APPENDIX 13.6

13.6.1 Modelling Program Details

The consequences of each release were calculated using the proprietary computer software PHAST version 6.53.1 (DNV 2008). The program calculates the discharge and dispersion of the material and the effects of fire and explosion.

13.6.1.1 Dispersion of Flammable Gases and Vapours

The models within PHAST predict the dispersion following a ground-level or elevated release of gas or liquid or two-phase releases from pressurised equipment or simply under gravity. It can model the following effects in an integrated manner:

- jet dispersion;
- droplet evaporation and rainout, touchdown;
- pool spread and vaporisation;
- heavy gas dispersion; and
- passive dispersion.

To quantify the hazard from a release of flammable vapour it is necessary to predict the dispersion of the vapour cloud. Dispersion is the dilution of the vapour cloud by mixing with air. Dispersion is characterised by a number of factors, such as: the momentum of the initial release, density of the dispersing fluid and the atmospheric conditions. If the flow is sonic (equating to high initial momentum) it forms a momentum jet. Such jets are narrow, entrain air and disperse relatively rapidly. Low momentum releases (plume releases) disperse comparatively slowly because air entrainment will be low. Releases with low momentum create larger clouds of toxic or flammable material for the same release rate and are wider, particularly in low wind speeds. In general, for a buoyant release where the material is less dense than air, the plume will rise by an amount determined by the initial density difference and the density stratification in the atmosphere. If the material is denser than air then the plume will fall and it will spread if in contact with the ground. Dense plumes that are spreading on the ground mix more slowly with air than neutrally buoyant clouds released at ground level.

The models used within PHAST to predict the dispersion of a vapour cloud are described by Witlox and Holt (1999).

The concentration of flammable vapours is calculated based on flammable averaging times of 18.75s respectively. For dispersion of flammable releases the concentration is calculated for a height 1m above ground level (unless stated otherwise in a specific scenario).

A value of 0.1 m surface roughness has been selected to reflect that the tank farm is close to the sea. This is cautious as distances to disperse flammable clouds below the lower flammable limit increase with decreasing surface roughness reflecting the lower degree of turbulence in smoother terrain.

13.6.1.2 Pool Fire Scenario Assumptions

Pool fires occur on ignition of a liquid release which has spread on the ground. A pool fire is characterised by a lower flame temperature than a jet fire, since the mixing of the flammable materials with air is not rapid. Large quantities of smoke can be produced.

PHAST® calculates two types of pool fire following a release of flammable fluid; the early pool fire and the late pool fire. An early pool fire occurs immediately after rainout, before the cloud has started to disperse away from the pool. For calculation of the late pool fire, the program takes the state of the evaporating pool at the time at which it reaches its largest diameter. Depending on the type of release, the pool may be some distance from the point of release. The distance of impact from a late pool fire is greater than that from an early pool fire. Consequently the late pool fire data results are presented.

The radiation model used within PHAST to estimate the effects of pool fire is based on the Mudan and Croce model (1988) and is described in Cook, Bahrami and Whitehouse (1990).

The key parameter for pool fires is the size of the pool.

For bulk storage of flammable liquids, the HSA define two events:

- Event 1 where some of the fluid flows over the top of the bund giving larger pool sizes (termed an uncontained fire);
- Event 2 where all of the fluid on fire is only in the bund (a contained fire).

For spills into a bund such as Event 2, the pool size is limited by the bund dimensions, with the diameter of a circular pool used in the model having equal area to the net bund floor.

The HSA provide a maximum pool size of 100m diameter for uncontained fires such as Event 1. Event 1 is assumed to be centred at a distance 50m from the bund wall. Event 2 is assumed to be located at and centred on the centre of the bund.

Consequences are modelled using PHAST© and in accordance with the requirements of the HSA land-use policy document pentane is used as the surrogate material for Class 1 materials.

Flash Fire and Vapour Cloud Explosion

Flash Fire envelopes were identified by dispersion analysis examining the extent of the cloud down to LFL.

The potential for VCE was considered by examining the flammable cloud footprint for each of the representative scenarios under different dispersion conditions and whether these enveloped areas of congested plant or other equipment.

Vapour cloud explosions can be modelled within PHAST using several models. The Multi-Energy Model (MEM) is preferred by the HSA (Land-use policy document page 20) HSE and is described in Wiekema (1980). Primarily, it allows for vapour cloud explosion modelling within a structure which is partially confined and turbulence generating.

The MEM uses a blast curve which is obtained from the mathematical modelling of vapour explosions which is valid in both the near and far fields.

Source Terms

The impact of an incident is largely dependent on the amount and conditions of material released, the source term. The hazard scenario will identify the failure scenario, type of material involved, storage conditions and size and duration of release. The typical scenarios considered are leaks from storage containers and catastrophic rupture of vessels and piping. A liquid release may be contained by a bund, from which evaporation could lead to a further source of vapour for dispersion in the atmosphere. Bund over-topping is considered.

Where appropriate the release duration for each hazard scenario has been considered on an individual case basis depending on the method of detection and the ease with which the release could be isolated. The typical release durations recommended by Purdy (1991) are summarised in Table 13.6.1.1 below.

Table 13.6.1.1Typical Release Durations	
Method of Isolation	**Typical Release Duration (minutes)**
Manual valve	20
Remote manually initiated shut off valve	5
Automatic valve 1	1

Table 13.6.1.1: Typical Release Durations

Meteorological Conditions

The weather conditions at the time of a release will have a dominant influence on the dispersion of the flammable vapour cloud. The burning rate of a pool fire increases with wind speed. The wind speed and direction also influences flame tilt which in turn affects the levels of thermal radiation experienced at ground level with higher levels being seen when the wind is high. Wind also has the effect of shortening horizontal and shortening and tilting vertical jet fires.

To simplify the calculations the full range of wind speeds and atmospheric stability (which determines the degree of turbulent mixing) are represented by two combinations:

- Low wind speed, stable atmospheres where mixing and dispersion is poor:
  - 2 m/s wind speed and F stability;
- Average and good dispersion conditions with higher wind speeds and less stable atmosphere:
  - 5 m/s wind speed and D Stability.

This is a standard approach in risk assessment and is considered to give conservative (pessimistic) results.

13.6.2 Harm Criteria

Over-Pressure Criteria

Events such as a “vapour cloud explosion” (VCE) create an overpressure wave which can injure people and damage property. Normally damaging overpressures will only be generated where a flame front passes through an area of turbulence generated by obstacles such as may be present in process areas or where there are elevated arrays of pipes. In fact the risk to people at lower overpressures can be greater if they are indoors; because of the possibility of injury should the roof or walls of the building collapse. The blast wave is characterised by the overpressure it creates at the receptor. Table 13.6.2.1 gives the effects on people of some key overpressure levels (taken from HSA land use policy document and Glasstone, 1962).

Table 13.6.2.1	Key Explosion Overpressure Levels: Effects on People	
Explosion Overpressure kPa	**Direct Effects on People**	**People Indoors**
2	Annoying noise (137kB), if of low frequency (10-15HZ)	'Safe distance' (Probability 0.95 no serious damage beyond this value)
5		1% probability of fatality
16.8	1% probability of fatality	
30		50% probability of fatality
34	Threshold for eardrum rupture	Pipe bridge displaced, pipe failures
36.5	10% probability of fatality	
83	Threshold for lung damage	
94.2	50% probability of fatality	
100		100% probability of fatality
270	Threshold for lethality	

Table 13.6.2.1: Key Explosion Overpressure Levels: Effects on People

The above table gives the overpressure impacts on people where as Table 13.6.2.2 gives the effect of over-pressure on property.

Table 13.6.2.2	Key Explosion Overpressure Levels: Effects on Property	
Explosion Overpressure Bar	**Effects on Properties / People Indoors**	**Reference**
2	'Safe distance' (Probability 0.95 no serious damage beyond this value)	Clancey, 1972
5	Lower limit of damage to doors and cladding Minor damage to house structure	UK HSE LPG SRAG HSA LUP policy document
8	Houses rendered uninhabitable but repairable	HSA LUP policy document
15	Lower limit of severe structural damage to buildings. Walls made of concrete blocks may collapse.	UK HSE LPG SRAG; TNO, 1979
20	Steel frame building distorted and pulled away from foundations.	Clancey, 1972
30	Cladding of light industrial buildings ruptured	HSA LUP policy document
50	Loaded tank car over-turned	HSA LUP policy document
70	Probable total destruction of buildings; heavy machine tools moved and badly damaged	HSA LUP policy document

Table 13.6.2.2: Key Explosion Overpressure Levels: Effects on Property

In order to predict the overpressures resulting from VCE's in confined areas, the TNO Multi-Energy Method was utilised. This requires a confined/unconfined strength and confined volume or confined fraction to be entered into the model. The unconfined strength is an integer number ranging between 1 (completely unconfined, e.g., open farmland) and 2 (slight confinement, e.g., fences, bunds or hedges). Confined strength is also an integer number ranging between 3 (lowest) and 10 (highest). There is little guidance available on choosing the appropriate strength, however. The greater the confined strength, the more the flame front can accelerate and lead to increases in overpressure (values of 7 to 9 are typically used for process units). The HSA specify that ignition strength 7 be used for large flammable storage site based on actual over-pressures experienced at Buncefield.

Thermal Radiation Criteria

The level of thermal radiation from fires can be calculated using PHAST.
It is possible to determine the likely effects of thermal radiation both on people and buildings / equipment from published literature. The following table 13.6.2.3 provides some limits for injury and pain and for equipment damage.

Table 13.6.2.3 Limits for Thermal Radiation Design and Assessment Guidance BS 5980

Thermal Radiation Intensity (kW/m^2)	Design Guidance Limit (BS 5980)
37.5	Intensity at which damage is caused to process equipment
25	Intensity at which non-piloted ignition of wood occurs
12.5	Intensity at which piloted ignition of wood occurs
6.3	Corresponds to a 1% lethality threshold for about a 90 second exposure, and second degree burns for exposure times of about 60 seconds. Limit for short term emergency actions (< 30 seconds) without shielding but wearing protective clothing
4.5	Intensity sufficient to cause pain to personnel unable to reach cover in 20 seconds, though blistering of skin (first degree burns) unlikely.
1.6	Intensity sufficient to cause discomfort for long exposures

Table 13.6.2.3: Limits for Thermal Radiation Design and Assessment Guidance BS 5980

The effects on personnel are assessed against "Dangerous Thermal Dose" criteria. Thermal dose is a function of Thermal Radiation level (kW/m^2) and duration of exposure in seconds (s). This relationship is not linear indicating that high levels of thermal radiation are more significant than time duration. The Thermal Dose is measured in thermal dose units (tdu) and is defined as follows:

$$\text{Thermal dose (tdu)} = [\text{Thermal Radiation } (kW/m^2)]\ (4/3) \times \text{Time (s)}$$

For long duration fires the HSA assume an exposure time of 75 seconds to take account of the time required to escape.

The effects of varying levels of thermal dose are tabulated below.

Table 13.6.2.4 Thermal Radiation Effects (HSE HFL SRAG, p46)

Dangerous Dose – Thermal Radiation (tdu)	Thermal Radiation Intensity based on Exposure			Effects
	20 sec	30 sec	75 sec	
1800 tdu	29.8 kW/m2	21.6 kW/m2	10.8 kW/m2	Significant likelihood of death
1000 tdu	18.8 kW/m2	13.9 kW/m2	6.98 kW/m2	Dangerous dose for average members of society
500 tdu	11.2 kW/m2	8.2 kW/m2	4.1 kW/m2	Dangerous dose for vulnerable people
125 tdu	4.0 kW/m2	-	-	1st degree burns in 20s

Table 13.6.2.4: Thermal Radiation Effects (HSE HFL SRAG, p46)

Flash Fire

It is assumed that all personnel outside within the flammable envelope receive fatal burns and that there are no casualties outside the flammable envelope. People in buildings are assumed to be protected as the flash fire is of short duration.

13.6.3 Consequence Modelling Results

This section of the Appendix provides a summary of the consequence modelling results for the report. The areas covered include the two terminals, Topaz and Leeside, as well as the consequence modelling results conducted for the Jetty. The consequence results for the new pipeline which will run from the new jetty to the Topaz terminal are also included. The Leeside terminal will not be supplied from the new jetty.

13.6.3.1 Topaz

Vapour Cloud Explosion (VCE)

For the VCE effects, two cases were considered in this study:

Scenario	Basis	Applicable to
Bulk & Day Storage of Gasoline	Volume=50,000m^3, Ignition Strength=7, Combustion Energy=3.5MJ/m^3	Topaz, Leeside
Out-loading of Gasoline and Ethanol	Width=12.45m Height=5.0m, and Length=40.5m	Topaz

Table 13.6.3.1: Topaz Vapour Cloud Explosion Scenarios

The VCE is assumed to be centred on the main bulk storage bund centre as this gives the most uniform risk profile.

The consequence of a VCE at the Out-loading bay are modelled on the same basis as the bulk and day tank VCE but with the vapour cloud volume defined as the volume of the Out-loading bay (congested area) with the VCE assumed to have occurred at the centre of the bay. It has been assumed that the volume is 5m x 40.5m x 12.45m.

The results for the VCEs for storage and Out-loading are presented in Table 13.6.3.2.

Table 13.6.3.2 VCE: Distance (m) to Over-pressures (Topaz)		
Over-pressure (kPa)	**VCE Storage Tank**	**VCE Out Loading**
100	50m	20 m
94.2	62 m	22 m
36.5	170	67 m
30	190	70 m
16.8	280 m	100 m
5	640 m	240 m
2	1600 m	600 m

Table 13.6.3.2: VCE: Distance (m) to over-pressures (Topaz)

Pool Fire

As instructed by HSA, two events need to be considered when determining the consequences of a pool fire (see Page 22 of the guidance):

- Event 1: A major unbunded pool fire extending up to 100 m from the bund wall (This event is taken to be centred at a distance of 50m from the bund);
- Event 2: A pool fire which covers the entire surface of the bund. (This is centred in the bund).

At the Topaz site there are two gasoline tanks – the bulk tank of capacity 15,000 m^3 and a day tank of capacity 793 m^3. Both of these are greater than 175 m^3 so capable of resulting in a maximum 100m diameter pool in an unconfined release. The day tank is within its own smaller bund and so event 2 was modelled as a separate case.

In addition to these scenarios, a pool fire caused by failure of an ethanol storage tank was modelled. The results are tabulated below for D5 conditions.

Note that the consequence distance from the centre of the pool are the same for event 1 and bulk tank event 2. This is because the bulk storage tank bund has an equivalent diameter of 100 m which coincidentally is the same as the maximum unconfined pool fire. The unconfined pool fire (event 1) is centred 50 m from the edge of the bund and so the consequences can potentially extend 100 m further than for bulk tank event 2.

Table 13.6.3.3 Consequence Distances from Centre of Pool, D5 (Topaz)

Event → Distance to ↓	Bulk Tank Event 1	Bulk Tank Event 2	Day Tank Event 1	Day Tank Event 2	Bulk Tank Event EDNT
4.0kW/m^2	230 m	230 m	230 m	138 m	182 m
6.8kW/m^2	200 m	200 m	190 m	110 m	155 m
9.23kW/m^2	158 m	158 m	158 m	96 m	132 m
12.7kW/m^2	138 m	138 m	138 m	85 m	118 m
13.4kW/m^2	130 m	130 m	130 m	75 m	115 m
25.6kW/m^2	70 m	70 m	70 m	37 m	96 m
37.5kW/m^2	50 m	50 m	50 m	30 m	79 m
Centre of pool	50 m from bund wall	Centre of main bund	50 m from bund wall	Centre of day tank bund	50 m from bund wall

Table 13.6.3.3: Consequence Distances from Centre of Pool, D5 (Topaz)

13.6.3.2. Leeside Site

The worst case events for the Leeside site are vapour cloud explosions (VCEs) from the storage tank and a major failure that over tops the bund giving rise to a pool fire.

The source terms for these scenarios are defined in the same way as for the Topaz site and so the consequences reported for the Topaz site also apply to the Leeside site.

An analysis of the consequences of an over-topped pool fire (Event 1) showed that the levels of thermal radiation at the new development would be less than 4 kW/m^2 and therefore would not present a significant hazard. Therefore modelling of smaller scenarios (event 2) was not required.

Table 13.6.3.4Consequence Distances from Centre of Pool, D5 (Leeside)				
Event → Distance to ↓	Bulk Tank Event 1	Bulk Tank Event 2	Day Tank Event 1	Day Tank Event 2
4.0kW/m^2	230 m	230 m	230 m	138 m
6.8kW/m^2	200 m	200 m	190 m	110 m
9.23kW/m^2	158 m	158 m	158 m	96 m
12.7kW/m^2	138 m	138 m	138 m	85 m
13.4kW/m^2	130 m	130 m	130 m	75 m
25.6kW/m^2	70 m	70 m	70 m	37 m
37.5kW/m^2	50 m	50 m	50 m	30 m
Centre of pool	50 m from bund wall	Centre of main bund	50 m from bund wall	Centre of day tank bund

Table 13.6.3.4: Consequence Distances from Centre of Pool, D5 (Leeside)

13.6.3.3. Jetty

Petroleum will be unloaded from tankers at the jetty. Design of the jetties is at an early stage although sufficient information is available to enable analysis for planning purposes. Amec has been advised that the Petroleum products will be unloaded through hard arms.

This analysis is based on the diameter of the unloading hose being the same as the transfer pipeline i.e. 10" nominal bore (254.4 mm internal diameter). The operating pressure is in the range 4 – 8 bar and consequence modelling is based on 8 barg. The transfer rate is 550 m^3/hr (pumped from the ship). Ships will transfer in lots of approx 4,000 m^3.

Three release cases were considered:

- Full bore rupture;
- 80mm leak (representing 10% of the cross sectional area);
- 10mm leak.

A number of possible outcomes were considered which included flash fires, pool fires (which would occur if liquid 'rained out') and jet fires.

The consequence distance depends on the orientation of the release and on the wind and dispersion conditions. In order to simplify the analysis consequences were modelled for horizontal releases and vertical releases in weather conditions represented by Pasquill stability and wind classes of F2 and D5.

For hole sizes up to 85mm the rate of release will be governed by line pressure and hole diameter. Above this the release rate becomes limited by the pumping rate from the ship and the pressure in the line will drop off.

For a full bore rupture the pressure inside the line would be approximately 0.1 barg which is the pressure required to generate a release rate which is equal to the transfer rate of 550 m^3/hr. This pressure is insufficient to cause a jet fire.

The modelling assumed that the pool was uncontained. The release duration was conservatively taken as 20 minutes. In practice the unloading operation would be supervised by personnel both on the ship and in the harbour (at the jetty) and the expectation is that any release would be isolated relatively quickly (e.g. within a few minutes). Furthermore as described in Appendix 3.34 it is planned that booms will be deployed during unloading operations so that should a release occur it would be contained and could be recovered.

The results for each outcome are tabulated below. The results are reported to levels of thermal radiation and to thermal dose based on 75 seconds exposure time. The maximum distances to the lower flammable limit (LFL) and 0.5 lower flammable limit were determined for cases of delayed ignition. Note that this assumes that the cloud ignites at its maximum extent. If it ignited earlier the effects area would be smaller.

Table 13.6.3.5 Jetty Flash Fire: Distance to LFL and ½ LFL

Release Type	Release Direction	Weather Type	Flash Fire	
			0.5 LFL	LFL
Full Bore Rupture	Horizontal	2F	312.9	243.3
		5D	144.2	86.7
		15D	95.7	54.4
	Vertical	2F	275.4	204.4
		5D	204.4	137.5
		15D	157.3	89.7
80mm Leak	Horizontal	2F	440.4	338.0
		5D	300.1	220.8
		15D	228.0	156.7
	Vertical	2F	309.7	33.5
		5D	63.6	40.7
		15D	56.9	31.4
10mm Leak	Horizontal	2F	61.3	41.2
		5D	40.0	22.1
		15D	16.8	8.3
	Vertical	2F	9.5	3.1
		5D	7.6	3.3
		15D	6.2	3.2

Table 13.6.3.5: Jetty Flash Fire: Distance to LFL and ½ LFL

Table 13.6.3.6 Jetty Jet Fire: Distance (m) to Thermal Radiation Levels and Thermal Exposure

Release Type	Release Direction	Weather Type	Jet Fire (m)								
			6.8kW/m2	9.23kW/m2	12.7kW/m2	13.4kW/m2	25.6kW/m2	37.5kW/m2	500 tdu	1000 tdu	1800 tdu
80mm Leak	Horizontal	2F	209.0	194.5	181.3	179.2	157.9	147.7	237.1	207.7	187.6
		5D	189.0	174.1	160.7	158.6	137.0	126.8	217.8	187.6	167.1
		15D	171.2	157.5	145.1	143.2	123.4	114.1	197.8	170.0	151.0
	Vertical	2F	125.0	108.4	92.4	89.8	58.5	37.3	156.1	123.5	100.2
		5D	114.9	99.6	85.8	83.9	64.6	54.1	143.4	113.5	92.1
		15D	107.9	97.4	87.6	86.1	69.7	61.1	128.2	107.0	92.3
10mm Leak	Horizontal	2F	32.8	30.7	28.8	28.5	25.3	23.8	36.6	32.6	29.7
		5D	29.3	27.1	25.2	24.9	21.7	20.2	33.4	29.1	26.1
		15D	27.4	25.3	23.4	23.1	20.0	18.6	31.5	27.2	24.3
	Vertical	2F	20.5	17.9	15.2	14.7	8.6	N/R	25.6	20.3	16.5
		5D	22.6	19.9	17.5	17.1	12.6	10.9	27.6	22.3	18.7
		15D	20.5	18.8	17.2	17.0	14.4	13.2	24.0	20.4	18.0

Table 13.6.3.6: Jetty Jet Fire: Distance (m) to thermal Radiation Levels and Thermal Exposure

Release pressure in event of full bore rupture is insufficient to cause jet fire

Table 13.6.3.7Jetty Pool Fire: Distance (m) to Thermal Radiation levels and Thermal Exposure

Release Type	Release Direction	Weather Type	Pool Fire (m)								
			6.8kW/m2	9.23kW/m2	12.7kW/m2	13.4kW/m2	25.6kW/m2	37.5kW/m2	500 tdu	1000 tdu	1800 tdu
FB Rupture	Horizontal	2F	114.3	88.7	76.0	76.0	N/R	N/R	167.4	111.9	79.5
		5D	128.5	93.9	71.7	70.3	N/R	N/R	188.3	124.8	80.7
		15D	145.9	98.1	68.1	66.2	N/R	N/R	202.7	141.2	79.6
	Vertical	2F	110.9	85.5	72.9	72.9	N/R	N/R	163.4	108.5	76.4
		5D	122.6	89.0	67.4	66.0	N/R	N/R	180.6	119.1	76.3
		15D	139.2	94.9	66.3	64.3	N/R	N/R	191.6	134.2	77.5
80mm Leak	Horizontal	2F	122.4	101.3	89.9	89.9	N/R	N/R	165.9	120.3	93.4
		5D	131.7	106.1	88.9	87.2	N/R	N/R	177.8	129.6	96.0
		15D	142.0	113.1	93.3	91.7	N/R	N/R	178.5	139.2	101.2
	Vertical	2F	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		5D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		15D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
10mm leak	Horizontal	2F	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		5D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		15D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
	Vertical	2F	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		5D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout
		15D	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout	No Rainout

Table 13.6.3.7: Jetty Pool Fire: Distance (m) to Thermal Radiation Levels and Thermal Exposure

13.6.3.4 Pipeline

Three petroleum unloading lines will be provided from the new jetty to the Topaz Terminal (The Leeside site will not be supplied from the new jetty). The pipelines will run in a concrete chamber below ground level as shown on Drawing 2139-2187. The chamber will be impervious. The trench will be approximately 3 m wide in total.

Approximately every 100-m a dividing wall will be installed which will limit the spillage spreading further along the trench. The volume of each such chamber is approximately 180 m^3 and in event of a major release would fill in approximately 20 minutes (based on full flow). The dividing walls will have an overflow to the next chamber in event that the leak is not detected and isolated before the chamber fills. Never the less it cannot be ruled out that gasoline could migrate to the surface.
The line diameter is as described for the jetties above.

The range of possible outcomes is wide depending upon the release diameter, line pressure at the time of release, whether the trench is covered or uncovered, orientation of release and whether the release ignites. For the purposes of assessing the risk a number of representative cases and outcomes are defined.

Three release cases were considered:

- Full bore rupture;
- 80-mm leak (representing 10% of the cross sectional area);
- 10-mm leak.

Possible outcomes considered were flash fire, pool / trench fire, jet fire and explosion.

It was assumed that:

- For releases that occur in normal operation, it was considered that the gasoline would fill the section of the lined trench and If not detected and isolated gasoline would overflow to the neighbouring sections. Nevertheless it cannot be ruled out that gasoline could migrate to the surface with the risk of pool and flash fire;
- Although ignition sources will not be present within the chamber in normal operation it is possible that a spillage could ignite causing a vapour cloud explosion. Depending on the amount of vapour involved this may or may not cause damage to the duct. If there is a sizeable petroleum inventory in the trench when damage occurs it would be followed by a trench fire;
- When the line is uncovered e.g. for maintenance, a vertical spray release could project gasoline beyond the trench, forming a jet and / or an unconfined pool fire;
- When the line is uncovered a horizontal release would impinge on the walls of the trench and is therefore considered unlikely to give rise to a spray release. (Gasoline is a liquid and line pressure would drop off). If ignited this would produce a trench fire.

The consequences of a pool fire depend upon the pool dimension across which the wind is blowing. So for a trench fire this could vary considerably depending on whether the wind was across or along the trench.

For the purposes of defining a case it was assumed that the wind is blowing at an angle of 20 degrees to the pipe. The results are tabulated below. A sensitivity analysis was also carried out at 45 degrees and at 90 degrees.

For cases of release while the pipeline is uncovered the results determined for vertical jet fire and pool fire for the jetty apply. This may be conservative in the case of pool fire in that the jetty analysis is based on the ground being impermeable. Releases from the pipeline may be to areas of hard standing (roads, yards etc.) but may also be to lanscaped areas in which case the pool would not spread as far and consequence distances would be reduced.

Table 13.6.3.8 Pipeline Trench Fire

Release Type	Weather Type	Pool Fire (m)								
		6.8kW/m2	9.23kW/m2	12.7kW/m2	13.4kW/m2	25.6kW/m2	37.5kW/m2	500 tdu	1000 tdu	1800 tdu
Pool fire 90 degrees wind	2F	21.0	18.1	15.0	14.5	7.7	4.9	25.9	20.7	16.6
	5D	23.0	20.7	18.4	17.9	9.6	5.7	27.7	22.7	19.6
	15D	24.7	22.6	20.4	20.1	12.2	6.7	28.3	24.5	21.5
Pool fire 45 degrees wind	2F	27.1	22.6	17.5	16.6	8.3	6.0	34.4	26.7	20.2
	5D	31.2	27.6	22.9	21.5	9.7	6.0	37.3	30.9	25.6
	15D	34.0	30.7	28.1	27.5	11.0	6.1	39.3	33.8	29.4
Pool fire 20 degrees wind	2F	30.1	24.0	17.4	16.5	8.2	8.1	39.6	29.6	20.5
	5D	36.5	31.1	22.0	20.5	8.8	8.1	44.2	36.1	26.3
	15D	40.5	37.2	28.1	26.0	9.0	8.1	47.7	40.2	34.6

Table 13.6.3.8: Pipeline Trench Fire