internal floating roof
		378	7200	Floating pan
		7971	1844	Internal floating roof
		7972	1737	Internal floating roof
		482	5450	Cone

Contents of tank	DG Class	Tank number	Tank volume (m^3)	Tank type
Ethanol	DG3 (PGII)	500	110	Horizontal
		7969	233	Internal floating roof
Jet fuel / jet additives	DG3 (PGIII)	187A	4	Cone
		187B	4	
		187C	4	
		6	3748	
		7	2631	
Slop / bioslops	DG3 (PGII)	15721	629	Internal floating roof
		620	35	Horizontal
Diesel / biodiesel / diesel additives	C1 (DG9 PGIII)	1	1663	Cone
		16	5	Horizontal
		352	5905	Cone
		4	46	Underground
		7970	671	Cone

4.1.2 Segregation

The materials stored at the fuel depot are compatible and would not present any reaction hazards if inadvertently placed in contact with each other. There are no relevant segregation requirements for the major storages of materials stored at the depot.

4.1.3 Potential Hazardous Incidents and Their Control

Introduction

In accordance with the requirements in HIPAP10 (Ref 1), it is necessary to identify potential hazardous events associated with the Caltex fuel depot. As per the guidelines for hazard and risk analysis, the HRA focuses on atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water. In keeping with the principles of risk analysis, credible, hazardous events with the potential for off-site effects have been identified. That is, “slips, trips and falls” type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake.

A search of available literature and information was conducted to review the types of historical events that can occur at bulk fuel depots. The search included the following references:

1. Frank Lees, Loss Prevention in the Process Industries (Ref 7);
2. Australian, US and UK Departments of Transport records;
3. US National Transport Safety Board statistics;
4. US Occupational Health and Safety Administration statistics;
5. US Chemical Safety and Hazard Investigation Board statistics;
6. UK Health and Safety Executive statistics; and
7. Previous risk studies for fuel depots.

Hazardous Events – Fuel Depot Operations

The large majority of the identified potential major incident scenarios are generic equipment failures, e.g. failures of tanks, pipes etc. These are supplemented by process incidents due to other abnormal modes of operation, control system failure and human error, e.g. overfill of a storage tank.

The credible, significant incidents identified are summarised in the Hazard Identification Word Diagram (Table 7).

Rev 1 Revision 1 of this report, as per Caltex's comments on earlier versions, also includes the so called *Buncefield* type overfill scenarios[5] which are barely credible for the fuel depot.

The diagram in Table 7 presents the causes and consequences of potentially hazardous events, together with the minimum preventative and protective features that are included as part of the standard design and operation of this type of fuel depot and follow the basic requirements in Codes, Standards and Regulatory requirements. This follows the major assumption that the Caltex fuel depot has been constructed and is operated in accordance with standard good practice for fuel depots in Australia.

Rev 1 [5] These scenarios can occur in extreme circumstances, involving prolonged overfilling of a gasoline tank at nil wind speed and the formation of a large flammable vapour cloud which, in the case of a delayed ignition, may generate overpressure with effect outside of the site boundary. This type of scenario is extremely uncommon and only three (3) incidents are known to have occurred worldwide (Buncefield in 2005 and Jaipur and San Juan, both in 2009). The events occurred at larger terminals compared to the relatively small Wickham fuel depot (which is about 15% of the capacity of the Buncefield terminal in 2005) and were not considered a credible type of event for this depot in earlier versions of the HRA. However, as they cannot be entirely ruled out (i.e. it cannot be given a nil risk level) they have been included in Revision 1 of this report, and included as a possible outcome in scenario 4 in Table 7.

Table 7 - Hazard Identification Word Diagram

Event ID No.	Hazardous Event	Cause	Possible Consequences	Prevention and Mitigation Control Measures
1	Major mechanical failure of tanks.	Metal fatigue; Faulty fabrication; Corrosion of tank base / weld; Tank explosion due to lightning strike / breach of hazardous area ignition source controls; Adjacent tank on fire; Blocked vent.	Large spillage of flammable or combustible materials into bund and evaporation of flammable vapours. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	Code requirements apply (e.g. API 650, Ref 8 / AS1940, Ref 4 or other). Regular maintenance and inspection procedures. Tank and site fire repression facilities as per PIRMP (Ref 2). DG3 flammable liquids tanks have floating roofs to minimise formation of a flammable atmosphere (Ref 2) - explosions would only occur when ullage vapour is between LEL and UEL Control of ignition sources, including electrical continuity, earthing, permit to work system etc. as part of basic Australian Standard requirements. Diesel is combustible liquid (difficult to ignite).
2	Tank roof failure.	Flammable atmosphere in tank roof space (ignition by lightning / breach of hazardous area ignition source controls); Vents blocked during filling procedure; High speed filling.	Rim seal fire (floating roof tanks) Initial explosion possible leading to a tank top fire. Potential for spill into the bund with a fire if ignition occurs. Boil over possible if water layer exists. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	DG3 flammable liquids tanks have floating roofs (Ref 2) - minimises formation of a flammable atmosphere. Regular maintenance and inspection procedures as per regulatory requirements. Level alarms, controlled tank filling as part of Code requirements. Foam injection system (Ref 2) and fire-repression system (Ref 2) – this is not taken into account in the risk HRA.

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Event ID No.	Hazardous Event	Cause	Possible Consequences	Prevention and Mitigation Control Measures
3	Pipe failure (i.e. piping within the fuel depot, outside of bunded areas).	Corrosion; Impact; Maintenance work; Pressure surge.	Spillage of flammable or combustible material to ground and into trade waste and evaporation of flammable vapours. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	Code requirements apply (e.g. ASME31.3, Ref 9 / AS 4041, Ref 10 or similar). Regular maintenance and inspection procedures to regulatory requirements. Fire repression system as per #2 above.
4	Spillage of flammable or combustible material into bunds.	Tank overfilled during transfer; Tank drain valve left open or tank sampling valve left open, e.g. human error	Spill into bund and evaporation of flammable vapours. Bund fire if vapours are ignited. Possible tank fire and boil over. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion). In extremely unlikely circumstances associated with the overfill of a tall (>5m), atmospheric gasoline storage tank at high rates (>100m^3/hr), flammable vapour clouds may form, which, in the case of a delayed ignition, may generate overpressure with effect outside of the site boundary. These scenarios are referred to as the *Buncefield* scenarios in this HRA as it occurred in this location in 2005 (and then later in Jaipur in 2009). They are barely credible for the Wickham depot.	Operating procedures. Level alarms, controlled tank filling as part of Code requirements. Firefighting system as per #2 above. Independent high level shut down (each tank). Flammable vapour / liquid hydrocarbon detection in bunds (LEL 20%, for early detection of spill) CCTV of all bunds (for early detection of fire / spill). Bund foam pourers (flammable liquid bunds) – manually initiated (Ref 15)

Rev 1

Event ID No.	Hazardous Event	Cause	Possible Consequences	Prevention and Mitigation Control Measures
5	Leak during filling of road tanker.	Failure of loading arm / hose; Leak from valves or fittings; Road tanker overfill.	Leak of petroleum product in loading area and evaporation of flammable vapours. Fire if ignited. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	Surveillance and shutdown systems as per Code requirements. Drivers are trained as per Australian DG transport requirements so as to minimise chance of operator error and ensure quick response to leaks (as per legal requirement). Control of ignition sources as per #1 above. Spill drains away from road tanker area, e.g. to oily water separator.
6	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.	As above. Ignition source present (road tanker engine), hence fire more likely.	Driver training as per #5 above. Brakes managed prior to connection and until disconnection as per standard good practice for road tanker filling at fuel depots.
7	Leak at product pumps.	Pump seal, shaft or casing failures.	As above.	Condition monitoring and preventative maintenance of pumps. Pumps in contained area (Ref 2). Fire repression system as per #2 above.
9	Aircraft crash.	Pilot error; Bad weather; Plane fault.	Propagation to tank / bund fires. Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	As per aviation standards.
10	Strong winds, earthquakes.	Strong winds cause equipment damage etc.	Loss of containment leading to a fire if ignited (as above).	Code requirements apply (e.g. API 650 / AS 1692 / AS 1170) to resist the combined effects on internal pressure due to contents, weight of platforms, ladders, live loads, wind loads, earthquake forces and hydrostatic test loads.
12	Breach of Security / Sabotage.	Disgruntled employee or intruder.	Possible release of product leading to a fire if ignited (as above).	Security measures include fencing, CCTV, security patrols, operator / driver vigilance.

4.2 Risk Analysis

4.2.1 Introduction

The assessment of risks associated with the impact on a proposed development from an industrial site such as the Caltex fuel depot requires the application of the basic steps outlined in Section 1. The methodology takes account of credible hazardous situations that may arise at the fuel depot and that may have an effect at the Wickham Wool Stores or buildings 4 and 5.

This is done by first assessing the consequences of an incident at the target (in this case the Wickham Wool Stores or buildings 4 and 5). For the events which do not contribute to risk at the Wickham Wool Stores or buildings 4 and 5 no further risk analysis is warranted. When the consequence of an event contributes to a risk at the Wickham Wool Stores or buildings 4 and 5, the likelihood and hence risk must be analysed.

The effect on an individual at the target is determined using standard correlations and probit-type methods. This method determines the probability of an incident causing harm at the target.

Estimation of the likelihood of the event is undertaken using a probabilistic approach to vessel and pipe failures for all tanks and vessels containing hazardous materials. Specific incidents, identified by a variety of techniques, are then added and the combined data used to generate composite risk contours.

Having assembled data on possible incidents, risk analysis requires the following general approach for individual incidents (which are then summated for all potential recognised incidents to get cumulative risk):

Risk = Likelihood x Consequence

4.2.2 Method and theories

Modelling Software

Consequence calculations were undertaken using the Netherlands Organisation for Applied Scientific Research (*TNO)* consequence modelling software program *Effects®* (version 10.0.3) and risk modelling software package *Riskcurves®* (version 7.6). The TNO software tools are internationally recognised by industry and government authorities and the consequence models used within the packages are well known and are fully documented in *The Yellow Book* (Ref 11).

The credible hazardous events associated with the operation of the Caltex fuel depot are mainly pool fires resulting from the ignition of potential losses of containment of flammable (or combustible) liquids. A pool fire is a turbulent diffusion flame, burning above a horizontal pool of vaporising liquid, with little or no momentum. The flame can emit damaging and even fatal levels of radiant heat to the surrounding area. Pool fires will result following the ignition of a (continuous or instantaneous) release of flammable (or combustible) liquid stored at atmospheric conditions. The size of a pool fire is determined by operating conditions, the burning rate of material and the presence of spill containment. The assumptions made in this HRA relating to the size of the fire scenarios are listed below:

- The size of a pool fire resulting from the ignition of a release from a storage tank (and/or associated equipment) into the surrounding bund is assumed to be limited to the surface area of the bund (excluding the area of the bund occupied by storage tanks).
- A full-surface tank fire (which also behaves as a pool fire) could occur following an internal explosion of a fixed roof tank or the sinking of a floating roof tank. The size of a tank fire is assumed to be limited to the diameter of the tank.
- The pumps are located within a kerbed or bunded area, with the pool size assumed to be limited to the area described by the kerb or bund.
- The pipelines located outside of bunded areas would drain to the oily water interceptor. The pool size is assumed to be spreading and unbunded, located at the interceptor.

Rev 1 ***Other Modelling Technique***

Rev 1 The potential for formation of major vapour clouds from prolonged overfill of tall atmospheric storage tank with gasoline during calm wind weather conditions is considered (refer the Hazard Identification Word Diagram in Table 7), with the consequences to hazardous levels detailed in Table 11. These vapour clouds have been estimated based on the model by the Health Safety and Laboratory (HSL) paper (Ref 12), estimating the rate of formation of falling droplets drawing in air as they spray, and forming a cold, well-mixed flammable cloud that moves due to gravity and local eddies rather than bulk air wind speed.

4.2.3 Combustion Products

In a fire, unburned toxic substances and toxic combustion products can be released to the environment. For fires in the open, as would be the case for the fuel depot, the high temperatures associated with the fire would cause the plume of combustion products to rise. This plume rise is assumed to occur immediately and no lethal effects are expected. Exposure to unburned toxic substances and toxic combustion products do not have to be considered within the scope of this HRA as they would be very unlikely to cause acute injury or fatality.

4.2.4 Failure Rates

The likelihood of each postulated equipment failure was determined using the data in the Table 8 below.

Table 8 - Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy[6])
PIPELINES WITHIN FIXED PLANT[7] (Ref 13)	
Leak (outflow is from a leak with an effective diameter of 10% of the nominal diameter, a maximum of 50 mm):	
< 75 mm	5 / m
> 75 mm but < 150 mm	2 / m
> 150 mm	0.5 / m
Guillotine fracture (full bore):	
< 75 mm	1 / m
> 75 mm but < 150 mm	0.3 / m
> 150 mm	0.1 / m
ATMOSPHERIC STORAGE TANK (Ref 13)	
Instantaneous release of the complete inventory	5
Continuous release of the complete inventory in 10 min at a constant rate of release	5
Continuous release from a hole with an effective diameter of 10 mm	100
PUMPS (Ref 13)	
Rupture – full bore of largest connecting pipe	10
Leak - outflow from a leak with an effective diameter of 10% of the nominal diameter, with a maximum diameter of 50 mm	50
FULL-SURFACE TANK FIRE (Ref 14)	
Full-Surface Tank Fire Frequency - Floating Roof (Full-Surface Tank Fire)	1200
Fixed Roof - Internal Explosion and full surface roof fire	90
Fixed with Internal Floating - Roof Internal	90

[6] per million per year

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

Type of Failure	Failure Rate (pmpy[6])
Explosion and Full-Surface Tank Fire	
OVERFILLING (Ref 14)	
Major overfill event of a storage tank[8] (average)	1.9
Minor overfill event at storage tank[9] (average)	19

The references for the data in Table 8 are detailed below:

- Where available, Planager uses the frequencies in the database documented in the *Purple Book* (TNO, Ref 13) which is a worldwide recognised source of reference in QRAs of potentially hazardous industry.

- The TNO data does not cover the likelihood of tank top fires and instead, the 2010 *Risk Assessment Data Directory* by the International Association of Oil and Gas Producers (IOGP) entitled *Storage incident frequencies* (Ref 14) was used. Conservatively, the likelihood of tank top fires is assumed to be relevant for both flammable and combustible liquids even though the probability of igniting the vapour space in a tank containing combustible liquid (i.e. diesel in this HRA) is extremely low.

- The likelihood of overfilling a storage tank depends on a number of factors including installation of alarms and process trips. Details as to overfill prevention at the Caltex fuel depot is not available to inform this HRA, and the statistics, referred to in the *Storage incident frequencies* report (Ref 14), that 19% of all leaks outside of storage tanks have historically been caused by overfilling, has been used to determine the likelihood of overfilling at the Caltex fuel depot. This applies to the 'average' fuel depot and is probably conservative for a depot operated by an experienced operator such as Caltex. A reasonable estimate for likelihood of a major tank overfill is therefore 10pmpy x 19% = 1.9pmpy, as extrapolated from IOGP data and using the major atmospheric storage tank leak frequencies (rupture and complete inventory lost after 10min) of 10pmpy.

Rev 1

This data applies to an average hydrocarbon storage facility designed and operated to principles applicable to the period of time where the data for the database was gathered. For the Wickham fuel depot, additional risk mitigating controls have been installed which serve at further reducing the likelihood of tank overfill and/or the consequences should

[8] A reasonable estimate is extrapolated from OGP Report No. 434 – 3 Storage incident frequencies, that 19% of all leaks outside of storage tank are caused by overfilling, using only the major atmospheric storage tank leak frequencies (rupture and complete inventory lost after 10min): 10pmpy x 19% = 1.9pmpy.

[9] As per foot note above, but for smaller leaks, limited to cover the surface area of the sump, uses the minor storage tank frequency (10mm hole): 100pmpy x 19% = 19pmpy

an overfill occur (Ref 15). These controls include independent high level shut-down (automatic) on all tanks; flammable vapour / liquid hydrocarbon detectors in the bunds (set at 20% LEL; for early detection of a spill); CCTV of all bunds (also for early detection of a spill as well as a fire); and manually initiated bund foam pourers (to mitigate ignited or unignited spills). In this case, the overfill frequency can be reduced by at least two factors of magnitude, to 0.019 per million per year (CCPS). This is in line with the estimation in the report by Sherpa on behalf of Caltex (Ref 15).

4.2.5 Meteorological Data

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

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

The wind/weather data set used in this HRA was obtained from the period of 2001 and was divided into two classes based on wind speed and weather class as follows:

- Wind 4m/s, weather stability class D (to represent typical daytime); and
- Wind 2m/s, weather stability class F (to represent typical night time).

Rev 1 Calm weather accounted for 0.41% of all wind weather categories (Ref 16).

The annual average ambient weather conditions identified for the site are as follows:

- 18^{o}C;
- 70% humidity.

4.2.6 Ignition Probability

The 2010 *Risk Assessment Data Directory* by IOGP on *Ignition probabilities,* was used to determine the probability of an ignition following a release of flammable or combustible liquid. This is the most recent publication of ignition probability, with data sourced from the mathematical functions drawn from the UKOOA look-up correlations (Ref 17). It refers to the publication entitled *Classification of Hazardous Locations* by Cox, Lees and Ang (Ref 18) and the *Purple Book* by TNO (Ref 13). As such it appears to be particularly robust and most applicable to the Caltex fuel depot.

The values presented relate to *total* ignition probability, which can be considered as the sum of the probabilities of immediate ignition and delayed ignition, where:

- Immediate ignition can be considered as the situation where the fluid ignites immediately on release through auto-ignition or because the incident which causes the release also provided an ignition source.
- Delayed ignition is the result of the build-up of a flammable vapour cloud which is ignited by a source remote from the release point. It is assumed to result in flash fires or explosions, and also to burn back to the source of the leak resulting in a jet fire and/or a pool fire.

Total ignition probabilities (i.e. immediate plus delayed ignition) following a release of flammable or combustible liquid at the Caltex fuel depot are calculated using the following scenarios from the publication:

- *IOGP Scenario 13 - Tank Liquid 100mx100m Bund (Liquid release from onshore tank farm where spill is limited by small or medium size bund)* and
- *IOGP Scenario 30 – Tank Liquid – diesel fuel oil (Liquid release from onshore tank farm of liquids below their flash point, e.g. diesel or fuel oils)*

Rev 1 *IOGP Scenario 8 – Large Plant Gas LPG* was used for ignition probability of overfill scenarios due to the air entrainment into the cascade of falling liquid and splashing in such events.

The probability increases as a function of the size of the release. For the smallest releases the ignition probability may be less than 1%, increasing to 1.5% for large petrol releases.

The probability of the delayed ignition of a formed flammable gas cloud, for on-plant incidents, is calculated using the methodology outlined in the Orica HAZAN Course notes (Ref 19) and Effects®.

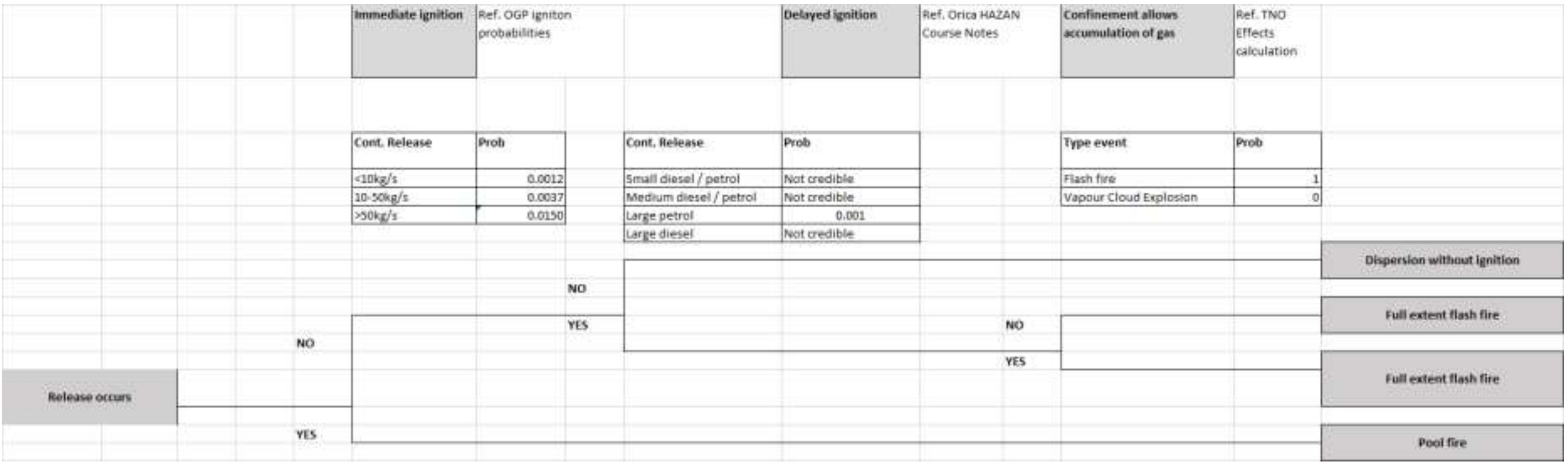
Rev 1 Values are dependent on the explosive mass of the vapour cloud, which in turn depends on rate of which the flammable vapours are added to the vapour cloud, and the dispersion rate.

Table 9 – Probability of Ignition

Material	Ignition probability	
	Total (Immediate and Delayed) (times/demand)	**Delayed (times/demand)**
Flammable liquids DG3		
Minor: <10kg/s	0.0012	Not credible
Major: 10-50kg/s	0.0037	Not credible
Rupture / massive: >50kg/s	0.0150	0.001
Combustible liquids C1		
Minor: <10kg/s	0.0010	Not credible
Major: 10-50kg/s	0.0014	Not credible
Rupture / massive: >50kg/s	0.0024	Not credible

The Event Tree in Figure 4 represents the logic used in determining the consequences associated with releases of flammable and combustible liquids, together with relevant probabilities.

Figure 4 – Event Tree for Ignition of Flammable and Combustible Liquid Releases



TNO, Ref 13
(I)OGP ignition probabilities, Ref 14
Orica HAZAN Course, Ref 19

4.2.7 Repression Systems and Protection Barriers

Various repression systems and protection barriers are installed at the Caltex fuel depot to limit the effects following a loss of containment. These are shown on the fire system plan in the Caltex PIRMP (Ref 2). Examples are sprinkler installations to limit the spread of a fire, water shields to prevent the effect of heat radiation from a fire and the use of foam to limit vapour formation from a pool and either prevent ignition or quench a pool fire.

A valid barrier is defined as a barrier that is effective, independent and auditable. These terms can be defined as follows:

- *Effective*: An effective barrier is a barrier that, by itself, prevents the consequence when it functions as designed;
- *Independent*: An independent barrier is a barrier that is independent of the threat (initiating event) and any other barriers already claimed for the same scenario;
- *Auditable*: An auditable barrier is a barrier that can be evaluated to ensure that it will operate correctly upon demand.

These terminologies are similar to those used by the Centre for Chemical Process Safety (CCPS), in their industry standard guide to layer of protection analysis (LOPA) methodology (Ref 20).

Rev 1 **A. Preventative controls**

Rev 1 The preventative controls which affect the likelihood of an overfill scenario, as listed in Section 4.2.4, have been included as barrier in this study, with the probability of failure given a rate of 10% (refer CCPS and other).

Rev 1 No other preventative controls are included in the hazard and risk assessment.

Rev 1 **B. Fire repression**

The fire repression systems at the Caltex fuel depot, as detailed in Caltex's PIRMP (Ref 2) would fit the definition of a valid barrier. The TNO Purple Book (Ref 13) states that a repression system may appear in quantitative risk calculations with a failure upon demand default value of 0.05 per demand being suggested, i.e. the risk of the hazardous event would be reduced by 95%.

However, no risk reduction has been assumed for the fire repression system or the presence of the fire wall at the Caltex fuel depot as it has not been possible to verify the operation of this system. This is a highly conservative assumption and may over-estimate the risk from some of the major hazard events at the depot by up-to 95% for those scenarios where fire repression systems would come into use.

4.2.8 Terrain – Roughness Length Description

The explosive mass in a flammable vapour cloud relates to the amount of vapour in the cloud that is at a concentration higher than the Lower Explosive Limit (LEL). It depends on a number of factors, including wind speed and the roughness of the ground surface under the cloud. The TNO software model (Effects®) uses *roughness length* which is an artificial length-scale relating wind speed over the surface and surface roughness. A set of *roughness length descriptions* in the model enables the user to determine the appropriate roughness length for the location under analysis.

The roughness description which most closely describes the area where the Wool Stores and the fuel depot are located is *Regular large obstacle coverage (suburb, forest)*. The roughness length assigned to this description is 1m[10].

When a roughness length of 1m is used as an input in calculating cloud concentrations for the scenarios identified in this HRA, concentrations above the LEL are not reached. This suggests that delayed ignition events resulting in flash fires or explosions are not credible. However, given the inherent uncertainties in dispersion modelling, it may not be possible to categorically rule out the delayed ignition of a flammable vapour cloud resulting from a massive release of a flammable liquid. Using the more conservative roughness length of 0.5m associated with the description *parkland, bushes, numerous obstacles* results in a calculated maximum explosive mass of 100kg. This is associated with the worst case wind-weather combination of F2, representing night time conditions.

While a flash fire could occur under these circumstances, the mass is too small to produce an explosion in open (unconfined) sites such as the Caltex fuel depot and therefore, explosions are not considered credible scenarios in this HRA[11].

[10] A previous version of *Effects®* assigned the same roughness length to the alternate description …*an industrial area with obstacles which are not too high*

Rev 1 [11] As per comments by Caltex during the review of earlier revisions, a so called Buncefield type overfill scenario has been included. While this type of scenario is barely credible for this depot, there is a risk, albeit small, and hence it has been included in Revision 1 of this report.

4.2.9 Population Densities

Population density in the Wickham Wool Stores and buildings 4 and 5 is used in the societal risk calculations to determine if the proposed increase in residential use will significantly affect the societal risk of the area and potentially exceed tolerable societal risk criteria.

The Australian Bureau of Statistics in their Housing and Lifestyle survey (Ref 21) report that the average number of people per bedroom in separate houses is 0.8 and in high-rise units is 1.0

While the Wickham Wool Stores and building 5 are not classified as either *separate houses* or *high rise units*, the higher value of 1.0 persons per bedroom is used to determine the population density of the Wool Stores and no differentiation is made between apartments and townhouses.

Building 4 will be used for retail and may be used for activities such as a micro brewery. Judging from the smaller size of this building it assumed that the population will be as per 50 one-bedroom apartments present on-site day and night.

4.2.10 Results of Consequence Calculations

The distances to specified radiant heat levels for the potential fire scenarios that may affect the Wickham Wool Stores and buildings 4 and 5 are shown in Table 10.

The quoted effect of heat radiation levels are for a person in the open as per the HIPAP10 guidelines. In accordance with this guideline, any protection associated with being inside a building is not included in the calculations.

Table 10 - Fire Scenarios Calculation Data and Results

Bund fire surface excludes the surface occupied by the tank(s)
Minor leaks from tanks assumed to cover the surface area of the sump, with the fire covering the same area. Consequence calculations show that none of the sump fires would affect the Wickham Wool Stores
Tank top fires assumed to cover the full surface of the tank at the height of the tank
Leaks from pipes and pumps in bunded areas assumed to occur at a release rate of 20 tonnes over 30 minutes = 10kg/s except for in the Sydney-Newcastle pipeline receiving and shipping area which is assumed to cover the full surface of the pump bund (higher transport rates assumed in this pipeline)
Effect of heat radiation levels are for a person in the open as per HIPAP10 guidelines. Protection from buildings is not included

Item No.	Item description	Area (surface) of fire (bund or tank top, m^2)	Consequences may affect the Wickham Wool Stores or and buildings 4 & 5 (YES / NO)	Distance to Specified Effects Level (m) from centre of fire (only provided for scenarios where consequences may affect the Wickham Wool Stores and buildings 4 & 5)		
				Propagation buffer 23 kW/m^2	Fatality buffer 12.6 kW/m^2	Injury buffer 4.7 kW/m^2
1	Bund fire due to LOC of Tank T1911	806	NO	Heat radiation levels do not reach the Wool Stores		
2	Bund fire due to LOC of Tanks T214, T378, and T15721	1441	YES	Heat radiation levels do not reach the Wool Stores		80
3	Bund fire due to LOC of Tanks T500, T7696, T7970, T7971, T7972	2755	YES	59	77	107
4	Bund fire due to LOC of Tanks T16, T187A/B/C, and T620	333	NO	Heat radiation levels do not reach the Wool Stores or buildings 4 & 5		
5	Bund fire due to LOC of Tanks T1, T6, T7	3394	YES	65	105	125
6	Bund fire due to LOC of Tank T352	1103	YES	41	56	80

Item No.	Item description	Area (surface) of fire (bund or tank top, m^2)	Consequences may affect the Wickham Wool Stores or and buildings 4 & 5 (YES / NO)	Distance to Specified Effects Level (m) from centre of fire (only provided for scenarios where consequences may affect the Wickham Wool Stores and buildings 4 & 5)		
				Propagation buffer 23 kW/m^2	Fatality buffer 12.6 kW/m^2	Injury buffer 4.7 kW/m^2
7	Bund fire due to LOC of Tank T482	3193	YES	68	90	128
8	Tank top fire T352	415, 254, 177	YES	Heat radiation levels do not reach the Wool Stores or buildings 4 & 5		49
9	Tank top fire from all other tanks	various	NO	Heat radiation levels do not reach the Wool Stores or buildings 4 & 5		
10	Fire at the Sydney to Newcastle receiving / shipping pump area	1253	YES	42	54	76
11	Pipe and pump leaks in other bunded areas including the interceptor pit	Various	NO	Heat radiation levels do not reach the Wool Stores or buildings 4 & 5		
12	Sump fires from minor leak in storage tank	Various	NO	Heat radiation levels do not reach the Wool Stores or buildings 4 & 5		

Rev 1

Table 11 – Major Overfill (Buncefield) Scenarios - Calculation Data and Results

Rev 1

Flow rate assumed to be 600kL/hour (about 120kg/s)
30 min release overfill duration assumed to be worst case scenario. This assumes both high level trip and operator initiated ESD have failed
Width of the vapour cloud assumed to be similar to the Length (to LFL concentrations), consistent with CFD modelling results undertaken as part of the Buncefield investigation. This may be affected by specific bund and building configurations.
Slops, bio-slops and ethanol tanks excluded as filling rate too low for Buncefield scenarios; jet fuel and diesel tanks excluded due to material properties; refer Buncefield report
Tank 1911 too short (1 m) for major vapour cloud formation, refer Buncefield report
Tanks 7971/7972 reported "Out of Service" but as it is not known whether this is temporary or permanent they are assumed to be in service for this QRA
The below outcomes are only considered possible during "calm" conditions, refer Buncefield report.

Item No.	Tank description	Tank height / Tank diameter (m)	Consequences may affect the Wickham Wool Stores or and buildings 4 & 5 (YES / NO)	Distance to Specified Effects Level (m) from centre of fire (only provided for tall tanks used for gasoline)	
				Length Vapour Cloud (m)	Width Vapour Cloud (m)
Current storage regime					
14	214	9 / 19	YES	186	186
15	378	15 / 25	YES	234	234
16	7971	9 / 16	YES	178	178
17	7972	9 / 16	YES	178	178
18	482	10 / 26	YES	217	217
Discussion on other tanks and whether these could store petrol in the future					
19	353	Reported as storing diesel (refer Caltex' PIRMP 2015 and 2018, with the 2018 report being current). Based on the limited separation distance between T-352 and the boundary (7.5m), gasoline storage is not suitable without significant additional measures which would require Council approval			
20	1 and 6	Reported as storing diesel. Not AS1940:2017 compliant for gasoline storage without significant additional measures which would require Council approval.			
21	6	Reported as storing jet fuel / diesel. Not AS1940:2017 compliant for gasoline storage without significant additional measures which would require Council approval.			

The values of interest for radiant heat (NSW DPIE, HIPAP10 and HAZAN Course notes) are shown in Table 12.

Table 12 - Radiant Heat Impact

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure. High chance of injury Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failure
35	Significant chance of fatality for people exposed instantaneously Cellulosic material will pilot ignite within one minute's exposure

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

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

Exposure of buildings to heat radiations of 23kW/m^2 may cause thermal stress temperatures of structural steel.

4.2.11 Frequency of Outcome of Each Incident Event

The frequency of outcome of each individual incident scenario, where the consequences affect the Wickham Wool Stores or buildings 4 and 5 (defined as heat radiation exceeding 4.7kW/m^2 is listed in Table 13 below.

Table 13 – Frequency of Outcome of Fire Events

Notes:

- Item numbers refer to the incident scenario in Table 10 above;
- Only those events where the consequences may affect Wickham Wool Stores or buildings 4 or 5 are listed in the table below;
- pmpy: per million per year (equivalent to *times per 10^6 years*)

Item No.	Item description	Frequency of Achieving a Certain Effect (pmpy) (only provided for scenarios where consequences may affect the Wickham Wool Stores or buildings 4 or 5)		
		Potential Propagation to Industrial Facility 23 kW/m^2	**Potential Fatality 12.6 kW/m^2**	**Potential Injury 4.7 kW/m^2**
2	Bund fire from LOC of Tanks T214, T378, and T15721	Does not reach the Wool Stores		0.45
3	Bund fire from LOC of Tanks T500, T7696, T7970, T7971, T7972	0.6	0.6	0.6
5	Bund fire from LOC of Tanks T1, T6, T7	0.32	0.32	0.32
6	Bund fire from LOC of Tank T352	0.02	0.02	0.02
7	Bund fire from LOC of Tank T482	0.02	0.02	0.02
8	Tank top fire T352	Does not reach Wool Stores or buildings 4 or 5		0.02
10	Fire at the Sydney to Newcastle receiving / shipping pump area	0.15	0.15	0.15

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Table 14 – Frequency of Outcome of Major Vapour Cloud Events

Rev 1 Notes:

- Item numbers refer to the incident scenario in Table 10 above;
- Only those events where the consequences may affect Wickham Wool Stores or buildings 4 or 5 are listed in the table below;
- pmpy: per million per year (equivalent to *times per 10^6 years*)
- Buncefield type scenarios are assumed to cause fatality AND injury with 100% probability
- Frequency of overfill at Wickham fuel depot estimated as 0.019 pmpy per tank. Multiply with 0.41% as the probability of it coinciding with “calm” conditions (refer Section 4.2.5).

	Item No.	**Item description**	**Frequency of Achieving a Certain Effect (pmpy) (only provided for scenarios where consequences may affect the Wickham Wool Stores or buildings 4 or 5)**	
Rev 1			**Potential Fatality (Flash fire or vapour cloud explosion)**	**Injury (Flash fire or vapour cloud explosion)**
Rev 1	14	T214 Overfill event potential Buncefield type vapour cloud formation	7.79E-5	7.79E-5
	15	T378 Overfill event potential Buncefield type vapour cloud formation	7.79E-5	7.79E-5
	16	T7971 Overfill event potential Buncefield type vapour cloud formation	7.79E-5	7.79E-5
	17	T7972 Overfill event potential Buncefield type vapour cloud formation	7.79E-5	7.79E-5
	17	T482 Overfill event potential Buncefield type vapour cloud formation	7.79E-5	7.79E-5

4.2.12 Risk Calculations

Risk has been assessed in terms of:

- *The total likelihood of achieving a certain damaging effect* - calculated by adding together the likelihoods of each event that has the potential to cause the effect. If the total likelihood is much lower than the acceptable risk criteria, even before taking into account the probability of the effect being achieved (i.e. probability set as 100%), it follows that the risk is acceptable. It is a much simpler approach than individual risk calculations which include both the likelihood of the event and the probability of actually achieving the effect levels. This method of calculation is shown below to be sufficient for injury and propagation risk (refer discussion below).

- *Individual risk* - calculated by considering each modelled scenario and combining its frequency with the extent of the *harm footprints.* In this HRA, individual risk is calculated using Riskcurves®, TNO's risk calculation and contour plotting program. Riskcurves® considers all scenarios, for each wind-weather combination, and sums their risk contributions across all points.

  It is then used to plot so-called *iso-risk contours* (i.e. lines of constant risk) to represent *individual risk*.

  As per the HIPAP10 guidelines (Ref 1), individual risk calculations conservatively assume that a person is present at a given location, outdoors, all of the time (24 hours per day, 365 days per year), and takes no account of the individual occupancy of the area or the chance that people could escape or seek shelter indoors.

  In practice the actual risks to persons would be much lower, since people would only be present outdoors for a fraction of the time. In particular, the risk to people inside the Wickham Wool Stores 1, 2 and 3 and buildings 4 and 5 is likely to be much lower than that calculated due to the shelter provided by the building; and

- *Societal risk* - calculated (using Riskcurves®) by assessing the likelihood of having a population present in time and space of a hazardous event, combined with the probability of the effect on members of the population.

The results of these three forms of risk calculations are presented below:

Total Likelihood of Damaging Effect

The total likelihoods of each damaging effect (injury, fatality or propagation) at the Wickham Wool Stores and buildings 4 and 5 from all events at the Caltex fuel depot are calculated using the information in Table 13 to determine the need to calculate the actual individual risk levels at the Wool Stores.

- *Total Likelihood of Injury - All Events* - The total likelihood of injury at any location of the Wickham Wool Stores and buildings 4 and 5 is calculated as 1.6 per million per year (pmpy). As this is well below the maximum individual injury risk criterion of 50pmpy at a residential area, the actual individual injury rate does not need to be calculated.

- *Total Likelihood of Propagation - All Events* - The total likelihood of propagation at any location of the Wickham Wool Stores and buildings 4 and 5 is calculated as 1.1 pmpy. As this is well below the maximum propagation risk criterion of 50pmpy and the actual individual propagation rate will not need to be calculated.

- *Total Likelihood of Fatality - All Events* - The total likelihood of fatality at the any location of the Wickham Wool Stores is 1.1 pmpy. As this is marginally above the maximum individual fatality risk criteria of 1pmpy the actual individual fatality rate will need to be calculated, refer Section 3.

Individual Risk of Fatality

Individual fatality risk contours for the Caltex fuel depot as imposed on the Wickham Wool Stores 1, 2 and 3 and buildings 4 and 5 are shown in Figure 5. The results are discussed below:

- *Risk criterion for industrial areas – 50 pmpy risk (dark red contour)* – The risk contour is fully contained within the site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot. It does not reach the Wickham Wool Stores or buildings 4 and 5.

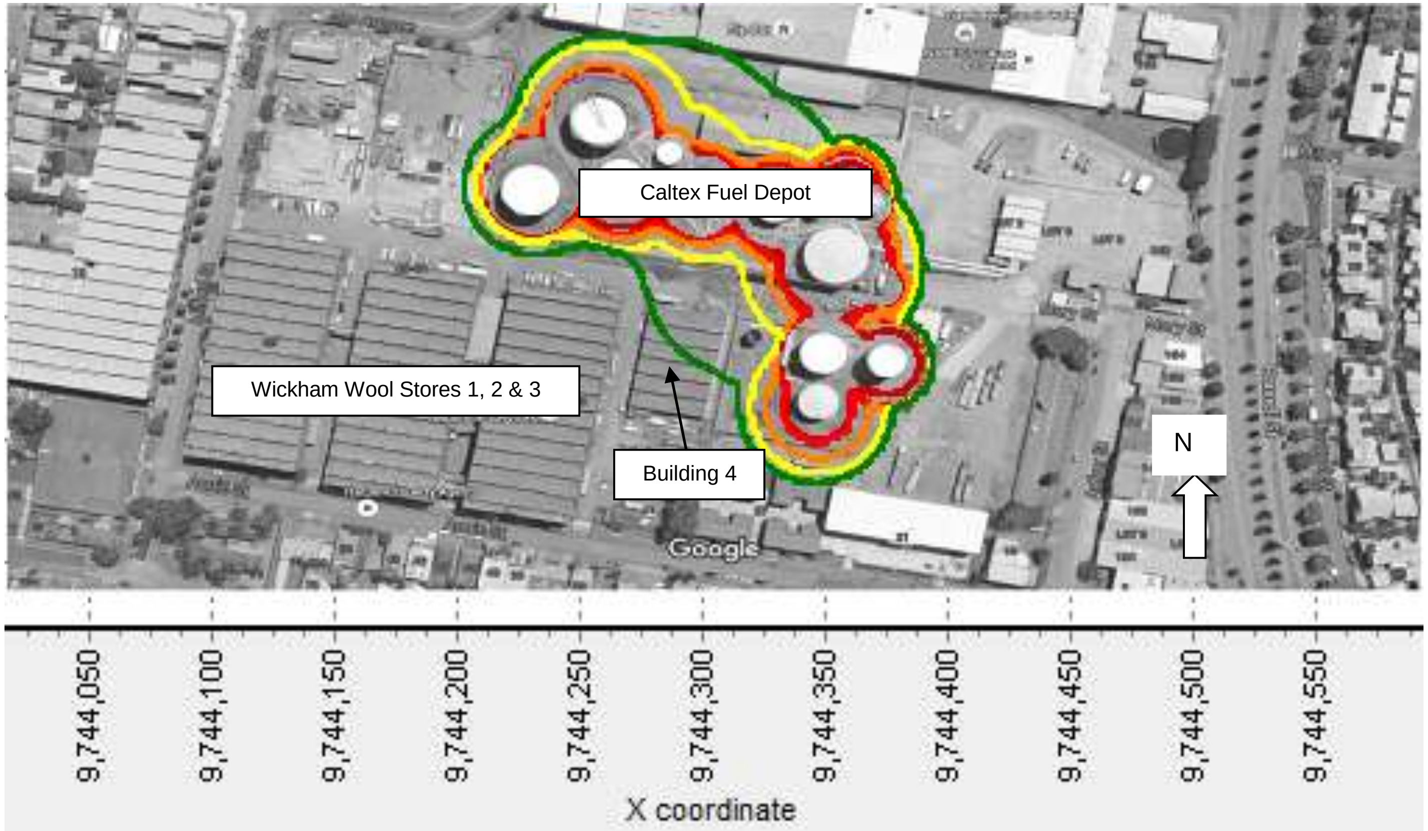
- *Risk criterion for active open space - 10 pmpy risk (light red contour)* - The risk contour is fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations). It does not encroach onto the Wool Stores or buildings 4 and 5.

- *Risk criterion for commercial development – 5 pmpy risk (orange risk contour)* - The risk contour is fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations). It does not encroach onto the Wool Stores or buildings 4 and 5.

- *Risk criterion for residential areas – 1 pmpy risk (yellow risk contour)* - The risk contour is largely contained within the Caltex site boundary except for an excursion into the (currently) unused area to the west of the fuel depot. It does not encroach onto the Wool Stores or buildings 4 and 5.

- *Risk criterion for sensitive development – 0.5 pmpy risk (green risk contour)* - The risk contour is mainly contained within the Caltex site boundary except for an excursion into the (currently) unused area to the west of the fuel depot and another excursion into the Caltex easement to the south of the site. It does not encroach onto the Wool Stores or building 5 but it does encroach onto building 4.

Figure 5 - Individual Fatality Risk Contours



Legend:			
	(dark red line)	50pmpy	Industrial development buffer
	(red line)	10pmpy	Active open space buffer
	(orange line)	5pmpy	Commercial development buffer
	(yellow line)	1pmpy	Residential buffer
	(green line)	0.5pmpy	Sensitive development buffer

Societal Risk

The societal risk graph is presented in Figure 6. It represents the incremental increase in societal risk from the proposed development at the Wickham Wool Stores and buildings 4 and 5.

Rev 1 The incremental increase in societal risk from the increase in population of the Wool Stores never enters the intolerable risk zone.

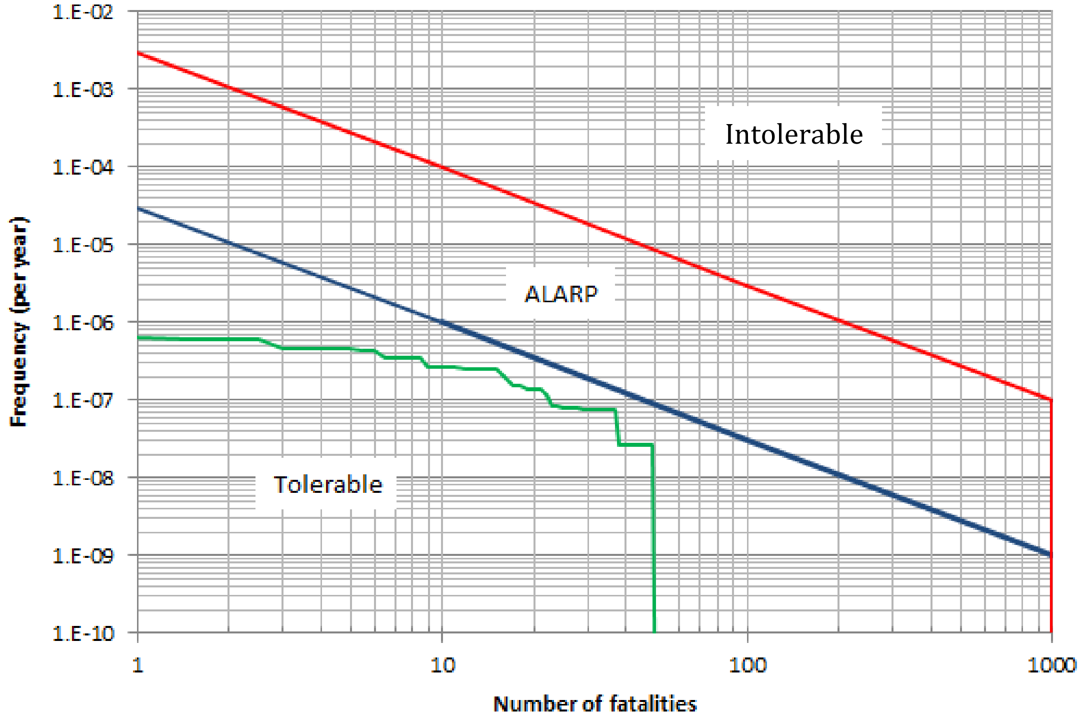
In the case where the Buncefield overfill scenarios are not included, the societal risk is within the tolerable risk zone for the full range.

With inclusion of the overfill scenarios associated with major fuel terminals (as per Buncefield (2005) and Jaipur and San Juan (2009)), the incremental increase in societal risk from the increase in population at the Wool Stores remains mainly within the tolerable zone, entering the lower region of the ALARP zone at a number of points. The small entry into the lower region of the ALARP zone can be regarded as tolerable with reference to HIPAP10 (Ref 1, Section 5.4.2), refer further discussion below.

Note that societal risk only looks at risk to occupants of the Wickham Wool Stores and buildings 4 and 5 and not at risk to staff at the fuel depot or to other neighbours around the fuel depot.

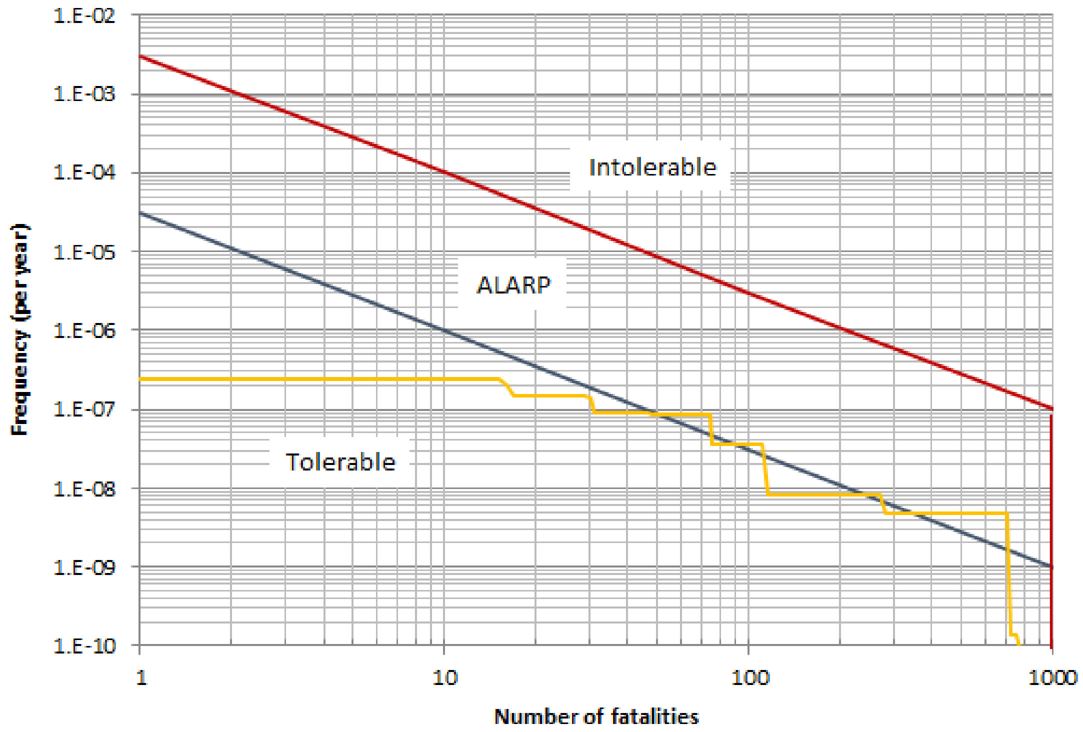
Figure 6 – Incremental Societal Risk Increase

Major overfill (Buncefield) scenarios not included



Rev 1

Major overfill (Buncefield) scenarios included



5 Summary of Findings

5.1 Fires

- Some major fire scenarios at the Caltex fuel depot have the potential to affect the Wickham Wool Stores;
- The buildings in themselves are likely to provide certain protection against the potential fires at the fuel depot;
- Australian and internationally recognised Codes and Standards provide guidance for separation of facilities such as the Caltex fuel depot and residential dwellings, including the NFPA30 (Ref 5) and AS1940 (Ref 44). The minimum NFPA separation distances between the tanks and the Wool Stores are adhered to in all circumstances. The AS1940 requirements for separation are largely adhered to with a small encroachment onto the northern front of Wool Store 3 and the northern and eastern sides of building 4. The northern front of Wool Store 3 and building 4 will not be used for residential purposes.

5.2 Vapour Explosions

Vapour cloud explosions are considered extremely rare events for the types of facilities, materials and quantities associated with the Caltex fuel depot. The computer modelling carried out for the worst case scenarios under the worst case wind weather conditions found very little flammable vapours in the vapour cloud for all mechanical failure scenarios.

Rev 1 Modelling of overfill scenarios resulting in a loss of containment into the bund with evaporation of flammable vapours during all normal wind weather conditions (including F2 conditions during the night) also result in very little flammable vapours in the vapour cloud for all mechanical failure scenarios

Rev 1 The extreme circumstance exists, however unlikely, for flashfires or vapour cloud explosions to result from major, prolonged overfills of gasoline from storage tanks during nil wind (the so called *Buncefield* scenarios). These scenarios are only known to have occurred three (3) times worldwide and, as such, are extremely unlikely, in particular for a fuel depot the size of Wickham[12]. However, they cannot be entirely ruled out (i.e. they cannot be given a NIL risk level) and have therefore been included in Revision 1 of this HRA following comments by Caltex on earlier version of the HRA report. Due to the very low likelihood of occurrence they do not affect the Individual Risk assessment (refer

[12] Estimation by Planager indicates that the capacity of the fuel depot in Wickham is about 15% of that in Buncefield

Figure 5) but are responsible for the slight excursion into the ALARP zone in the societal risk graph (Figure 6).

5.3 ADHERENCE TO RISK CRITERIA

The NSW DPIE uses a *risk-based* methodology as the basis of a framework for locational guidance for developments in the vicinity of existing potentially hazardous industry (PHI, Ref 1). In a risk based approach the likelihoods of major incidents are combined with the potential consequences to determine the risk of exposure. The resulting risk is compared with the risk criteria defined by the NSW DPIE (Ref 1). The results of the QRA is discussed in Section 5.3.

Table 15 – Adherence to Risk Criteria

Risk criteria	Results	Impact on development
Industrial development criterion 50 pmpy risk (dark red contour)	Fully contained within the site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot. It does not reach the Wickham Wool Stores or buildings 4 and 5.	Industrial development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Industrial development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Active open space criterion 10 pmpy risk (light red contour)	Fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations). It does not encroach onto the Wool Stores or buildings 4 and 5.	Active open space development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Active open space development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Commercial development criterion 5 pmpy risk (orange contour)	Fully contained within the Caltex site boundary except for a very small excursion into the (currently) unused area to the west of the fuel depot (it follows the industrial risk contour in most locations).	Commercial development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. Commercial development is excluded from the small area defined by the excursion into the (currently) unused area to

Risk criteria	Results	Impact on development
	It does not encroach onto the Wool Stores or buildings 4 and 5.	the west of the depot.
Residential development criterion 1 pmpy risk (yellow contour)	Largely contained within the Caltex site boundary except for an excursion into the (currently) unused area to the west of the fuel depot. It does not encroach onto the Wool Stores or buildings 4 and 5.	Residential development at the Wickham Wool Stores and buildings 4 and 5 is acceptable. The maximum individual fatality risk at any location of the Wool Stores and nearby buildings is 0.8 pmpy (i.e. below the NSW DPIE criterion for residential development of 1 pmpy). Residential development is excluded from the small area defined by the excursion into the (currently) unused area to the west of the depot.
Sensitive development criterion 0.5 pmpy risk (green contour)	The sensitive development risk contour is mainly contained within the Caltex site boundary except for an excursion into the (currently) unused area to the west of the fuel depot and another excursion into the Caltex easement to the south of the site. It does not encroach onto the Wool Stores or building 5 but it does encroach onto buildings 4.	The risk from the Caltex fuel depot does not preclude sensitive development at Wool Stores 1, 2 and 3 or building 5. The maximum individual fatality risk at Wool Stores 1, 2 and 3 is 0.1pmpy which is less than the criterion for sensitive development of 0.5pmpy. Sensitive development is excluded from: • Building 4 - the maximum individual fatality risk at building 4 is 0.8pmpy which is above than the criterion for sensitive development of 0.5pmpy; • The small area defined by the excursion into the (currently) unused area to the west of the depot;

Risk criteria	Results	Impact on development
		and • The area defined by the excursion into the Caltex easement to the south of the site.
Irritation risk 50 pmpy	The total likelihood of injury at any location of the Wickham Wool Stores or buildings 4 and 5 is calculated as 1.6 per million per year (pmpy).	The individual risk of injury at the Wool Stores 1, 2 and 3 and at buildings 4 and 5 is well below the maximum risk criterion.
Propagation risk 50 pmpy	The total likelihood of propagation at any location of the Wickham Wool Stores or buildings 4 and 5 is calculated as 1.1 per million per year (pmpy).	The individual risk of propagation at the Wool Stores 1, 2 and 3 and at buildings 4 and 5 is well below the maximum risk criterion.
Rev 1 Societal risk	The incremental increase in societal risk from the increase in population of the Wool Stores never enters the intolerable risk zone. - In the case where the Buncefield overfill scenarios are not included, the societal risk is within the tolerable risk zone for the full range. - With inclusion of the overfill scenarios associated with major fuel terminals (as per Buncefield (2005) and Jaipur and San Juan (2009)), the incremental increase in societal risk from the increase in population at the Wool Stores remains mainly within the tolerable zone, entering the lower region of the ALARP zone at a number of points.	The proposed development at the Wickham Wool Stores has very little impact on the cumulative societal risk for the Wickham area. The small entry into the lower region of the ALARP zone for the case where the Buncefield style overfill scenarios are taken into account does not appear significant given the fact that these scenarios are barely credible for the Wickham fuel depot and the number of highly conservative assumptions made throughout this HRA, as discussed below.

6 FINAL CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

In NSW, land use safety is determined based on risk, and in risk terms the Wickham Wool Stores are acceptable for the proposed development because the likelihoods of major incidents at the Caltex fuel depot are very low.

Rev 1 The levels of risks to public safety from a proposed residential and/or commercial development of the Wickham Wool Stores and the adjacent buildings 4 and 5 are within the most stringent accepted risk criteria for land use safety (individual and societal risk considerations).

Rev 1 Individual risk criteria for residential and commercial areas, as appropriate, are adhered to for this development. While the result show that building 4 cannot be used for sensitive development, this usage is not within the proposed development plan. The use of the area immediately to the west of the fuel depot as parkland or playground confirms with the land use restriction in this area.

Rev 1 The incremental increase in societal risk in the area resulting from the proposed development is very low and the societal risk associated with the increase in population is well within the tolerable zone for the full range with a small excursion into the lower region of the ALARP zone for the case where the barely credible Buncefield scenarios are included. It never enters the intolerable region

Rev 1 Given that scenarios of the type which occurred in Buncefield in 2005 are extremely uncommon and is not expected to be a credible type of event for the relatively small fuel depot at Wickham[13]; and given the extensive additional mitigation measures designed into the buildings closest to the fuel depot[14], and lastly given that all other risk criteria are met, this small excursion into the ALARP region does not appear significant and the risk associated with the

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[13] Given that the Buncefield style scenarios have only occurred three (3) times worldwide at much larger fuel terminals than the one at Wickham, they were not considered credible for a fuel depot the size of the one at Wickham and were therefore not included in the earlier versions of this HRA report. As a response to comments by Caltex on the earlier version of the HRA and as they cannot completely be ruled out (i.e. cannot be given a nil risk), they were included in Revision 1 of this HRA.

[14] A number of mitigating features have been designed into the buildings as discussed in Section 2.3, including fire rated walls along the full length of the side of Wool Store 3 and fire proofing of parts of building 4 (yet to be defined); and modifying Wool Store 3 in order to increase the separation distance between people working in the building and the Caltex site, deleting the residential component from the side of the building facing the fuel depot. These mitigating features have not been included in the risk assessment calculations but would help to improve safety for the occupants of the buildings.

development can be considered tolerable. This follows the guidance in the NSW DPIE document HIPAP10 (Ref 1).

Rev 1 The provision of fire proofing against radiant heat levels from major fire incidents at the fuel depot at Wool Store 3 and building 5, while not quantified, is expected to reduce the actual risk at the proposed development. Such fire proofing would also significantly reduce the risk of flammable vapours entering the buildings, and therefore would also mitigate from effects resulting from the extreme case Buncefield scenario.

Any potential use of the building 4 for sensitive development (child care, elderly care etc.) is restricted. This building is planned for retail usage.

Restrictions also apply to the area immediately to the west of the fuel depot (within the development area) and from the easement between the Wool Stores and the depot.

6.2 RECOMMENDATION

Radiant heat levels from major incidents do impinge on Wool Store 3 and building 4 and damage to windows, building and walls may occur. Radiant heat radiation levels also impinge on the currently undeveloped area to the west of the depot.

Rev 1 This has been taken into account in the design of Wool Store 3, with a buffer provided between the wall facing the fuel depot and the wall of the building and with the building wall having been designed with fire rating (to be confirmed). **It is recommended that the fire rating of the northern wall facing the fuel depot be determined as part of the detailed design of Wool Store 3.**

Rev 1 The North side of building 4 facing the fuel depot and the Northeast corner of building 4 facing the larger tank may be impacted by heat radiation from major incidents at the fuel depot. **It is recommended that fire rating on the north side and north eastern corner of building 4 be considered in detailed design.**

Such design solutions are likely to reduce the risk to the occupants of the building which have not been assessed quantitatively in the HRA.

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