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QRA for G3X EIS Alcan Gove NT

MARSH

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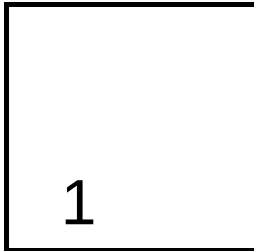
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DISCLAIMER

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1. Executive Summary

This quantified risk assessment (QRA) of the Environmental Impact Statement (EIS) has been prepared by Marsh on behalf of URS. URS are the company undertaking the EIS for Alcan Gove. It has been prompted by the third stage expansion, which has also required that a “baseline” EIS be prepared for the Gove operation.

This study has shown that there are no significant risks to life or property at the boundaries of the lease. Contours of effect from explosion, heat flux, projectiles and hazardous materials have been produced to reach this conclusion. The findings have considered the separations, and the risk management processes in place as suitable for the control of potential boundary hazards associated with the Alcan Gove Facility.

Alcan Gove is located in an inherently safe location, being on a peninsula and bounded on three sides by the ocean. The nearest residential area is located at Gallupa, which is near the southern plant boundary, but is well separated from hazardous process areas.

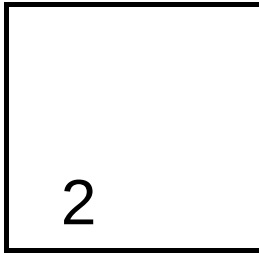
Hazard endpoints were estimated using mathematical and empirical simulation, for each of the scenarios, where a potential boundary hazard was considered possible. The results of these calculations for worst case scenarios are summarised in Table 1.1, below.

Table 1.1 – Hazard Endpoint Summary

Scenario	Hazard Endpoint Description	Value
1 – Chlorine Release	Toxicity Limit	4.8km
	Serious Injury Threshold	1.7km
2 – LT Digester Overpressure	7kPa Incident Overpressure	386m
	35kPa Incident Overpressure	134m
	70kPa Incident Overpressure	75m
3 – LT Digestion Flash Vessel Overpressure	7kPa Incident Overpressure	292m
	35kPa Incident Overpressure	101m
	70kPa Incident Overpressure	57m
4 – LT Digestion Flash Vessel Explosion	7kPa Incident Overpressure	141m
	35kPa Incident Overpressure	47m
	70kPa Incident Overpressure	33m
6 – HT Digester Overpressure	7kPa Incident Overpressure	299m
	35kPa Incident Overpressure	101m
	70kPa Incident Overpressure	67m
7 – HT Digestion Flash Vessel Overpressure	7kPa Incident Overpressure	384m
	35kPa Incident Overpressure	134m
	70kPa Incident Overpressure	74m
13 – Calcination ESP Explosion	7kPa Incident Overpressure	292m
	35kPa Incident Overpressure	98m
	70kPa Incident Overpressure	66m
14 – Boiler Fuel Side Explosion	7kPa Incident Overpressure	186m
	35kPa Incident Overpressure	63m
	70kPa Incident Overpressure	43m
15 – Boiler Steam Side Explosion	7kPa Incident Overpressure	336m
	35kPa Incident Overpressure	117m
	70kPa Incident Overpressure	65m
16 – Condensate Receiver Overpressure	7kPa Incident Overpressure	78m
	35kPa Incident Overpressure	27m
	70kPa Incident Overpressure	15m
17 – Natural Gas Vapour Cloud Explosion	7kPa Incident Overpressure	1830m
	35kPa Incident Overpressure	614m
	70kPa Incident Overpressure	416m
19 – Diesel Tank Explosion	7kPa Incident Overpressure	152m
	35kPa Incident Overpressure	51m
	70kPa Incident Overpressure	35m
20 – Light Fuel Tank Farm Fire	Injury Zone	144m
	Fatality Zone	100m
21 – Bunker Oil Tank Explosion	7kPa Incident Overpressure	234m
	35kPa Incident Overpressure	79m
	70kPa Incident Overpressure	53m

As a result of the above conditions only two scenarios were identified that could potentially effect the facilities neighbours. These were a vapour cloud explosion (Scenario 17), occurring near the Gate Station, and a chlorine release (Secnario 1). The chlorine storage facility is located remote from the refinery at a water treatment facility, which is located approximately 1km from the airport. This is the nearest know occupied area.

An analysis of the likelihood of these scenarios eventuating shows that the risk to local residents falls within the acceptable region as defined by the NSW Department of Planing (1997).



2. Introduction

As part of the G3X expansion EIS development process Marsh was commissioned by Alcan Gove to assist in the formulation of a Quantified Risk Assessment of site boundary hazards. This document describes and models a series of potential boundary hazard scenarios that were developed in a workshop situation on Friday 15 August, 2003. The following people were present at this workshop.

- Dave Sutherland
- Greg Daniels
- Steve Vellacott
- Dick O'Hanlon
- Nick Marsh
- Paul Mastin
- Dave Brodie
- Dave Syme
- Dave Holmyard
- Gill Tetley
- Dalis Raynor (Marsh)
- James Keneally (Marsh)

The scope of the investigation was defined as a “quantitative risk assessment on baseline case & G3X that could lead to a fatality beyond the fenceline during operation (ie, post construction).” The areas considered were:

- Mine & borefields
- RDA
- Refinery/wharf/power station/harbour tank farm
- Overland conveyor

The following scenarios were identified for boundary consequence and risk analysis during the workshop.

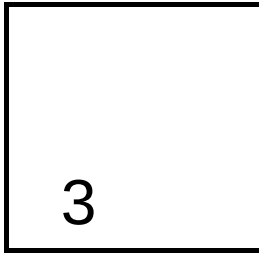
- Scenario 1 – Chlorine Release from Water Treatment
- Scenario 2 – LT Digester Overpressure
- Scenario 3 – LT Digestion Flash Vessel Overpressure
- Scenario 4 – LT Digestion Flash Vessel Explosion
- Scenario 5 – LT Digestion Boiling Caustic Cloud Release
- Scenario 6 – HT Digester Overpressure
- Scenario 7 – HT Digestion Flash Vessel Overpressure
- Scenario 8 – HT Digestion Flash Tank Explosion
- Scenario 9 – Structural Failure of Thickener / Washer
- Scenario 10 – Liquor Purification Kiln Explosion
- Scenario 11 – Hydrate Filtration Tank Failure
- Scenario 12 – Precipitator Vessel failure
- Scenario 13 – Calcination Kiln Explosion
- Scenario 14 – Boiler Explosion (Fuel Side)
- Scenario 15 – Boiler Explosion (Steam Side)
- Scenario 16 – Condensate Receiver Overpressure
- Scenario 17 – Unconfined Vapour Cloud Explosion (Gate Station)
- Scenario 18 – Pipeline Jet Fire at Gate Station
- Scenario 19 – Jet A1 or Petrol Tank Explosion
- Scenario 20 – Light Fuel Tank Farm Fire
- Scenario 21 – Bunker Oil Fire

A detailed investigation of each potential boundary hazard scenario is provided in Section 4 of this document.

The process was to first measure the consequences of each scenario to determine in particular if a fatality could be caused at the site boundary by any identified event. The likelihood of any such event would then be estimated to determine the probability of a fatality. This would lead to two outcomes:

1. An understanding of the tolerability of the risk, and
2. The opportunities available to reduce the risk, including the extent to which the risk could be affected.

Alcan Gove is situated in an inherently safe location, being on a peninsula and bounded on three sides by the ocean. The nearest residential area is located at Gallupa, which is near the southern plant boundary, but is well separated from hazardous process areas. A chlorine storage facility is located remote from the refinery at a water treatment plant, which is located approximately 1km from the airport. This is the nearest know occupied area to this potential hazard.



3. Methodology

The scenarios identified in the workshop were each modelled using at least one appropriate method. In most cases a computer based modelling program, ARCHIE, was used.

Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) is a publicly available air dispersion and explosion model primarily intended for use by emergency response personnel. ARCHIE was produced by Hazmat America, Inc., and has been approved for distribution by the Federal Emergency Management Agency (FEMA), the U. S. Department of Transportation (DOT), and EPA.

ARCHIE will generally overestimate potential threats to communities, but in occasional cases underestimations are possible (US EPA Handbook of Chemical Hazard Analysis Procedures). For this reason, where possible, two methods were used to model a single scenario of each type. For example, the results provided by ARCHIE for vessel overpressure explosions were tested for accuracy using the TNT equivalent method described in Lees (1991). The method which provided the most conservative consequence estimate was then adopted for the remainder of similar scenarios. As each scenario is discussed in Section 4, the applicable consequence modelling methodology is described.

The results of each of the scenario hazard analyses are provided in Section 4 of this document. They are also plotted as consequence contours on diagrams of the site (see attachments) to give a pictorial indication of the distances to salient consequence levels assuming that the hazardous scenario in question eventuates. For example, the 5kW/m^2 radiation contour is plotted for the pool fire scenario in Section 4.20 because this represents the minimum distance at which a 10 second exposure to the fire could result in pain, or at which a 1 minute exposure has a 10% chance of causing 2nd degree burns.

Table 3.1 – Incident Overpressure Effects

Incident Overpressure	Damage
2kPa	Missile Limit; 10% window glass broken
3.5kPa	Large and small windows usually shattered; occasional damage to window frames
7kPa	Partial demolition of houses, made uninhabitable; residential housing limit
14kPa	Partial collapse of walls and roofs of houses
35kPa	Wooden utility poles snapped; nearly complete destruction of houses; 20-25% chance of fatality for people inside buildings
70kPa	Total destruction of buildings; 30% chance of eardrum rupture for person in open; ,<1% chance of fatality for person in open

(Lees, 1999) and (Emergency Plans – Guidelines for Major Hazard Facilities, 1996)

In the case of Scenario 1 (Section 4), ARCHIE was not considered to be a suitable modelling tool (the reasons for this are discussed in Section 4.1). The boundary hazard analysis was therefore conducted using information provided in the US EPA document, *Risk Management Program Guidance for Offsite Hazard Analysis* (1999).

Scenarios that were shown by modelling to be potentially hazardous to Alcan Gove neighbours were further investigated to estimate the likelihood of these scenarios eventuating and causing harm. This was done using documented failure frequency and consequence estimations. The methodologies that were utilised are discussed in the sections of this report relevant to the appropriate boundary hazard scenario.

Suggested individual fatality risk criteria are provided by the NSW Dept of Urban Affairs and Planning (1997). These are summarised in Table 3.2, below.

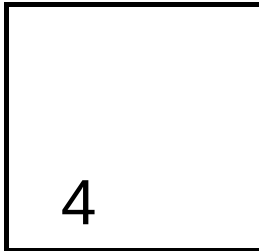
Table 3.2 - Suggested Individual Fatality Risk Criteria

Land Use	Suggested Criteria (risk in a million per year)
Hospitals, schools, child care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial	50

Detailed likelihood estimations were only conducted where permanent dwellings could be potentially affected by hazardous scenarios. This is due to the fact that the exposure timeframe for people on the surrounding beaches or bushland is considered to be low (ie, minimal *people seconds* in the impact zone).

The potential effects of missiles due to explosions were not quantified, as the density of permanent dwellings within the potential missile range is low. This means that the likelihood of a person occupying the space in which a small missile may land at a given time is very low. Permanent residential areas (Gallupa) account for less than 0.7% of the land area within a 1km radius of the centre of the process area, and less than 0.2% within 2km.

A full list of reference material, supporting the methodology utilised in this investigation is provided in Section 6 of this document.



4. Consequence Analysis for Scenarios

4.1. Scenario 1 – Chlorine Release from Water Treatment

The US EPA document, *Risk Management Program Guidance for Offsite Consequence Analysis (1999)*, suggests that a suitable scenario for modelling of worst case toxic releases should assume that 100% of the stored gas is released in ten minutes to an atmosphere with a stability factor of F and a wind speed of 1.5m/s. An alternative scenario is also suggested, whereby a stability factor of D (clear day) is used along with a wind speed of 3m/s.

The toxic limit for chlorine is specified in the above document as 3ppm, being a concentration at which minor irritation may be expected in the receptor. According to *Emergency Plans – Guidelines for Major Hazard Facilities (1996)*, the threshold concentration for fatalities caused by chlorine is 20ppm. The LC₅₀ of chlorine is estimated at 293ppm/1H (rat) (BOC Gasses – Chlorine MSDS).

ARCHIE was not used as the primary modelling tool for this scenario as it does not provide suitable functionality for dense gas modelling. It was, however used to estimate scaling factors between contours of different toxic end points.

4.1.1. Model Parameters and Assumptions

Worst Case

- Mass of chlorine stored = 900kg
- Ambient temperature = 30⁰C
- Wind speed = 1.5m/s
- Release rate = 90kg/min
- Atmospheric Stability Factor = F

Alternative Scenario

- Mass of chlorine stored = 900kg
- Ambient temperature = 30⁰C
- Wind speed = 3m/s
- Release rate = 90kg/min
- Atmospheric Stability Factor = D

4.1.2. Model Results

Toxicity limits for the two scenarios, above, are presented in the US EPA document, *Risk Management Program Guidance for Offsite Consequence Analysis (1999)*. These are as follows.

Worst Case

Toxicity Limit Distance = 4.8km (ie, distance to 3ppm contour)

From ARCHIE under the same conditions a scaling factor of 3 exists for the relationship between the 3ppm contour and the 20ppm (significant injury, possible death), ie:

$$d_{20ppm} = \frac{d_{3ppm}}{3}, \text{ where } d = \text{distance to concentration threshold.}$$

The same approximate scaling factor is also suggested in a model provided in the document, *Emergency Plans – Guidelines for Major Hazard Facilities (1996)*.

Therefore it is estimated that the distance to the 20ppm contour for the scenario above is approximately 1.7km (there is potentially significant error in this estimation).

Alternative Scenario

Toxicity Limit Distance = 0.96km

And using the same approximation as above the distance to the 20ppm contour is estimated as 320m.

4.1.3. Likelihood Analysis

Owing to the fact that the Gove airport is estimated to lie 1km from the chlorine storage facility an analysis of the likelihood of a worst case release leading to a fatality is examined in this section.

For people at the airport to be affected by a chlorine release, the criteria listed in Table 4.1, below must all combine concurrently, ie the worst case conditions must be met.

Table 4.1 – Worst Case Scenario Conditions and Estimated Likelihood

Condition	Likelihood Estimate	Basis of Estimate
Sudden and total release	1x10 ⁻⁵ /yr	UK HSE (2003) Based on highest frequency of either vessel or pipe rupture
Stability Class F	~50%	Needs to be low wind conditions and at night (ARCHIE)
Wind in right direction	~50%	Based on information provided by URS, suggesting that prevailing wind conditions are highly seasonal.

The product of these likelihood estimates is 2.5x10⁻⁶/yr.

The NSW Dept of Planning (1997) recommends that the frequency of toxic concentrations which may cause significant injury to sensitive members of the public should not exceed 1×10^{-5} /yr in residential areas. From the above likelihood estimate it can be seen that according to these criteria, the risk associated with this scenario is acceptable.

The NSW Dept of Planning (1997) also suggests that the individual risk of fatality at a residential development should not exceed 1×10^{-6} /yr. If it is assumed that 10% of people may be fatally affected by an exposure to 20ppm then the risk of fatality at the Gove airport can be estimated at 2.5×10^{-7} /yr, and is therefore within the NSW DOP guidelines. This assumption is considered to be conservative considering that 20ppm is considered to be the threshold for fatality (Guidelines for Major Hazard Facilities, 1996) and that the LC_{50} (rat) is 293ppm/1H (rat) (BOC Gasses – Chlorine MSDS). This figure is also based on the assumption that the airport is occupied 100% of the time, which is also a conservative estimate.

It should also be noted that Gove airport is not a residential area. If this facility was considered to be an industrial site, then according to the NSW Dept of Planning (1997) guidelines the suggested fatality risk criteria would be 50×10^{-6} , or fifty times the fatality risk criteria for a residential area. Obviously, the estimated level of risk associated with a worst case chlorine release is well below this level – 20 times lower in fact.

4.2. Scenario 2 – LT Digester Overpressure

This scenario is based on the largest potential overpressure event in the low temperature digestion process, which could be caused by the rupture of one of the four G3X LT digesters.

At 250m³, the existing LT digesters are half the size of the G3X digesters and have a maximum delivery pressure of 31ata.

4.2.1. Model Parameters and Assumptions

G3X Digester

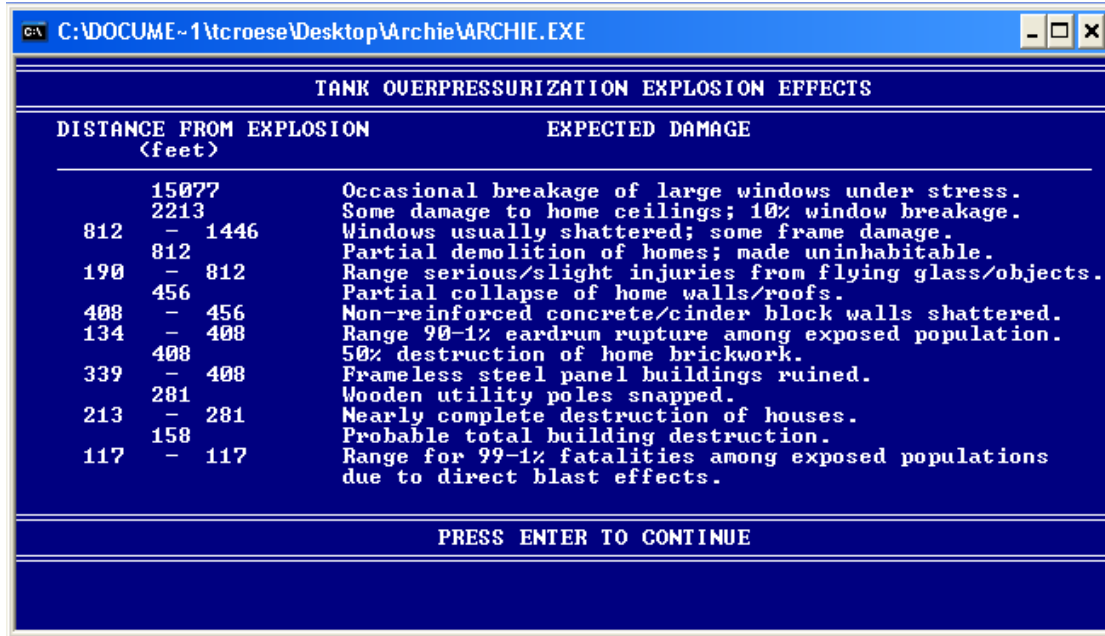
- Volume of vapour space = 430m³ (this is a significant overestimation as it assumes that 80% of the vessel is filled with vapour. Under normal circumstances there is no vapour space and under abnormal conditions a maximum vapour space of 20% is expected). It is assumed that the vessel could not be empty of liquid and still explode as a path for pressure relief would be available.
- Constituents of vapour space = assume steam, although some entrained caustic would be present.
- Internal Temperature = 145⁰C
- Ambient Temperature = 30⁰C
- Specific heat ratio of steam = assume 1.3 for polyatomic vapour
- Vessel rupture pressure = assume 60ata (5 x design pressure)
- Vertical cylindrical vessel

4.2.2. Model Results

ARCHIE was unable to model at the conditions shown above, so the model was run at a volume of 134m³ and scaled up using the relationship:

$$R_2 = \frac{R_1 W_2^{0.3333}}{W_1^{0.3333}} \text{ (This assumption was tested and proved accurate)}$$

Figure 4.1 – Incident Overpressure Effects Vs Distance for LT Digester Overpressure



The screenshot shows a window titled 'C:\DOCUME~1\mcroese\Desktop\Archie\ARCHIE.EXE'. Inside, a table titled 'TANK OVERPRESSURIZATION EXPLOSION EFFECTS' is displayed. The table has two columns: 'DISTANCE FROM EXPLOSION (feet)' and 'EXPECTED DAMAGE'. The data is as follows:

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
15077	Occasional breakage of large windows under stress.
2213	Some damage to home ceilings; 10% window breakage.
812 - 1446	Windows usually shattered; some frame damage.
812	Partial demolition of homes; made uninhabitable.
190 - 812	Range serious/slight injuries from flying glass/objects.
456	Partial collapse of home walls/roofs.
408 - 456	Non-reinforced concrete/cinder block walls shattered.
134 - 408	Range 90-1% eardrum rupture among exposed population.
408	50% destruction of home brickwork.
339 - 408	Frameless steel panel buildings ruined.
281	Wooden utility poles snapped.
213 - 281	Nearly complete destruction of houses.
158	Probable total building destruction.
117 - 117	Range for 99-1% fatalities among exposed populations due to direct blast effects.

At the bottom of the window, it says 'PRESS ENTER TO CONTINUE'.

From the overpressure effects table provided in Attachment 1, the following table showing incident overpressure against distance from the source can be generated.

Table 4.2 – Incident Overpressure Vs Distance for LT Digester Overpressure

Incident Overpressure (kPa)	Distance Calculated (m) (ARCHIE)	Distance Extrapolated (m) (ARCHIE)	Distance (m) (Lees)
70	51	75	49
35	91	134	74
14	147	217	131
7	262	386	218
3.5	466	687	385
2	714	1052	602

4.2.3. Test of Results

The results, above, provided by ARCHIE were compared with hand calculations based on formulae shown in Lees (1991). These calculations are based on a TNT equivalent method for estimating incident overpressure.

Lees' model assumes 100% explosion yield ie, 100% of available energy goes into forming the blast wave. This is more likely to be 40-80% due to dissipative effects including energy absorbed by the fracturing vessel and the ground (Lees, Perry). The 100% yield factor will be used as this provides the most conservative overpressure estimate. From Lees:

$$W_e = nRT \ln(P_1/P_2) \text{ (Assume ideal gas and adiabatic expansion)}$$

Where: W_e = Energy released by expansion of fluid
 n = Number of moles of vapour
 R = Ideal gas constant
 P_1 = Initial pressure of vapour
 P_2 = Ambient pressure (1ata)

$$W_e = 10,563\text{MJ}$$

The equivalent mass of TNT is calculated using the equation:

$$M_{\text{TNT}} = W_e/4.5$$

Where: M_{TNT} = Equivalent Mass of TNT
 4.5 = Explosive yield of TNT in MJ/kg

$$M_{\text{TNT}} = 2347\text{kg}$$

Multiply M_{TNT} by factor of 2 to account for blast wave being reflected off the ground (assume 100% reflection – conservative assumption)

Therefore TNT equivalent = 4695kg

By using the charts in Lees (1991) for incident overpressure as a function of scaled distance the distances in Table 4.1 can be calculated.

From a comparison of the overpressure distances calculated by ARCHIE, and using the method suggested by Lees (1991) it can be seen that ARCHIE provides a much more conservative estimate. This is largely because ARCHIE takes into account that the nature of fluid expansion in an overpressure event is different from a high explosive. More specifically, the incident pressure in the near field is generally significantly lower.

A similar comparison of results from ARCHIE and alternative calculation methods will not be conducted throughout this report. As ARCHIE has been shown to be the conservative model, its result for overpressure events will be used.

Attachment 2 shows the 7kPa overpressure contour for the LT Digester overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits. There are no third party owned properties within the 7kPa contour, and the 70kPa contour is well within the boundary.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 1052m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.3. Scenario 3 – LT Digestion Flash Vessel Overpressure

The flash vessel with the largest potential source of fluid expansion energy is the first vessel in the G3X line, based on the assumption that this vessel is completely full of vapour at its rupture pressure.

4.3.1. Model Parameters and Assumptions

G3X First Flash Vessel

- Volume of vapour space = 504m³ (this is a significant overestimation as it assumes that 100% of the vessel is filled with vapour. Under normal circumstances a maximum vapour space of 70% is expected).
- Constituents of vapour space = assume steam, although some entrained caustic would be present.
- Internal Temperature = 135⁰C
- Ambient Temperature = 30⁰C
- Specific heat ratio of steam = assume 1.3 for polyatomic vapour
- Vessel rupture pressure = assume 30ata (5 x design pressure)
- Vertical cylindrical vessel

4.3.2. Model Results

ARCHIE was unable to model at the conditions shown above, so the model was run at a volume of 252m³ and scaled up using the relationship:

$$R_2 = \frac{R_1 W_2^{0.3333}}{W_1^{0.3333}} \quad (\text{This assumption was tested and proved accurate})$$

Figure 4.2 – Incident Overpressure Effects Vs Distance for LT Digestion Flash Vessel Overpressure

TANK OVERPRESSURIZATION EXPLOSION EFFECTS		
DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
13325		Occasional breakage of large windows under stress.
1956		Some damage to home ceilings; 10% window breakage.
718	- 1278	Windows usually shattered; some frame damage.
718		Partial demolition of homes; made uninhabitable.
168	- 718	Range serious/slight injuries from flying glass/objects.
403		Partial collapse of home walls/roofs.
380	- 403	Non-reinforced concrete/cinder block walls shattered.
119	- 392	Range 90-1% eardrum rupture among exposed population.
392		50% destruction of home brickwork.
299	- 380	Frameless steel panel buildings ruined.
249		Wooden utility poles snapped.
188	- 249	Nearly complete destruction of houses.
140		Probable total building destruction.
106	- 112	Range for 99-1% fatalities among exposed populations due to direct blast effects.

PRESS ENTER TO CONTINUE

From the overpressure effects table provided in Attachment 1, the following table showing incident overpressure against distance from the source can be generated.

Table 4.3 – Incident Overpressure Vs Distance for LT Digestion Flash Vessel Overpressure

Incident Overpressure (kPa)	Distance Calculated (m) (ARCHIE)	Distance Extrapolated (m) (ARCHIE)
70	45	57
35	80	101
14	130	164
7	232	292
3.5	412	519
2	631	795

Attachment 3 shows the 7kPa overpressure contour for the LT Digestion Flash Vessel overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 795m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.4. Scenario 4 – LT Digestion Flash Vessel Explosion

This scenario is based on the assumption that a flash vessel could fill up with flammable hydrocarbon gas mixtures and be ignited.

The scenario is modelled as vapour cloud explosion with yield factor of 100%, occurring close to the ground. This will overestimate the resultant overpressure as it assumes that 100% of the available energy goes into forming the blast wave.

Overpressure and heat radiation contours are calculated using ARCHIE.

4.4.1. Model Parameters and Assumptions

- Volume of Vessel = 500m³
- Assume vessel at atmospheric conditions
- Assume ambient temperature = 30°C
- Assume contents of vessel are methane
- Treat methane as ideal gas for calculating quantity in vessel
- Assume methane concentration is 15% (ie UFL (Perry, 1996))
- Calculate quantity of methane = 48kg
- Assume explosive yield = 1
- Assume explosion near ground

4.4.2. Model Results

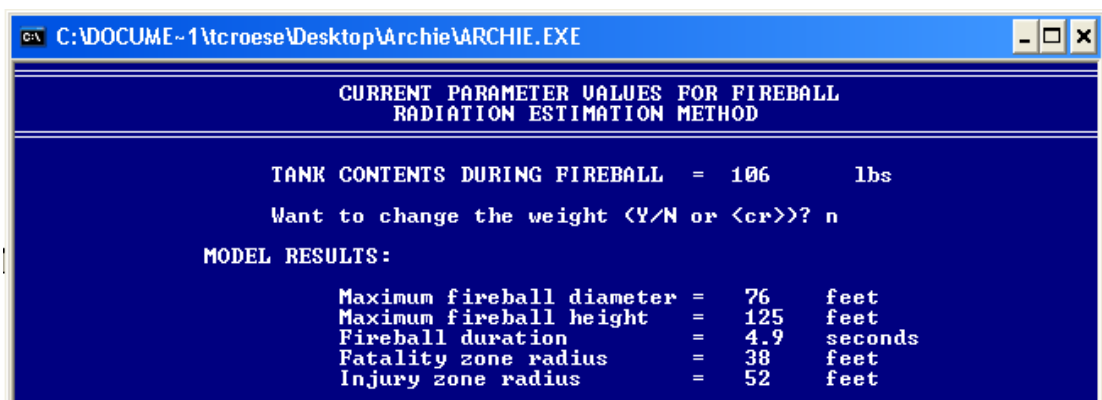
Figure 4.3 Incident Overpressure Effects Vs Distance for LT Digestion Flash Vessel Explosion

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS		
DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
8290		Occasional breakage of large windows under stress.
1168		Some damage to home ceilings; 10% window breakage.
436	757	Windows usually shattered; some frame damage.
436		Partial demolition of homes; made uninhabitable.
112	436	Range serious/slight injuries from flying glass/objects.
263		Partial collapse of home walls/roofs.
201	263	Non-reinforced concrete/cinder block walls shattered.
90	233	Range 90-1% eardrum rupture among exposed population.
227		50% destruction of home brickwork.
168	201	Frameless steel panel buildings ruined.
147		Wooden utility poles snapped.
121	147	Nearly complete destruction of houses.
100		Probable total building destruction.
60	82	Range for 99-1% fatalities among exposed populations due to direct blast effects.
PRESS ENTER TO CONTINUE		

Table 4.4 – Incident Overpressure Vs Distance for LT Digestion Flash Vessel Explosion

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	33
35	47
14	85
7	141
3.5	244
2	377

Figure 4.4 Effects of Fireball for LT Digestion Flash Vessel Explosion



Attachment 4 shows the 7kPa overpressure contour for the LT Digestion Flash Vessel overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 377m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

Both the injury and fatality zone radii in the fire ball analysis are well within the boundary.

4.5. Scenario 5 – LT Digestion Boiling Caustic Cloud Release

No credible scenario could be developed which would result in a boundary hazard. Therefore this event was not modelled.

4.6. Scenario 6 – HT Digester Overpressure

4.6.1. Model Parameters and Assumptions

HT Digester

- Volume of vapour space = 312m³ (this is a significant overestimation as it assumes that 100% of the vessel is filled with vapour. Under normal circumstances a maximum vapour space of 20% is expected).
- Constituents of vapour space = assume steam, although some entrained caustic would be present.
- Internal Temperature = 225⁰C
- Ambient Temperature = 30⁰C
- Specific heat ratio of steam = assume 1.3 for polyatomic vapour
- Vessel rupture pressure = assume 170ata (5 x design pressure)
- Vertical cylindrical vessel

4.6.2. Model Results

ARCHIE was unable to calculate this model, so the TNT equivalent method described in Lees (1991) was used. This is considered to be a suitable model for damage estimation from vessel overpressure events (Perry, 1996)

Lees models assumes 100% explosion yield ie, 100% of available energy goes into forming the blast wave. This is more likely to be 40-80% due to dissipative effects including energy absorbed by the fracturing vessel and the ground (Lees, Perry).

$W_e = nRT \ln(P_1/P_2)$ (Assume ideal gas and adiabatic expansion)

Where:

W_e	= Energy released by expansion of fluid
n	= Number of moles of vapour
R	= Ideal gas constant
P_1	= Initial pressure of vapour
P_2	= Ambient pressure (1ata)

$$W_e = 27,240 \text{ MJ}$$

The equivalent mass of TNT is calculated using the equation:

$$M_{\text{TNT}} = W_e / 4.5$$

Where:

M_{TNT}	= Equivalent Mass of TNT
4.5	= Explosive yield of TNT in MJ/kg

$$M_{\text{TNT}} = 6053 \text{ kg}$$

Multiply M_{TNT} by factor of 2 to account for blast wave being reflected off the ground (assume 100% reflection – conservative assumption)

Therefore TNT equivalent = 12106kg

By using the charts in Lees (1991) for incident overpressure as a function of scaled distance the distances in Table 3.1 can be calculated.

Table 4.5 – Incident Overpressure Vs Distance for HT Digester Overpressure

Incident Overpressure (kPa)	Distance (m) (Lees)
70	67
35	101
14	179
7	299
3.5	529
2	828

Attachment 5 shows the 7kPa overpressure contour for the LT Digestion Flash Vessel overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 828m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.7. Scenario 7 – HT Digestion Flash Vessel Overpressure

The worst case scenario is considered to be an overpressure explosion of the larger flash vessel, even though it operates at a lower pressure.

4.7.1. Model Parameters and Assumptions

- Assume 100% steam (usually 30% slurry)
- Vapour space = 590m³
- Contents = Steam (also entrained caustic, but modelled as steam)
- Temperature = 139C
- Assume ambient air Temp = 30C
- Operating Pressure = 2.6 ata
- Assume Fracture Pressure = 57 ata (ie 5 x design pressure)
- Tank orientation = Vertical cylinder
- Assume specific heat ratio = 1.3 (polyatomic gas (Archie))

4.7.2. Model Results

ARCHIE was unable to model at the conditions shown above, so the model was run at a volume of 1000ft³ and scaled up using the relationship:

$$R_2 = \frac{R_1 W_2^{0.3333}}{W_1^{0.3333}} \quad (\text{This assumption was tested and proved accurate})$$

Figure 4.5 - Incident Overpressure Effects Vs Distance for HT Digestion Flash Vessel Overpressure

TANK OVERPRESSURIZATION EXPLOSION EFFECTS		
DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
9234		Occasional breakage of large windows under stress.
1356		Some damage to home ceilings; 10% window breakage.
497	886	Windows usually shattered; some frame damage.
497		Partial demolition of homes; made uninhabitable.
117	497	Range serious/slight injuries from flying glass/objects.
279		Partial collapse of home walls/roofs.
253	279	Non-reinforced concrete/cinder block walls shattered.
82	253	Range 90-1% eardrum rupture among exposed population.
253		50% destruction of home brickwork.
208	253	Frameless steel panel buildings ruined.
173		Wooden utility poles snapped.
130	173	Nearly complete destruction of houses.
97		Probable total building destruction.
73	97	Range for 99-1% fatalities among exposed populations due to direct blast effects.
PRESS ENTER TO CONTINUE		

From the overpressure effects table provided in Attachment 1, the following table showing incident overpressure against distance from the source can be generated.

Table 4.6 – Incident Overpressure Vs Distance for HT Digestion Flash Vessel Overpressure

Incident Overpressure (kPa)	Distance Calculated (m) (ARCHIE)	Distance Extrapolated (m) (ARCHIE)
70	31	74
35	56	134
14	90	216
7	160	384
3.5	286	686
2	437	1049

Attachment 6 shows the 7kPa overpressure contour for the HT Digestion Flash Vessel overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 1049m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.8. Scenario 8 – HT Digestion Flash Tank Explosion

Based on information provided by Alcan Gove it is not expected that this scenario, which relates to ignition of a build-up of combustible gas in a HT Digestion flash vessel, would be significantly greater than for Scenario 4.

4.9. Scenario 9 – Structural Failure of Thickener / Washer

Secondary containment facilities are in place for accidental releases from the thickeners and washers. As such no conceivable scenario which would represent a hazard at the boundary could be established.

4.10. Scenario 10 – Liquor Purification Kiln Explosion

This scenario is based on the assumption that unburnt combustible gasses could accumulate in the kiln and be ignited. The model assumes a situation, such as at start-up where a failure to properly purge the kiln could result in an explosion.

With the volume of this kiln being only 120m³ (ie only 3% of the calcination kiln ESP volume – Scenario 13) it was not considered necessary to model this scenario. Another contributing factor regarding this decision was the central location of the kiln on the site.

4.11. Scenario 11 – Hydrate Filtration Tank Failure

Secondary containment facilities are in place for accidental releases from the hydrate filtration train. As such no conceivable scenario which would represent a hazard at the boundary could be established.

4.12. Scenario 12 – Precipitator Vessel failure

Secondary containment facilities are in place for accidental releases from the precipitator vessels. As such no conceivable scenario which would represent a hazard at the boundary could be established.

4.13. Scenario 13 – Calcination Kiln ESP Explosion

This scenario is based on the assumption that unburnt combustible gasses could accumulate in a calcination ESP and be ignited. The model assumes a situation, such as at start-up where a failure to properly purge the ESPs could result in an explosion.

The scenario is modelled as vapour cloud explosion with yield factor of 100%, occurring close to the ground. This will overestimate the resultant overpressure as it assumes that 100% of the available explosive energy goes into forming the blast wave. It also assumes an omnidirectional blast wave.

Overpressure and heat radiation contours are calculated using ARCHIE.

4.13.1. Model Parameters and Assumptions

- Volume of vessel 4450m³ (estimate)
- Assume ESP contains methane at UFL (15%)
- Consider start-up scenario (ie standard conditions)
- Modelled as an UVCE with yield factor of 1 occurring at ground level.
- Based on ideal gas assumption quantity of methane in vessel is 429kg.

4.13.2. Model Results

Figure 4.6 - Incident Overpressure Effects Vs Distance for Calcination Kiln ESP Explosion

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS		
DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
	17189	Occasional breakage of large windows under stress.
	2422	Some damage to home ceilings; 10% window breakage.
904	- 1568	Windows usually shattered; some frame damage.
	904	Partial demolition of homes; made uninhabitable.
232	- 904	Range serious/slight injuries from flying glass/objects.
	546	Partial collapse of home walls/roofs.
416	- 546	Non-reinforced concrete/cinder block walls shattered.
186	- 482	Range 90-1% eardrum rupture among exposed population.
	469	50% destruction of home brickwork.
347	- 416	Frameless steel panel buildings ruined.
	304	Wooden utility poles snapped.
250	- 304	Nearly complete destruction of houses.
	206	Probable total building destruction.
123	- 170	Range for 99-1% fatalities among exposed populations due to direct blast effects.
PRESS ENTER TO CONTINUE		

Figure 4.7 – Effects of Fireball for Calcination Kiln ESP Explosion

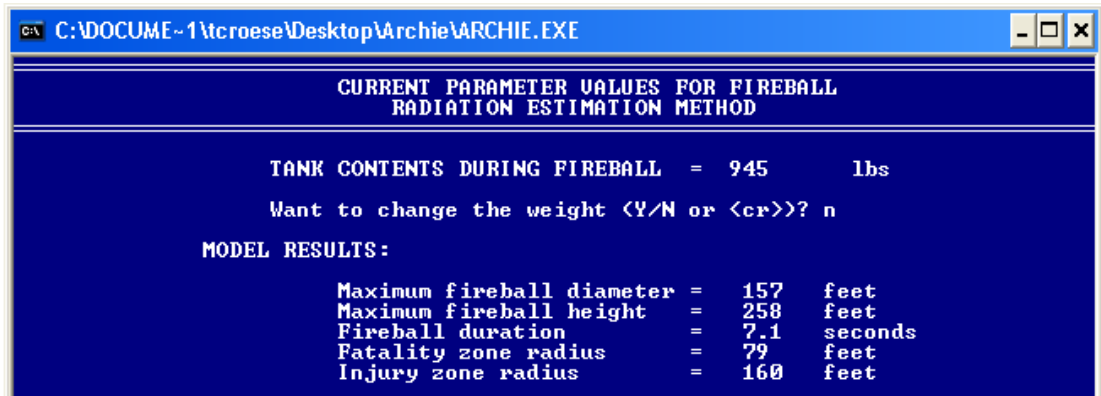


Table 4.7 – Incident Overpressure Vs Distance for Calcination Kiln ESP Explosion

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	66
35	98
14	176
7	292
3.5	506
2	781

Attachment 7 shows the 7kPa overpressure contour for the calcination kiln ESP explosion event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 781m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

The radiated heat zones are also within acceptable limits considering the lack of possible receptors at the boundary in this area..

4.14. Scenario 14 – Boiler Explosion (Fuel Side)

This scenario is based on the assumption that unburnt combustible gasses could accumulate on the boiler fuel side and be ignited. The model assumes a situation, such as at start-up where a failure to properly purge the boiler could result in an explosion.

The scenario is modelled as vapour cloud explosion with yield factor of 100%, occurring close to the ground. This will overestimate the resultant overpressure as it assumes that 100% of the available explosive energy goes into forming the blast wave. It also assumes an omnidirectional blast wave.

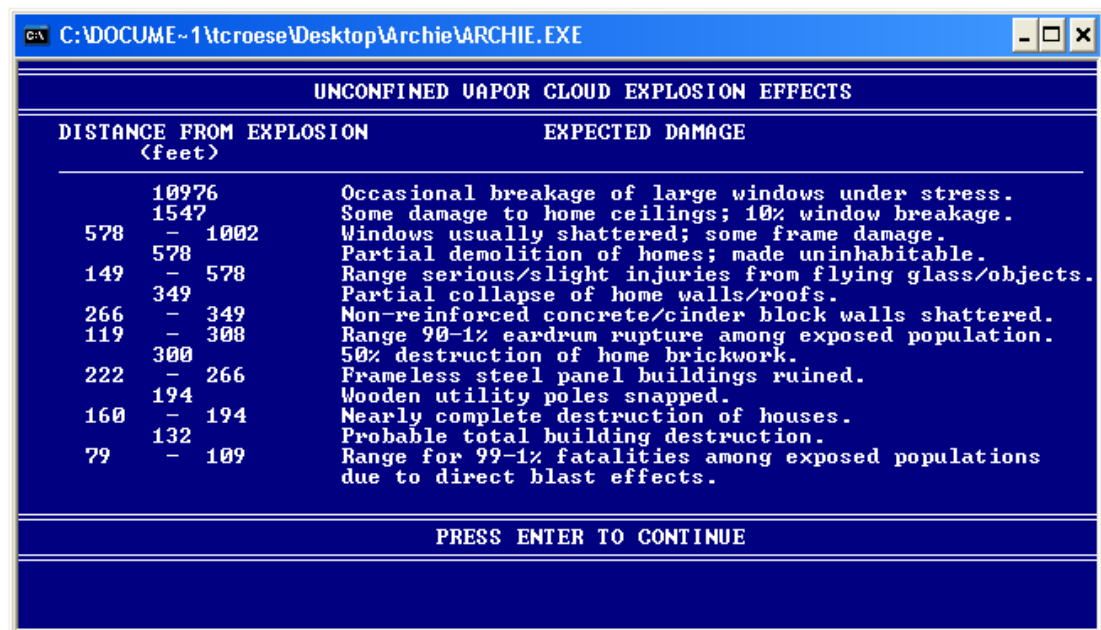
Overpressure and heat radiation contours are calculated using ARCHIE.

4.14.1. Model Parameters and Assumptions

- Volume of vessel 1174m³
- Assume methane at UFL (15%)
- Consider start-up scenario (ie standard conditions)
- Modelled as an UVCE with yield factor of 1 occurring at ground level.
- Based on ideal gas assumption quantity of methane in vessel is 112kg.

4.14.2. Model Results

Figure 4.8 – Incident Overpressure Effects Vs Distance for Boiler Fuel Side Explosion



The screenshot shows a window titled 'C:\DOCUMENTS\1\croese\Desktop\Archie\ARCHIE.EXE'. The main content is a table titled 'UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS'. The table has two columns: 'DISTANCE FROM EXPLOSION (feet)' and 'EXPECTED DAMAGE'. The data is presented in a series of ranges with corresponding damage descriptions.

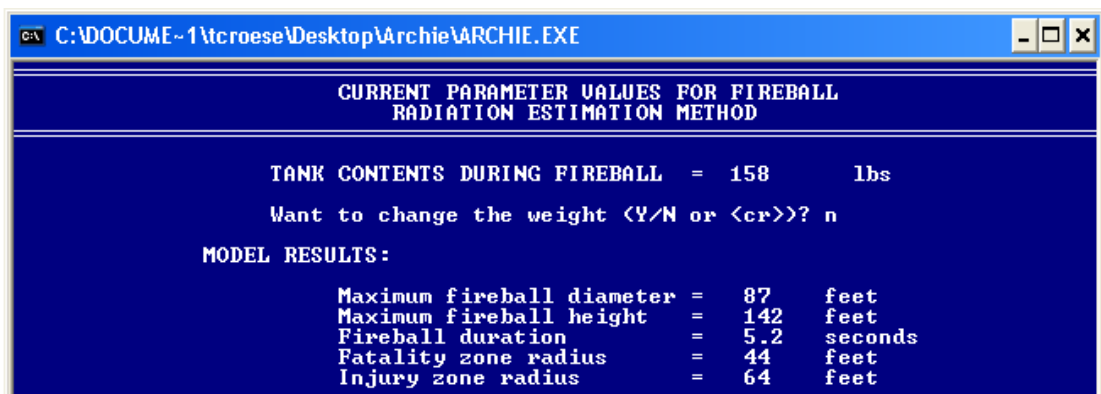
DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
10976	Occasional breakage of large windows under stress.
1547	Some damage to home ceilings; 10% window breakage.
578 - 1002	Windows usually shattered; some frame damage.
578	Partial demolition of homes; made uninhabitable.
149 - 578	Range serious/slight injuries from flying glass/objects.
349	Partial collapse of home walls/roofs.
266 - 349	Non-reinforced concrete/cinder block walls shattered.
119 - 308	Range 90-1% eardrum rupture among exposed population.
300	50% destruction of home brickwork.
222 - 266	Frameless steel panel buildings ruined.
194	Wooden utility poles snapped.
160 - 194	Nearly complete destruction of houses.
132	Probable total building destruction.
79 - 109	Range for 99-1% fatalities among exposed populations due to direct blast effects.

PRESS ENTER TO CONTINUE

Table 4.8 – Incident Overpressure Vs Distance for Boiler Fuel Side Explosion

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	43
35	63
14	113
7	186
3.5	323
2	499

Figure 4.9 – Effects of Fireball for Boiler Fuel Side Explosion



Attachment 2 shows the 7kPa overpressure contour for the boiler fuel side explosion event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 499m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

Both the injury and fatality zone radii in the fire ball analysis are well within the boundary.

4.15. Scenario 15 – Boiler Explosion (Steam Side)

The water tube boilers in use at Alcan Gove are unlikely to fail in an explosive manner on the water side – generally only a few tubes would be expected to fail at once. For the purposes of this assessment, however, it is assumed that all of the available fluid expansion energy on the wet side of the boiler is released explosively in an overpressure event.

4.15.1. Model Parameters and Assumptions

- Volume of vessel = 16.8m³
- Operating at 90ata (design pressure = 102ata) and 320°C
- Assume rupture pressure of 510ata (5 x Operating pressure)
- Contents of vapour phase are high pressure steam
- Assume ambient temperature = 30°C

4.15.2. Model Results

ARCHIE was unable to model at the conditions shown above, so the model was run at a volume of 6.72m³ and scaled up using the relationship:

$$R_2 = \frac{R_1 W_2^{0.3333}}{W_1^{0.3333}} \quad (\text{This assumption was tested and proved accurate})$$

Figure 4.10 – Overpressure Data for Model with Volume of 6.72m³

DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
14231		Occasional breakage of large windows under stress.
2089		Some damage to home ceilings; 10% window breakage.
766	– 1365	Windows usually shattered; some frame damage.
766		Partial demolition of homes; made uninhabitable.
180	– 766	Range serious/slight injuries from flying glass/objects.
430		Partial collapse of home walls/roofs.
308	– 430	Non-reinforced concrete/cinder block walls shattered.
127	– 370	Range 90-1% eardrum rupture among exposed population.
357		50% destruction of home brickwork.
308	– 308	Frameless steel panel buildings ruined.
266		Wooden utility poles snapped.
201	– 266	Nearly complete destruction of houses.
149		Probable total building destruction.
88	– 110	Range for 99-1% fatalities among exposed populations due to direct blast effects.

PRESS ENTER TO CONTINUE

Table 4.9 – Incident Overpressure Vs Distance for Boiler Wet Side Overpressure

Incident Overpressure (kPa)	Distance for 6.72m ³ Volume (ARCHIE)	Extrapolated Distance (m)
70	48	65
35	86	117
14	139	189
7	247	336
3.5	440	598
2	674	917

Attachment 4 shows the 7kPa overpressure contour for the boiler wet side overpressure event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 917m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.16. Scenario 16 – Condensate Receiver Overpressure

4.16.1. Model Parameters and Assumptions

- Operating at 120°C and 2ata
- 57.5m³ vertical cylinder
- Assume 100% vapour (usually one third)
- Assume rupture pressure of 10ata (ie 5 x operating pressure)
- Contents of vapour phase are steam
- Assume ambient temperature = 30°C

4.16.2. Model Results

Figure 4.11 - Incident Overpressure Effects Vs Distance for Condensate Receiver

DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
4494		Occasional breakage of large windows under stress.
660		Some damage to home ceilings; 10% window breakage.
242	431	Windows usually shattered; some frame damage.
242		Partial demolition of homes; made uninhabitable.
57	242	Range serious/slight injuries from flying glass/objects.
164		Partial collapse of home walls/roofs.
129	164	Non-reinforced concrete/cinder block walls shattered.
47	155	Range 90-1% eardrum rupture among exposed population.
150		50% destruction of home brickwork.
101	129	Frameless steel panel buildings ruined.
84		Wooden utility poles snapped.
64	84	Nearly complete destruction of houses.
47		Probable total building destruction.
36	47	Range for 99-1% fatalities among exposed populations due to direct blast effects.

PRESS ENTER TO CONTINUE

Overpressure

Table 4.10 – Incident Overpressure Vs Distance for Condensate Receiver Overpressure

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	15
35	27
14	53
7	78
3.5	139
2	213

Attachment 7 shows the 7kPa overpressure contour for the condensate receiver overpressure event. This contour represents the public housing limit (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

From this contour it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 213m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

4.17. Scenario 17 –Vapour Cloud Explosion (Gate Station)

The US EPA document, *Risk Management Program Guidance for Offsite Consequence Analysis (1999)*, suggests that a suitable scenario for modelling of worst case flammable gas releases should assume that 100% of the maximum gas inventory is released to an atmosphere with a stability factor of F and a wind speed of 1.5m/s.

In the case of the natural gas pipeline, the maximum pipeline length that could be emptied in a single event is 150km. This is based on preliminary design parameters and is subject to change.

A vapour cloud explosion was modelled using ARCHIE. ARCHIE was used to determine the discharge characteristics, prior to the vapour cloud explosion model being run.

It was assumed that the worst case release of natural gas would occur through a complete rupture of the pipeline near the gate station.

Natural gas was modelled as methane. This is a conservative assumption as the natural gas that will flow through the pipeline is expected to have a relatively high nitrogen content.

4.17.1. Model Parameters and Assumptions

- Pipe diameter – 16” (diameter of hole through which gas is released)
- Maximum pipe length that could be emptied – 150km
- Flow rate in pipe – 3.1 million standard cubic metres per day (25kg/s)
- Pressure in pipe – 15.3MPa
- Approximate temp in pipe – 30°C
- Ambient temperature – 30°C
- Heat of combustion of methane = 21,566 BTU/lb
- Explosive yield factor – 0.1

4.17.2. Model Results

Figure 4.12 - Incident Overpressure Effects Vs Distance for Natural Gas VCE

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS	
DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
107890	Occasional breakage of large windows under stress.
15201	Some damage to home ceilings; 10% window breakage.
5673 - 9842	Windows usually shattered; some frame damage.
5673	Partial demolition of homes; made uninhabitable.
1456 - 5673	Range serious/slight injuries from flying glass/objects.
3422	Partial collapse of home walls/roofs.
2611 - 3422	Non-reinforced concrete/cinder block walls shattered.
1164 - 3024	Range 90-1% eardrum rupture among exposed population.
2942	50% destruction of home brickwork.
2178 - 2611	Frameless steel panel buildings ruined.
1903	Wooden utility poles snapped.
1567 - 1903	Nearly complete destruction of houses.
1291	Probable total building destruction.
772 - 1067	Range for 99-1% fatalities among exposed populations due to direct blast effects.

PRESS ENTER TO CONTINUE

Table 4.11 – Incident Overpressure Vs Distance for Natural Gas VCE

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	416
35	614
21	842
14	1104
7	1830
3.5	3175
2	4904

Attachment 8 shows the 21kPa overpressure contour for the natural gas vapour cloud explosion event. It is estimated that there is a 20% chance of fatality for a person in building (NSW DOP, 1997) at this level of incident overpressure.

This scenario has the potential to cause an incident overpressure of 7kPa at the settlement at Gallupa, however, the likelihood is considered extremely remote. This assumption is based on data provided by Lees (1996) which suggests that the upper failure rate limit (ie worst case) for full rupture of pipelines over 3" diameter is 3×10^{-9} /hr (or 2.63×10^{-5} /yr). Lees (1996) also suggests that the likelihood of ignition of a vapour cloud is in the vicinity of 1 in 10. Both of these events would have to occur for the above consequences to result, suggesting that the likelihood of this scenario is approximately 2.63×10^{-6} .

Another contributing factor, which will further reduce the likelihood of this scenario eventuating is the weather conditions. For a vapour cloud of this magnitude to effect the residential area, the wind must be of low velocity and in a

north-westerly direction. This is most likely to occur in the wet season, and is expected to reduce the likelihood by approximately 50%.

The NSW Dept of Planning (1997) recommends that the frequency of incident overpressures in excess of 7kPa, occurring in residential areas should not exceed 5×10^{-5} /yr. Assuming that the data in the above paragraph is accurate (note: a worst case approximation was made), the risk to residents at Gallupa, based on the above scenario lies within an acceptable region.

The NSW Dept of Planning (1997) also suggests that the individual risk of fatality at a residential development should not exceed 1×10^{-6} . If it is assumed that 20% (NSW DOP, 1997) of people inside buildings may be fatally injured by an incident overpressure of 21kPa (ie the approximate overpressure contour at Gallupa) then the risk of fatality at Gallupa can be estimated at 2.63×10^{-7} , and is therefore within the NSW DOP guidelines. The probability of favourable wind conditions (ie 50%) is also incorporated into this estimation. Even if it was not, the resultant likelihood estimation would also fall within the acceptable region.

It is understood that the natural gas pipeline has not yet undergone detailed design. Although the likelihood of a vapour cloud explosion impacting on people is low, the potential effects of plant and equipment are significant and will be further considered during the detailed design.

4.18. Scenario 18 – Pipeline Jet Fire at Gate Station

Given the location of the gate station, relative to the nearest, Gallupa community it is not expected that a jet fire would significantly affect people in this area. This is as a result of the refinery infrastructure being located between the two areas. Furthermore, the likelihood of such an event is considered comparable to the vapour cloud explosion scenario, which is described in Section 4.17 and is extremely remote.

4.19. Scenario 19 – Petrol Tank Explosion

This scenario is based on the assumption that the largest of the petrol tanks in the light fuel farm could be filled with combustible gas and ignited.

The scenario is modelled as vapour cloud explosion with yield factor of 100%, occurring close to the ground. This will overestimate the resultant overpressure as it assumes that 100% of the available explosive energy goes into forming the blast wave. It also assumes an omnidirectional blast wave.

Overpressure and heat radiation contours are calculated using ARCHIE.

The Jet A1 tank, which is also located at the light fuel tank farm was not considered as it belongs to a third party.

4.19.1. Model Parameters and Assumptions

- Assume combustible gas is methane at UFL, ie 15% (Perry, 1996)
- Treat methane as ideal gas → 61kg in tank
- Tank volume is 637m³
- Assume tank contents at atmospheric conditions
- Assume ambient temperature = 30°C

4.19.2. Model Results

Figure 4.13 - Incident Overpressure Effects Vs Distance for Petrol Tank Explosion

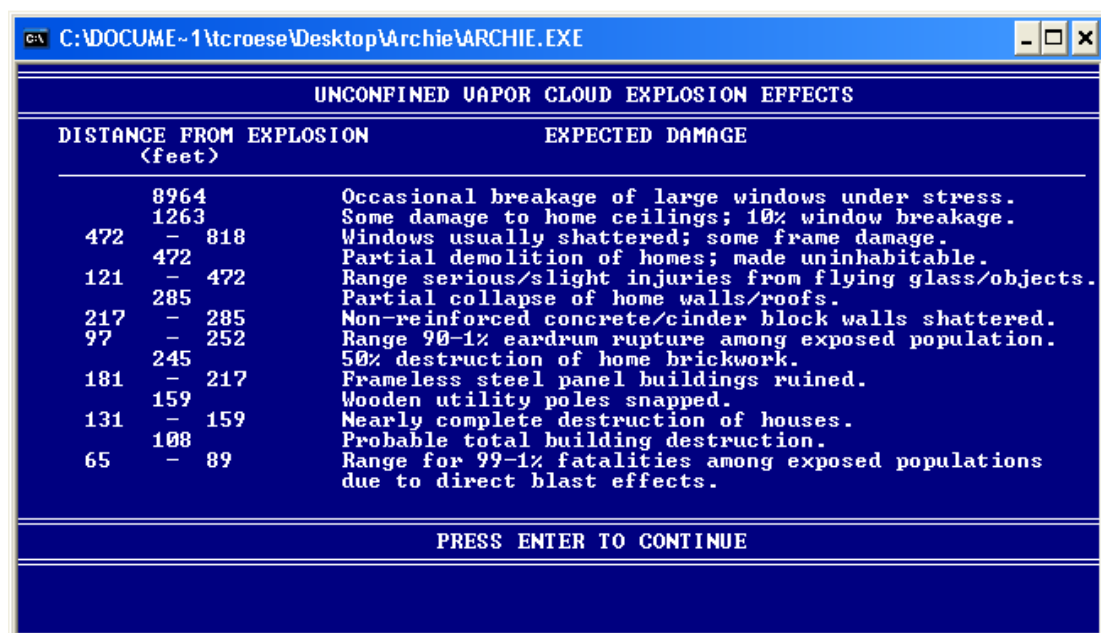


Figure 4.14 – Fireball Effects for Petrol Tank Explosion

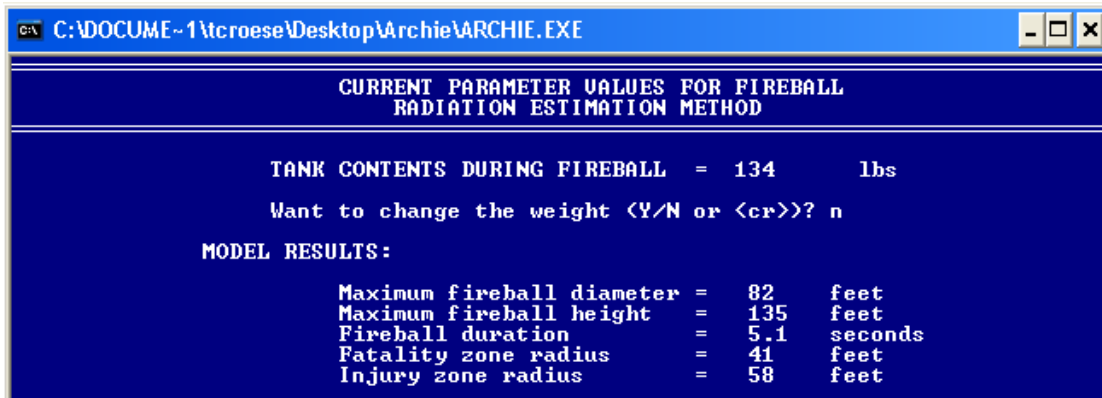


Table 4.12 – Incident Overpressure Vs Distance for Petrol Tank Explosion

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	35
35	51
14	92
7	152
3.5	264
2	407

Attachment 8 shows the 7kPa overpressure contour for the petrol tank explosion event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities*, 1996).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 407m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

The radiated heat zones are also within acceptable limits.

4.20. Scenario 20 – Light Fuel Tank Farm Fire

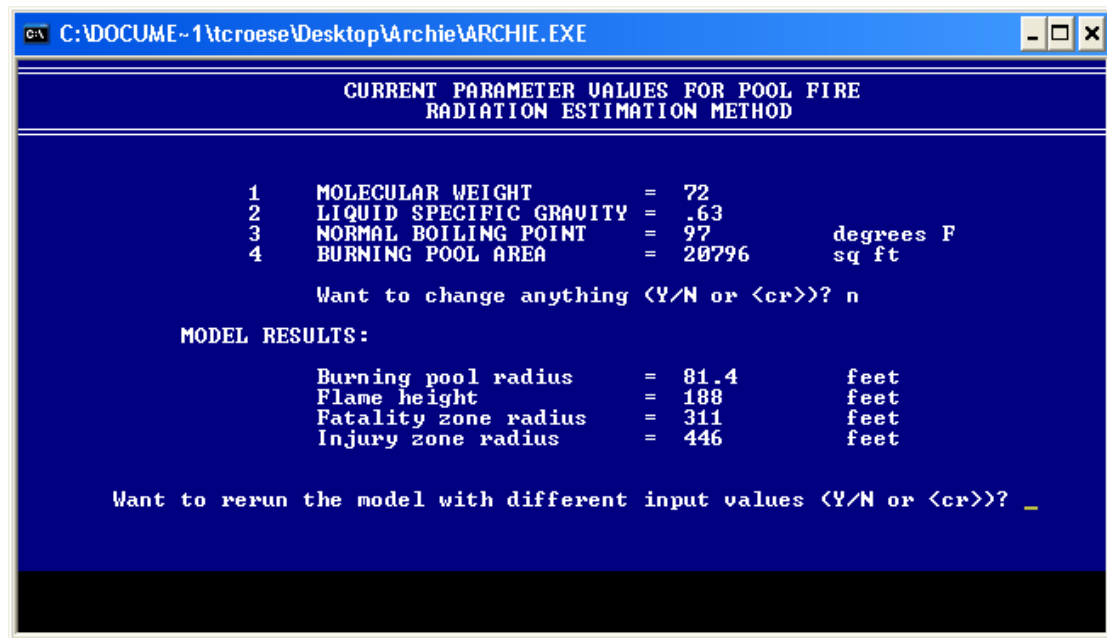
Scenario is based on the assumption that the largest diesel tank could release all its contents into the secondary containment bund and ignite. The resulting hazard would be radiated heat as a result of a pool fire.

4.20.1. Model Parameters and Assumptions

- Largest diesel tank volume is 4327m³
- Average depth of bund is 2m (assume linear variation between 1.5 and 2.5m)
- Therefore pool fire surface area is 2164m²
- Modelled as pentane spill

4.20.2. Model Results

Figure 4.15 – Radiated Heat Effects and Distances for Diesel Pool Fire



The injury zone is defined as the distance from the source at which a 40 second exposure could lead to second degree burns. The radiated heat flux at this point is 5kW/m² (*Risk Management Program Guidance for Offsite Consequence Analysis, 1999*). It should be noted that this distance could be increased on the downwind side of the fire by high winds which increase lateral convective movement of heat. The fatality zone represents the 10kW/m² boundary and is the threshold for fatality (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

The results for this scenario, generated by ARCHIE, were checked using the procedure outlined in the US EPA's *Risk Management Program Guidance for Offsite Consequence Analysis, (1999)*, ie:

$$d = PFFx\sqrt{A}$$

where d = Distance to injury zone

A = Pool surface area

PFF = Pool fire factor defined for pentane as 5.8

Using this method, the injury zone distance was calculated to be 836ft (270m). This is significantly larger than the figure generated by ARCHIE, and as such will be the one that is displayed in Attachment 3. The 10kW/m² zone is also shown in this attachment. It was estimated using the relationship (OSWERHCHAP Handbook of Chemical Hazard Analysis Procedures, US EPA):

$$\frac{1}{Q_1} \times \left(\frac{1}{X_1} \right)^{1.757} = \frac{1}{Q_2} \times \left(\frac{1}{X_2} \right)^{1.757}$$

where: Q = incident radiation
X = distance from source

This provides a Fatality Zone of approximately 182m.

Although this zone breaches the site boundary it does so in an unpopulated area, ie the sea. The likelihood of injury to people outside the site boundary is therefore expected to be acceptably low.

4.21. Scenario 21 – Bunker Oil Fire

This scenario is based on the assumption that the largest of the bunker oil tanks could be filled with combustible gas and ignited.

The scenario is modelled as vapour cloud explosion with yield factor of 100%, occurring close to the ground. This will overestimate the resultant overpressure as it assumes that 100% of the available explosive energy goes into forming the blast wave. It also assumes an omnidirectional blast wave.

Overpressure and heat radiation contours are calculated using ARCHIE.

4.21.1. Model Parameters and Assumptions

- Model combustible gas as methane at UFL
- Treat methane as ideal gas
- Tank volume is 50,136m³
- Assume tank contents at atmospheric conditions
- Assume ambient temperature = 30°C
- Tank contains bunker fuel oil
- Bunker oil vapour pressure at 38°C is approximately 700Pa or 0.7% by volume. This is within the flammable region, and is the concentration that will be modelled (US Oil and Refining Co. MSDS)
- From above, mass of methane in tank is assumed to be 222kg

4.21.2. Model Results

Figure 4.16 – Incident Overpressure Effects Vs Distance for Bunker Oil Tank Explosion

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS		
DISTANCE FROM EXPLOSION (feet)		EXPECTED DAMAGE
13791		Occasional breakage of large windows under stress.
1943		Some damage to home ceilings; 10% window breakage.
726	– 1258	Windows usually shattered; some frame damage.
	726	Partial demolition of homes; made uninhabitable.
186	– 726	Range serious/slight injuries from flying glass/objects.
	438	Partial collapse of home walls/roofs.
334	– 438	Non-reinforced concrete/cinder block walls shattered.
149	– 387	Range 90-1% eardrum rupture among exposed population.
	377	50% destruction of home brickwork.
279	– 334	Frameless steel panel buildings ruined.
	244	Wooden utility poles snapped.
201	– 244	Nearly complete destruction of houses.
	165	Probable total building destruction.
99	– 137	Range for 99-1% fatalities among exposed populations due to direct blast effects.
PRESS ENTER TO CONTINUE		

Figure 4.17 – Fireball Effects for Bunker Oil Tank Explosion

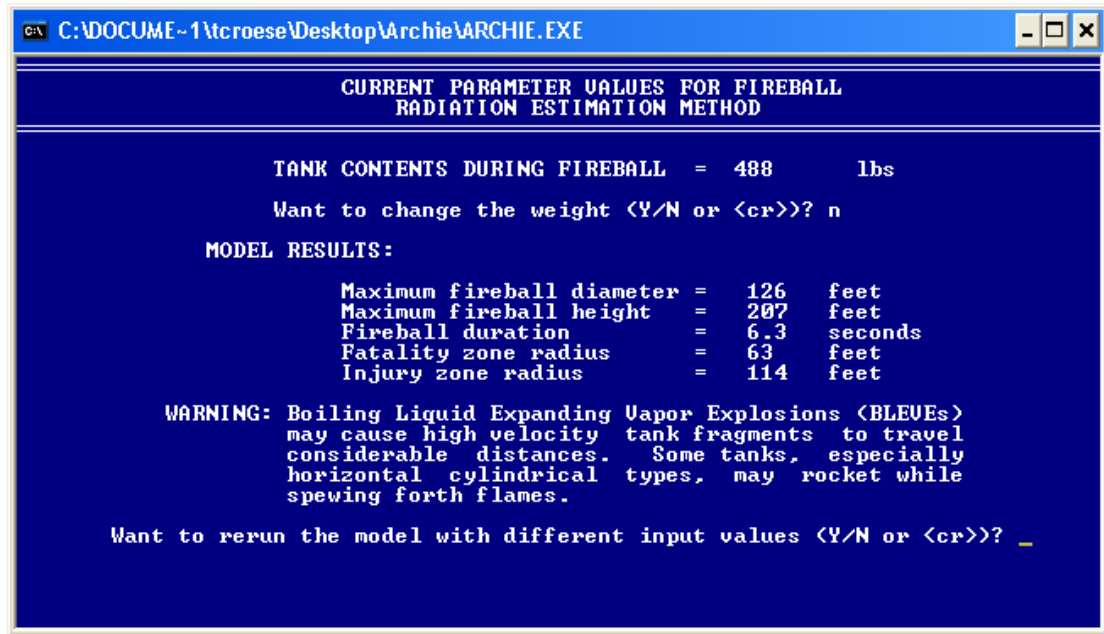


Table 4.13 – Incident Overpressure Vs Distance for Bunker Oil Tank Explosion

Incident Overpressure (kPa)	Distance (m) (ARCHIE)
70	53
35	79
14	141
7	234
3.5	406
2	925

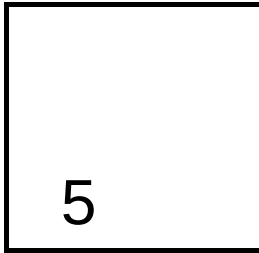
Attachment 2 shows the 7kPa overpressure contour for the bunker oil tank explosion event as well as the 35kPa and 70kPa contours. These contours are chosen for the reasons below (*Emergency Plans – Guidelines for Major Hazard Facilities, 1996*).

- 7kPa – Public housing limit
- 35kPa – 20 to 25% chance of fatality for people inside buildings
- 70kPa – Threshold for death caused by overpressure effects alone.

From these contours it can be seen that potential incident overpressure at the boundary for the scenario described above is within tolerable limits.

The 2kPa contour is not shown, but it represents the zone outside which there is a 5% chance of missiles landing. The distance of 925m calculated above for the 2kPa contour does not contain an area in which the population density is large enough to create an unacceptable likelihood of a person being struck by a missile.

The radiated heat zones are also within acceptable limits.



5. Conclusions

This study has shown that there are no significant risks to life or property at the boundaries of the lease. Contours of effect from explosion, heat flux, projectiles and hazardous materials have been produced to reach this conclusion. The findings have considered the separations, and the risk management processes in place as suitable for the control of potential boundary hazards associated with the Alcan Gove Facility.

Alcan Gove is located in an inherently safe location, being on a peninsula and bounded on three sides by the ocean. The nearest residential area is located at Gallupa, which is near the southern plant boundary, but is well separated from hazardous process areas.

As a result of the above conditions only two scenarios were identified that could potentially effect the facilities neighbours. These were a vapour cloud explosion (Scenario 17), occurring near the Gate Station, and a chlorine release (Scenario 1). The chlorine storage facility is located remote from the refinery at a water treatment facility, which is located approximately 1km from the airport. This is the nearest known occupied area.

An analysis of the likelihood of these scenarios eventuating shows that the risk to local residents falls within the acceptable region as defined by the NSW Department of Planning (1997).

6

6. References

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US EPA: Federal Emergency Management Agency, *Handbook of Chemical Hazard Analysis Procedures*. (includes ARCHIE User's Manual)

Appendix A

List of Attachments

ATT 1 – Tabulated consequences of incident overpressure

ATT 2 – Scenario Consequence Contours (a), includes

- Scenario 2 – LT Digester Overpressure
- Scenario 14 – Boiler Fuel Side Explosion Overpressure

ATT 3 – Scenario Consequence Contours (b), includes

- Scenario 3 – LT Digestion Flash Vessel Overpressure
- Scenario 20 – Light Fuel Tank Farm Pool Fire
- Scenario 21 – Bunker Oil Storage Explosion

ATT 4 – Scenario Consequence Contours (c), includes

- Scenario 4 – LT Digestion Flash Vessel Explosion
- Scenario 15 – Boiler Water Side Overpressure

ATT 5 – Scenario Consequence Contours (d), includes

- Scenario 6 – HT Digester Overpressure

ATT 6 – Scenario Consequence Contours (e), includes

- Scenario 7 – HT Digestion Flash Vessel Overpressure

ATT 7 – Scenario Consequence Contours (f), includes

- Scenario 13 – Calcination ESP Explosion
- Scenario 16 – Condensate Receiver Overpressure

ATT 8 – Scenario Consequence Contours (g), includes

- Scenario 17 – Natural Gas Vapour Cloud Explosion
- Scenario 19 – Diesel Tank Explosion

ATTACHMENT 1 – Consequences of Incident Overpressure

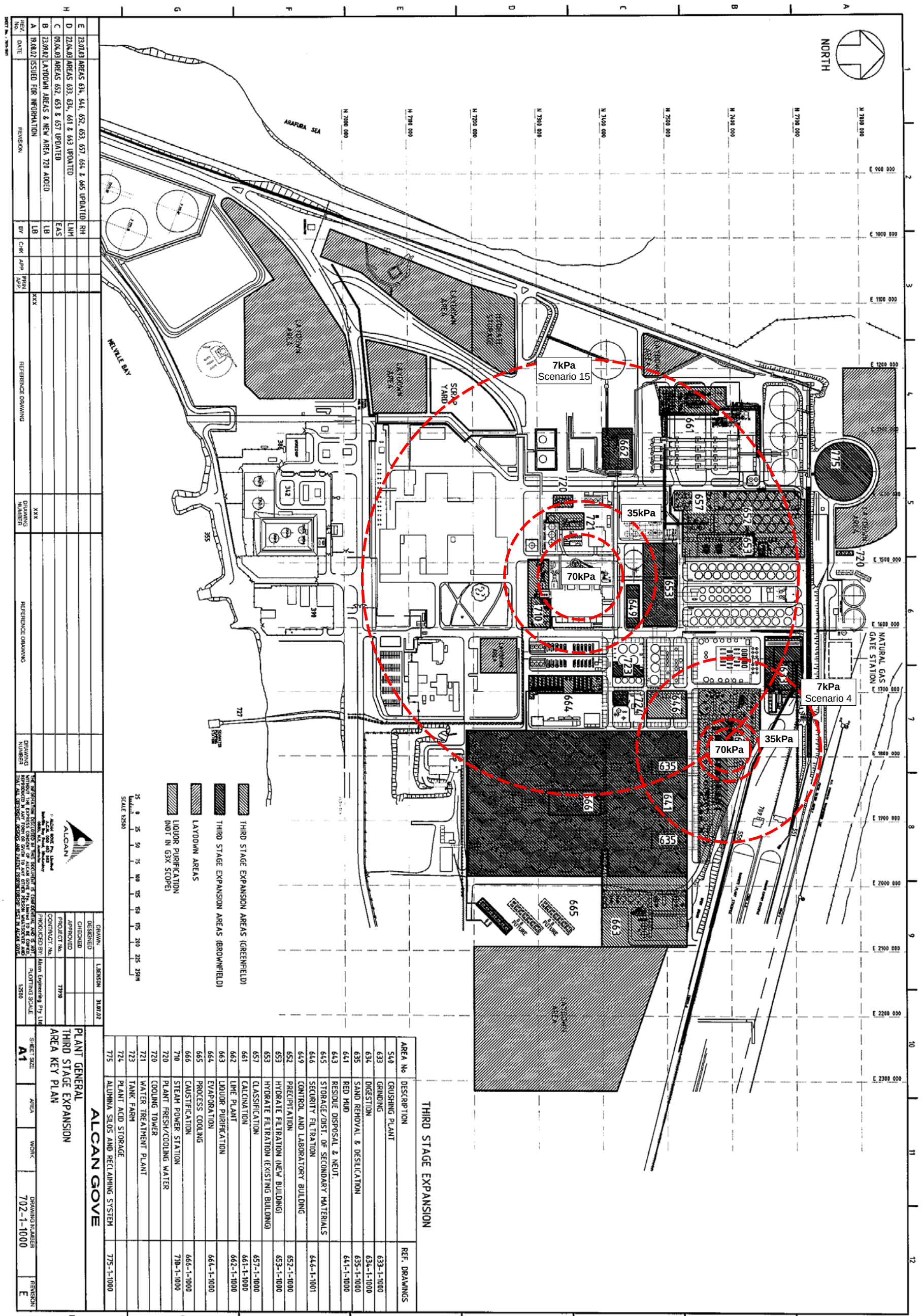
Incident Overpressure	Damage
2kPa	Missile Limit; 10% window glass broken
3.5kPa	Large and small windows usually shattered; occasional damage to window frames
7kPa	Partial demolition of houses, made uninhabitable; residential housing limit
14kPa	Partial collapse of walls and roofs of houses
35kPa	Wooden utility poles snapped; nearly complete destruction of houses; 20-25% chance of fatality for people inside buildings
70kPa	Total destruction of buildings; 30% chance of eardrum rupture for person in open; ,<1% chance of fatality for person in open

(Lees, 1999) and (Emergency Plans – Guidelines for Major Hazard Facilities, 1996)

Marsh

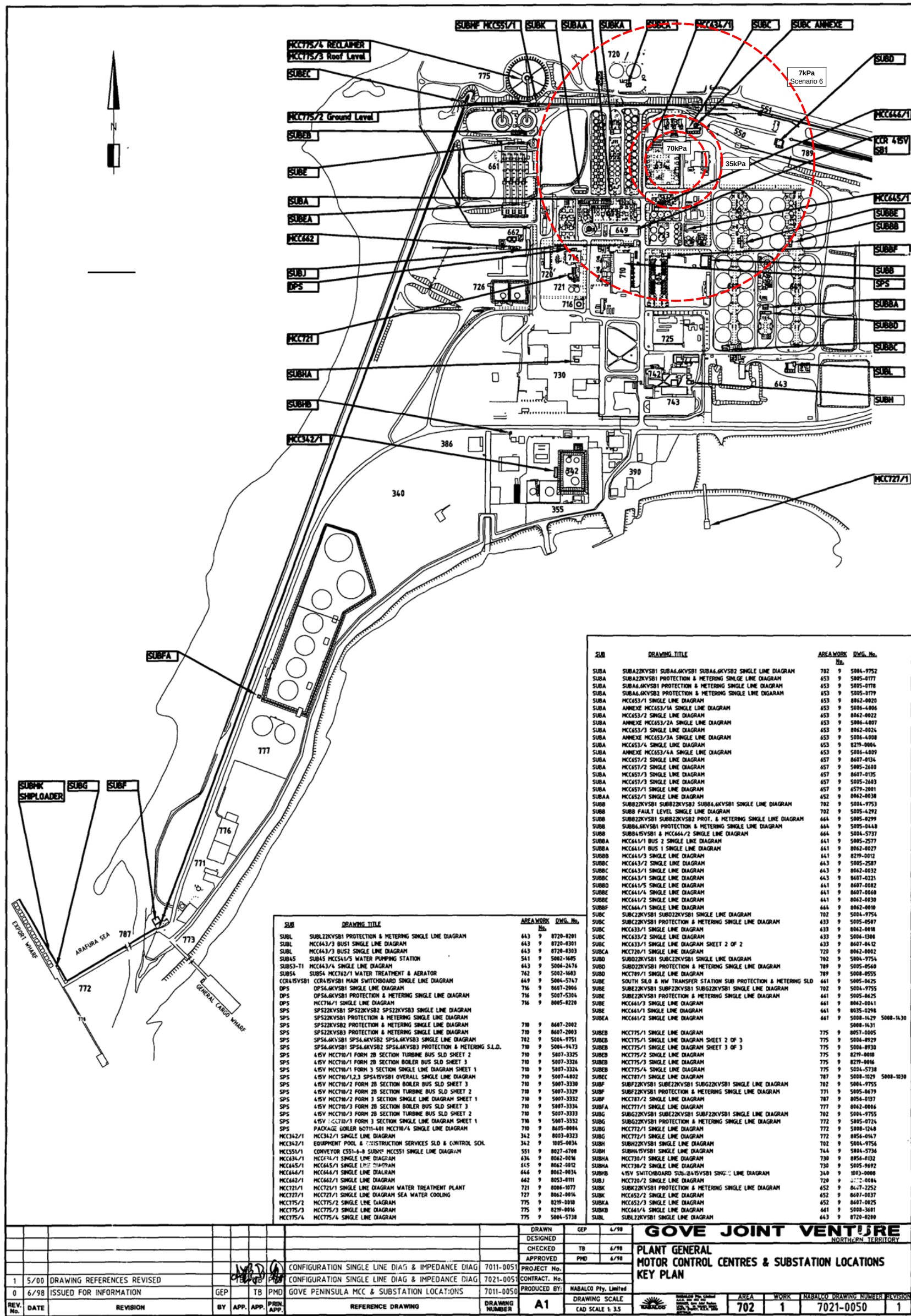
Marsh

ATTACHMENT 4 – SCENARIO CONSEQUENCE CONTOURS (C)



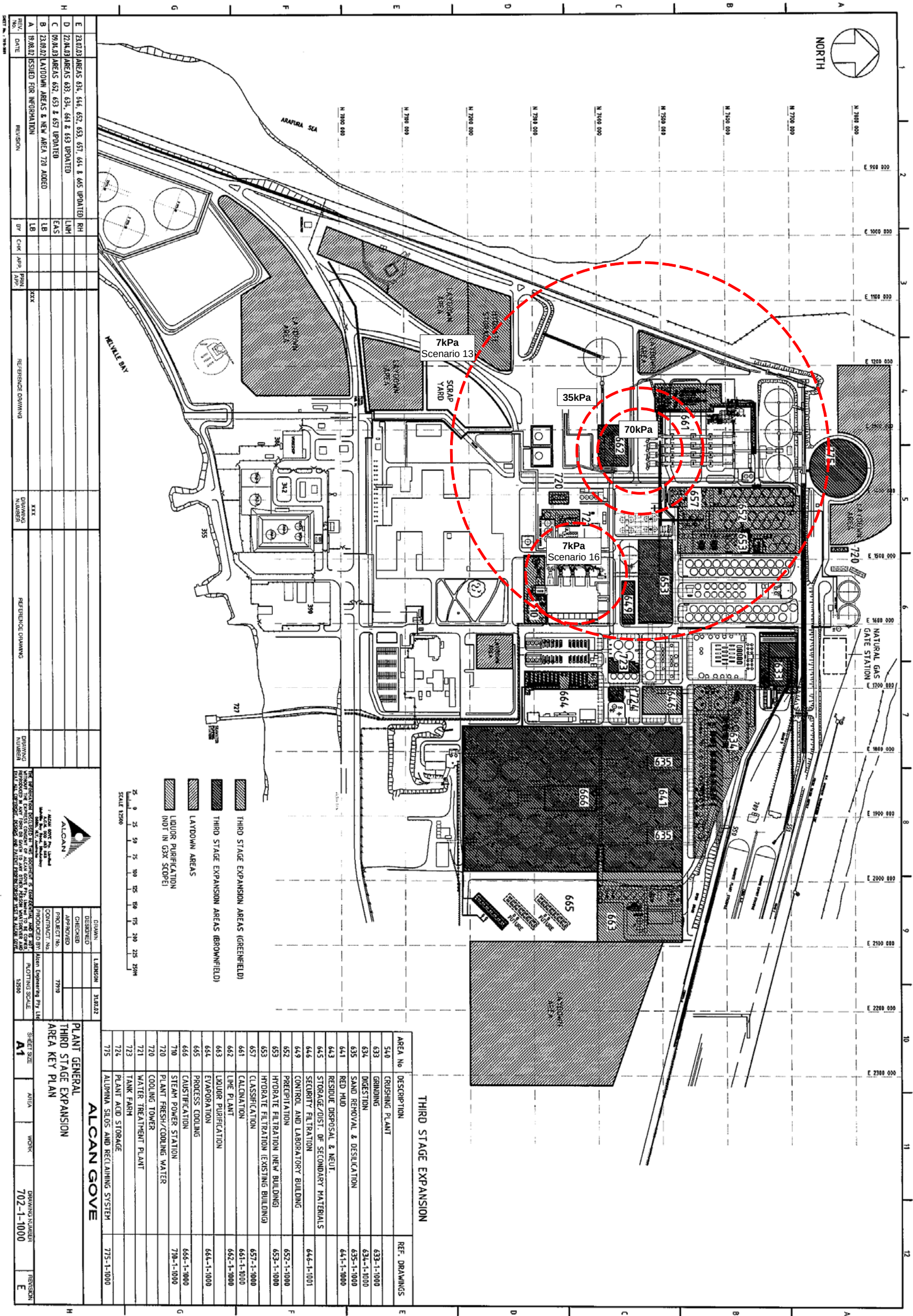
ATTACHMENT 5 – SCENARIO CONSEQUENCE CONTOURS (D)

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ATTACHMENT 7 – SCENARIO CONSEQUENCE CONTOURS (F)



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