

Land-use Planning Advice for Kilkenny County Council  
In relation to  
Grassland Fertilizers (Kilkenny) Ltd.  
at  
Palmerstown

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## **1. Executive Summary**

This document has been prepared for Kilkenny County Council in respect of a request for land-use planning advice in the vicinity of Grassland Fertilizers (Kilkenny) Ltd.

In formulating its advice, the Authority considered potential major accidents involving Ammonium Nitrate Fertilizer (ANF), and the potential for impact of these on the surrounding people and the environment.

The Authority determined the risk zones in relation to potential major accidents involving these substances and sets out its advice concerning future development in those zones.

## **2. General Introduction**

This document contains the basis for the conclusions of the HSA ('the Authority') with regard to the request for land use planning advice from Kilkenny County Council ('the Planning Authority') in relation to Grassland Fertilizers (Kilkenny) Ltd. ('the Establishment') at Palmerstown, Co. Kilkenny.

Based on the information supplied by the Establishment in its Notification, it is currently an upper-tier Seveso site under the European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, S.I 74 of 2006 ('the regulations'). Consequently the request falls within the remit of the Authority to offer technical advice in relation to land-use planning.

The responsibility for safety on the site rests with the Operator.

The operator is responsible for the appointment of competent persons to look after safety matters.

The Establishment is required, under the above regulations, to demonstrate to the Authority, at any time, that it has taken all necessary measures to prevent major accidents occurring and to limit the consequences of any such major accidents for man and the environment, and demonstrate that it has a safety management system in place.

It is required to produce a Safety Report that will demonstrate it is taking all necessary measures for the prevention and mitigation of major accidents. This document is required to be made available to members of the public who request it.

The operator is required to prepare an Internal Emergency Plan for the establishment.

The Local Competent Authorities are required to prepare an External Emergency Plan.

The operator is required to regularly provide information to the public on the actions to take in the event of an emergency.

The Establishment will be subject to regular inspection by Inspectors of appropriate technical expertise from the Authority, and a proportion of these will be unannounced.

The Authority acknowledges the role of the Fire Authority in relation to the general obligations to fire safety on the operator under the Fire Services Act of 1981 (as amended).

In the event of any 'development' that could have significant repercussions for major accident hazards, planning permission will be required.

In developing its advice, the Authority takes account of the requirements of the regulations as set out above, the commitment of the Establishment to comply with INDG 230 especially in relation to the limitation of stack size and separation distance, to improve its storage of combustibles and confine them to a designated outside area, the removal of combustible material from the bulk materials store, the removal of the gas meter to a suitably safe area and its undertakings in relation to examination of the oil storage tanks and provision of appropriate bunding arrangements. The absence of sawdust due to the under floor heating system was also taken into account.

### 3. Assessment by HSA

#### 3.1 Introduction

The functions of the Authority are set out in appendix 1. One of its many functions relates to the provision of land use planning advice to planning authorities, which is a legal obligation under SI 74 of 2006.

However there are a number of general exclusions contained in the regulations, the most relevant being as follows:

The occurrence outside an establishment of -

- the transport of dangerous substances by road, rail, internal waterways, sea or air
- associated intermediate temporary storage
- the transport of dangerous substances in pipelines and pumping stations.

Then there are some activities, not listed as exclusions, which do not come within the scope of the regulations:

- The Authority's advice does not deal with site selection or the suitability of one site over another.
- Activities related to site development /construction are not within the remit of the Authority in the context of the provision of Land-use planning advice.

#### **The Establishment area**

The establishment is considered to be the area within the security fence footprint where the hazardous substances are processed and stored.

This decision was taken in respect of previous planning applications and has been retained following discussions between the Authority and EU Commission officials and representatives of the other EU member states.

#### **Explanation of technical terms**

This report makes reference to specific terminology related to consequence and risk assessment modelling.

The way in which the Authority develops its general technical advice and the criteria it uses are set out in Appendix 2, where many of the technical issues related to risk assessment are explained.

The hazards that were considered by the Authority for the determination of risk posed by this establishment were:

- Fire giving rise to toxic fumes of Nitrogen Dioxide, to the dangerous dose\* endpoint of 56.6 ppm for a 30 minute exposure
- Fire giving rise to toxic fumes of Nitric Oxide, to the dangerous dose endpoint of 697 ppm for a 30 minute exposure
- Explosion following a fire: overpressure effects to 140 mbar

\*A **dangerous dose** is defined as one where

- There is severe distress to almost everyone.
- A substantial fraction requires medical attention.
- Highly susceptible people might be killed.

See appendix 4 for the detailed approach of the Authority to the provision of LUP advice relating to establishments storing Ammonium Nitrate Fertilizer (ANF).

### 3.2 Methodology

The main consequence-modelling package used for analysis in this case was PHAST v6.4 (DNV Technica). Use was also made of ALOHA (US EPA) and ADMS data supplied by Health & Safety Laboratory, UK. The risk calculation package used was Riskplot (ERM). Reference was also made to many relevant technical documents and these are listed in appendix 4.

### 3.3 Key Assumptions for Analysis

Upon examination of loss history databases and also through consultation, judgement and experience, the Authority chose a selection of events, from across the span of the site to determine the potential overall off-site consequences (see appendix 4 for the approach of the authority to LUP advice for sites storing ANF).

The key assumptions are outlined below for each stage of the risk assessment process.

### Inventory

The Establishment made a formal notification of their dangerous substance inventory to the Authority, shortly after the Regulations came into force. In summary:

	Dangerous Substances	Qty Tonne	Seveso Cat.	Upper Threshold
1	NPK Fertilizer 27:6:6 [UN 2067]	4000	Named subs	5000
2	NPK Fertilizer 30:6:0 [UN 2067]	4000	Named subs	5000
3	NS Fertilizer 27:3:7 [UN 2067]	4000	Named subs	5000

**Table 1: Notified inventory**

This class of Ammonium Nitrate Fertilizers are covered by Note 2 of Schedule 1 (of the regulations):

*This applies to straight ammonium nitrate-based fertilisers and to ammonium nitrate-based compound/composite fertilisers in which the nitrogen content as a result of ammonium nitrate is*

*- more than 24,5% by weight, except for mixtures of ammonium nitrate with dolomite, limestone and/or calcium carbonate with a purity of at least 90%,*

*- more than 15,75% by weight for mixtures of ammonium nitrate and ammonium sulphate,*





#### 4. HSA Comment on the Establishments own Assessment

To date, no assessment has been received from the Establishment. Their Safety Report is due for submission to the Authority in February 2007.

#### 5. Conclusions

Based on the foregoing assessment, the following table sets out the advice of the Authority in relation to future development in the vicinity of the establishment (the zones previously indicated in figure 2).

<b>Zone 1:</b> Risk > 10 cpm	Advise against residential, office and retail, permit occasionally occupied developments e.g. pump houses, transformer stations. Consult with H.S.A re. Industrial development.
<b>Zone 2:</b> Risk 1-10 cpm	Permit workplace development. Permit residential densities from 28 to 90 persons /ha., density increasing as risk decreases across the zone in developed areas and 22 to 70 persons/ha. in less developed areas. Permit modest retail and ancillary local services Advise against shopping centres, large-scale retail outlets, undue concentration of restaurant/pub facilities.
<b>Zone 3:</b> Risk 0.3-1 cpm	No restrictions except for sensitive developments, which would be subject to consultation if inside the zone and should not be at a risk greater than $0.3 \cdot 10^{-6}$ Sensitive developments include crèches, schools, hospitals, and nursing homes. Locations of major public assembly will be subject to individual assessment.

In interpreting the above table, 'industrial' should be taken as any organized workplace development not attracting significant numbers of the public. The level of development at any location will depend on the risk at that location, but a workplace development with 75 people on-site at any time and less than 3-storeys in height is likely to be suitable, with an emphasis on placing car parks, utility buildings etc. nearest to the  $1 \times 10^{-4}$  risk zone.

In applying the residential densities, calculate the total area from the centre of the proposed development to the site extents within the zoned area.

Notwithstanding the above, for very-high density and/or very sensitive developments or for developments in the vicinity of highly populated areas, a separate societal risk assessment may be necessary in order to furnish appropriate technical advice to the Council.



## Appendix 1 Role of HSA (Legal Framework)

### 1. Background

The Health and Safety Authority was set up under the Safety Health & Welfare at Work Act, 1989.

As the name implies, it is primarily concerned with the health and safety of people at work. The principal functions, as set out in Section 16 of that Act (now Section 34 of the 2005 act) are:

- To make arrangements for enforcement of relevant legislation
- To promote, encourage and foster the prevention of accidents
- To encourage & foster measures directed towards the promotion of health and safety of persons at work

The Authority is divided up into operational units.

The Process Industries Unit (PIU) is responsible for the implementation of the Seveso Regulations and provision of Land-use Planning advice thereunder.

### 2. Seveso II Legal Context

The Authority, acting as the Central Competent Authority under the EC (Control of Major Accident Hazards involving Dangerous Substances) Regulations, 2006 (SI 74 of 2006), gives technical advice to a planning authority when requested, under regulation 27(1), in relation to

- The siting of new establishments,
- Modifications to an existing establishment to which Article 10 of the Directive applies
- Proposed development in the vicinity of an existing establishment

SI 74 of 2006 implements EU Directive 96/82/EC [Control of Major-accident Hazards involving Dangerous Substances] as amended by directive 2003/105/EC. Article 12 of that Directive states:

'Member States shall ensure that their land-use and/or other relevant policies and the procedures for implementing those policies take account of the need, in the long term, to maintain appropriate distances between establishments covered by this Directive and residential areas, areas of public use and areas of particular natural sensitivity or interest, and, in the case of existing establishments, of the need for additional technical measures in accordance with Article 5 so as not to increase the risks to people.'

The Major Accident Hazard Bureau/ Joint Research Centre of the European Commission have produced guidance in this area for the National Competent Authorities, concerning the status of technical advice furnished to planning authorities:

'It is recognised that consideration of major-accidents is only one input to the process of land-use planning controls and policies... many other considerations can be relevant, and that these may already be elaborated in various national policies and implemented in national, regional or local structure and development plans.'

#### Exclusions

It should be noted that the Regulations exclude certain activities:

"These Regulations shall not apply to -

(a) any property occupied by the Defence Forces and any land or premises referred to in section 268(1) of the Defence Act, 1954 (No. 7 of 1954);

(b) Hazards created by ionising radiation;

(c) The occurrence outside an establishment of -

(i) the transport of dangerous substances by road, rail, internal waterways, sea or air,

- (ii) Intermediate temporary storage associated with a subparagraph (i) activity,
  - (iii) The loading or unloading of dangerous substances at docks, wharves or marshalling yards,
  - (iv) The transport to and from another means of transport at docks, wharves or marshalling yards, and
  - (v) The transport of dangerous substances in pipelines and pumping stations.
- (d) the activities of extractive industries associated with exploration for, and the exploitation of, minerals in mines and quarries or by means of boreholes (not excluded are thermal processing operations and storage involving dangerous substances);
- (e) waste land-fill sites (not excluded in some situations are operational tailings pond disposal activities).

It should also be noted that biological agents are not within the definition of 'dangerous substance' and are therefore not covered by the Regulations.

In giving its advice, the Authority considers only the effects of credible major accident scenarios at the establishment and does not deal with routine emissions. It is the understanding of the Authority that such emissions will be subject to EPA or Local Authority scrutiny and control.

The Authority's advice does not deal with site selection or the suitability of one site over another.

Activities related to site development / construction are not within the remit of the Authority in the context of the provision of Land-use planning advice.

In general, in assessing the risks or consequences of major accidents, the Authority will always look for the best estimate. Where there are uncertainties, it will tend to take a conservative approach and favour that which will overestimate the consequence or risk rather than underestimate it.

## Appendix 2 Criteria for Land Use Planning

### 1. Policy in Relation to Siting of New Establishments

The question considered by the HSA when it provides technical advice to a planning authority relating to a new establishment is:

'If operational, would the risks posed by this establishment be tolerable?'

The Board-approved policy of the HSA in relation to LUP for new establishments states that:

'It is ... necessary to demonstrate for new "Greenfield/Brownfield" establishments that they do not present a risk of a dangerous dose greater than  $5 \times 10^{-6}$ /yr. to their current neighbours or a risk of a dangerous dose greater than  $1 \times 10^{-6}$  /yr. to the nearest residential type property. This may be relaxed in respect of neighbours where the new development is the same/similar to the existing neighbours; for example new oil storage depot being set up in a location already occupied by tank farms.

The Authority will seek from the operators of proposed establishments a detailed consequence and risk assessment in order to help it formulate a response to a request for advice on a planning application.

The Authority will also consider any potential impact on local access/egress arrangements in the context of public behaviour in the event of an emergency and access for emergency services.

The Authority will give consideration to any other issues it deems relevant to a particular application notwithstanding what has been indicated above'

### 2. Technical Basis for Advice – the context of Land-use Planning

There are, as yet, no European or international standards for the provision of Land-use Planning advice. An EU working group (European Working Group on Land-use Planning), which has been in existence since 2002, was set up to consider the implementation of Article 12. The HSA represents Ireland on this group. This document has now reached final draft status, has been adapted by the Committee of Central Competent Authorities in October 2006, and is awaiting final approval.

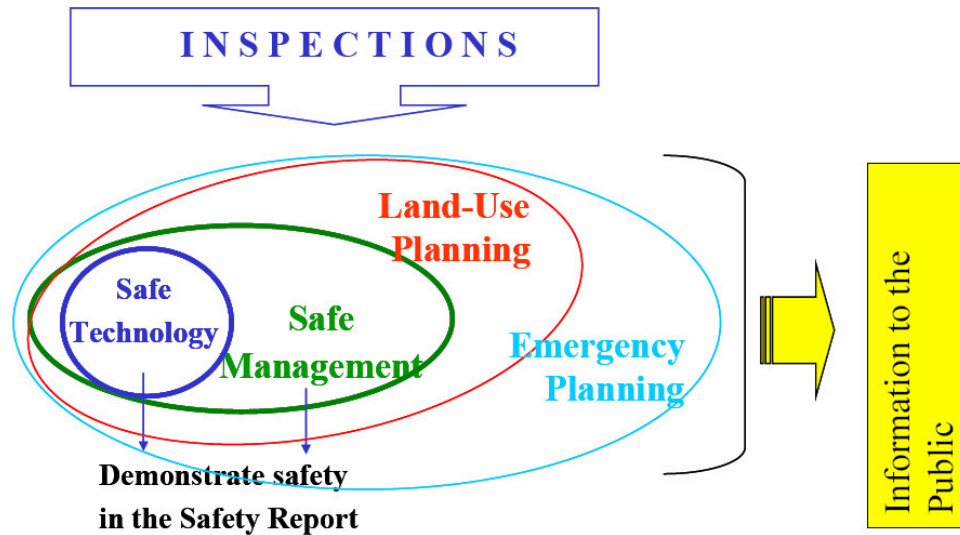
The Authority provides LUP advice in the context of the best practice described in that document.

It is worth noting a number of points from that document in relation to the context of LUP (and therefore the advice of the HSA to planning authorities).

- As pointed out on page 7 of the document, Article 12 **does not apply retrospectively**, but relates only to future developments.
- LUP is only one of the many tools for the protection of people and the environment, as represented in the following graphic:



- o In the context of the Directive, it is but one of many elements available in relation to major accident hazards:



At present in the EU, a variety of approaches are taken in developing LUP advice, including

- The use of generic distance tables, where the distance relates to activity or storage quantity
- Consequence only. i.e. the distance is related to the consequence
- Risk & Consequence i.e. the likelihood of the consequence is estimated

At present, the Authority takes either a 'consequence' or a 'risk and consequence approach' in relation to developments, depending on the nature of the activity. For new establishments, a 'risk & consequence' approach is usually taken. Advice is provided concerning the potential effects of major accidents at establishments.

**2.1 Establishment**

Establishment is defined in the Regulations-  
 "Establishment" means the whole area under the control of the same person where dangerous substances are present at or above the qualifying quantities (...in schedule 1) in one or more installations, and for this purpose two or more areas that contain installations under the control of the same person and separated only by a road, railway or inland waterway will be treated as one whole area.

In practice, the establishment is usually considered to be the area within the security fence footprint where the hazardous substances are processed and stored. This area comes under the remit of the regulations. This approach has historically been taken and has been retained following discussions between the Authority and EU Commission officials and representatives of the other EU member states.

## 2.2 Major Accident

The Regulations define a major accident as follows:

"Major accident" means an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment, leading to a serious danger -

- (a) to human health, or
- (b) to the environment,

whether immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.'

Major accidents inevitably involve a loss of containment of a dangerous substance.

The general approach adopted by the Authority is, therefore, to identify credible 'loss of containment' hazards, identify the consequences if such hazards were realised and, in certain cases, estimate the likelihood of those consequences.

Because Land-use planning concentrates on matters related to off-site risks, these form the focus of the approach. Lesser, but more likely, events are therefore not usually included as they do not have off-site impacts.

The Authority examines the process and material inventories of the proposed establishment to determine the location of inventories of dangerous substances that have the potential for an off-site impact in the event of a major accident. Bulk storage tanks, gas cylinders, pipelines, process and storage areas, road tankers etc. are all likely sources.

## 2.3 Credible Scenario

Credible accident scenarios that are considered (depending on the particular establishment) include major spills, releases of flammable or toxic vapours, fires, vapour cloud explosions and boiling liquid evaporating vapour explosions [BLEVE's].

The selection of credible scenarios is a critical part of any analysis. In selecting such scenarios, the HSA has particular regard to the Purple Book, the CCPS, reports published by the UK Health and Safety Executive (HSE) and other reliable sources.

Some events are not considered credible:

- Earthquake is ruled out, based on a paper by the Dublin Institute for Advanced Studies. (*A. W. B. JACOB, Seismic Hazard in Ireland. International Association of Seismology and Physics of the Earth's Interior and European Seismological Commission. The Practice of Earthquake and Hazard Assessment. Ed. by Robin K. McGuire, 150-152, 1993.*)

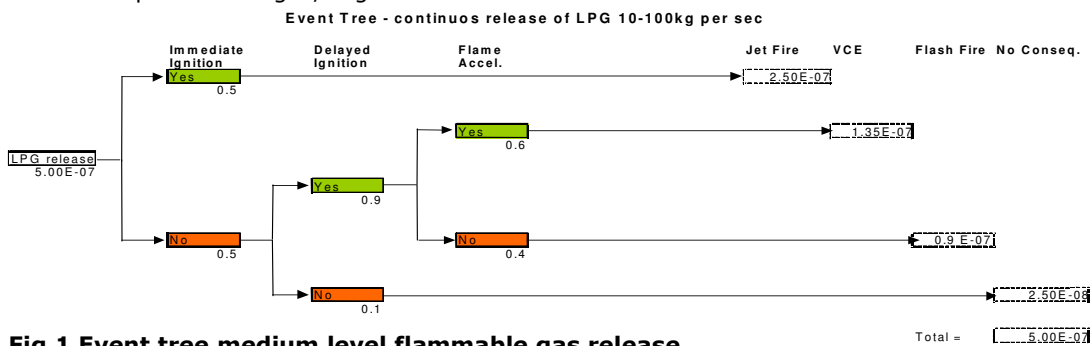
Using a methodology set out in a UK HSE commissioned research report (*CRR 150 1997, The calculation of aircraft crash risk in the UK*) aircraft crash can be ruled out other than for sites near an airport or significant flight path.

Other off-site initiators of major accidents are considered on a case-by-case basis. They will not be included if -

- The event is of equal or lesser damage potential than the events for which the plant has been designed.

- The event has a significantly lower frequency of occurrence than other events with similar uncertainties and could not result in worse consequences than those events.
- The event cannot occur close enough to the plant to affect it.
- The event is included in the definition of another event.
- The event is slow in developing and there is sufficient time to eliminate the source of the threat or to provide adequate response.

On the other hand, instantaneous failure of storage tanks and pressure vessels may be considered credible, as are full-bore pipeline failures and fires in storage areas. The precise events chosen are based around 'Event Trees', which describe the different scenarios that could result from the loss of containment. An example, for a leak of flammable pressurised gas, is given below.



**Fig.1 Event tree medium level flammable gas release**

The HSA tend to use a high probability of on-site ignition even though more detailed models might predict lower probabilities.

For many events the weather will be an important variable. The HSA will often use weather data from the nearest weather station in F<sub>2</sub> and D<sub>5</sub> conditions (see note 3, appendix 3 on dispersion modelling), as supplied by Met Eireann and re-formatted by the Authority. If the site is a very great distance from any of the named weather stations then the Authority will use the F<sub>2</sub>/D<sub>5</sub> weather-stability pairs for dispersion modelling, assuming a split of 25% F<sub>2</sub> and 75% D<sub>5</sub>; this will give a more conservative result than using data from any of the known stations.

For new establishments the Authority performs an 'Intermediate Quantitative Risk Assessment (QRA)', in that a representative set of incidents is chosen and historical frequency values are applied. Given the conservative approach adopted by the Authority, insofar as off-site risk is concerned, this will yield results equivalent to a detailed QRA.

**2.4 The Consequences of Major Accidents**

Different types of physical effects could result, depending on the hazard:

Hazard	Effect
Release of Toxic material	Contamination of air/water
Vapour Cloud explosion, Physical Explosion	Overpressure wave, Heat flux Physical effects of projectiles
Pool Fire, Jet Fire, BLEVE Flash fire	Heat Flux

**Table 1: Major Accident Consequences**

### 2.4.1 Effects of overpressure

A 'level of concern' at which these effects could be experienced must be chosen in order to draw conclusions about impact

The effects of overpressure are set out below:

Side-on Overpressure (kPa)	Description of Damage
0.15	Annoying noise
0.2	Occasional breaking of large windowpanes already under strain
0.3	Loud noise; sonic boom glass failure
0.7	Breakage of small windows under strain
1	Threshold for glass breakage
2	"Safe distance," probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken.
3	Limited minor structural damage
3.5-7	Large and small windows usually shattered; occasional damage to window frames
5	Minor damage to house structures
8	Partial demolition of houses, made uninhabitable
7-15	Corrugated asbestos shattered. Corrugated steel or aluminum panels fastenings fail, followed by buckling; wood panel (standard housing) fastenings fail; panels blown in
10	Steel frame of clad building slightly distorted
15	Partial collapse of walls and roofs of houses
15-20	Concrete or cinderblock walls, not reinforced, shattered
18	Lower limit of serious structural damage 50% destruction of brickwork of houses
20	Heavy machines in industrial buildings suffered little damage; steel frame building distorted and pulled away from foundations
20-28	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
30	Cladding of light industrial buildings ruptured
35	Wooden utility poles snapped; tall hydraulic press in building slightly damaged
35-50	Nearly complete destruction of houses
50	Loaded tank cars overturned
50-55	Unreinforced brick panels, 25-35 cm thick, fail by shearing or flexure
60	Loaded train boxcars completely demolished
70	Probable total destruction of buildings; heavy machine tools moved and badly damaged

**Table 2: Damage Produced by Blast**

Source: Guidelines for Evaluating Characteristics of Vapor Cloud Explosions, Flash fires and BLEVEs, CCPS 1994, ISBN 0-8169-0474-X, based on the work of Glasstone (1977)).

(Note 1 kPa = 10 mbar)

The Second Canvey Report has a table for overpressure effects on humans:

O/Pressure (psi)	O/pressure (mbar)	O/Pressure (kPa)	Human Effects
5	340	34	Threshold of eardrum damage
10	690	69	Threshold of lung damage
40	2760	276	Threshold of mortality

**Table 3: Effects of Overpressure on Humans**

#### 2.4.2 Effects of Thermal Radiation

Similarly, the effects of heat radiation can be listed:

Radiation Intensity (kW/m <sup>2</sup> )	Structural Damage
37.5	Sufficient to cause damage to process equipment
25	Minimum energy to ignite wood at indefinitely long exposures (non-piloted)
12.5	Minimum energy for piloted ignition of wood, melting of plastic tubing.
9.5	Pain threshold reached after 8 sec; second degree burns after 20 seconds
4	Sufficient to cause pain to personnel if unable to reach cover in 20 sec., secondary burns likely, 0% lethality.
1.6	Will cause no discomfort for long exposure

**Table 4: Effects of Thermal Radiation (World Bank, 1985)**

#### 2.4.3 Threshold Levels of concern (Dangerous Dose)

The threshold 'levels of concern' used by the Authority are:

Consequence	Level of Concern
Contamination of air	Dangerous Dose (Concentration varies with substance & exposure length)
Overpressure wave Missiles	600 mbar, 140 mbar, 70 mbar Distance travelled by a % of projectiles, 100m for cylinders/drums
Heat Flux, Thermal Dose	1800, 1000, 500 TDU

**Table 5: Levels of Concern used by HSA**



A dangerous dose is defined as one where there is severe distress to almost everyone. A substantial fraction requiring medical attention. Highly susceptible people might be killed. It assumes that most people are/can go indoors and will be less likely to suffer a dangerous dose therein (with the exception of overpressure, where in certain circumstance they may be more at risk due to building damage).

Where a full risk-based approach is taken, the levels of concern are:

Consequence	Level of Concern
Contamination of air with toxic	Dangerous Dose (Concentration varies with substance)
Overpressure wave Missiles	Dangerous Dose = 140 mbar Distance specific to event: a % travel distance, 100m for cylinders/drums
Heat Flux, Thermal Dose	Dangerous Dose = 1000 TDU (75s exposure for Pool & Jet Fire, Fireball duration for BLEVE)

**Table 6: Dangerous Dose for different consequences**

A thermal dose unit (TDU) is a measure of the heat flux and its duration. 1000 TDU is taken as the 'dangerous dose' based on research work commissioned by the HSE (CRR 285 of 2000- Thermal Radiation Criteria for Vulnerable Populations) [8].

The 140mbar side-on overpressure figure is taken as the 'dangerous dose' for overpressure, and the 70mbar figure is the limit for sensitive developments i.e. no fatalities even for sensitive developments (*Safety Cases for Consultation Distances For Major Hazard Installations*, P97 – see ref 8, appendix 3))

To calculate the distances from the source at which these endpoints could be expected, commercial software is used. The modelling software typically used by the Authority includes PHAST (DNV Technica), ALOHA (US EPA), TSCREEN (US EPA), methods from the American Institute of Chemical Engineers' Centre for Chemical Process Safety and the Yellow Book (note 1, appendix 3 gives a brief outline of these software programmes)

To determine how likely it is that these effects will happen, other software is used, most usually RISKPLOT.

The output of all this analysis is a series of individual risk profiles overlaid on a map of the establishment and its surroundings, illustrating the individual risk of receiving a dangerous dose.

## 2.5 Tolerable Risk

The following table, taken from The Second Canvey Report lists some common risks of accidental fatality:

Event	No. of Fatalities	Chance of the Average Individual Being Killed
Motor vehicle accidents	7,219	1.3 chances in 10 000 a year*
Accidents in the home	6,717	1.2 chances in 10 000 a year*
Accidents at work	753	0.3 chances in 10 000 a year**
Others	3,646	0.6 chances in 10 000 a year*
Total	18,335	

\* Averaged over the total population of Great Britain.

\*\* Averaged over 22 million employees.

**Table 7: Risk of death from accidents**

The risk of death from natural causes for different age-groups is shown in the following table:

Risk of death from natural causes in age groups	
Age	Risk
0- 4	34.4 in 10 000 a year
5-14	1.9 " " "
15-24	3.0 " " "
25-34	4.8 " " "
35-44	16.2 " " "
45-54	55.0 " " "
55-64	147.7 " "
65-74	422.3 " "
75-84	1, 073.0 " "
85+	2, 023.5 " "

**Table 8: Risk of death from natural causes**

Statistics available from the HSA on occupational fatality rates:

Economic sector	Fatalities		Total at work (QNHS 2002)	Rates per Million
	Total 2002	Worker 2002		
A - Agriculture, Forestry and Hunting	13	11	121,700	115
B - Fishing	3	3		
C - Mining and Quarrying	2	2		
D - Manufacturing	7	5	310,400	22.5
E - Electricity, Gas and Water Supply	2	0		
F - Construction	21	20	183,200	109.1
G - Wholesale and Retail	1	0	249,100	0
H - Hotels and Restaurants	0	0	108,700	0
I - Transport, Storage, Communication	8	7	108,900	64.2
J - Financial Intermediation	0	0		
K - Real Estate, Renting and Business Activities	1	1	226,400	4.4
L - Public Admin, Defence and Social Security	2	2	82,000	24.3
M - Education,	0	0		
N - Health and Social Work	0	0	260,000	0
O - Other	1	1	94,900	10.5
Total	61	52	1,745,500	34.9

**Table 9: Fatality Rates per million Workers**

Risk that is broadly acceptable is that which is trivial in comparison to the risk experienced in daily life. At the other end of the scale there clearly is a level of risk that is unacceptable. In deciding on LUP criteria the HSA concluded that for the general residential public an individual risk of dangerous dose greater than  $1 \times 10^{-5}$  (i.e. 1 in 100,000) per year would not be tolerable for developments around existing establishments, and for new establishments it should not exceed  $1 \times 10^{-6}$  (i.e. 1 in 1,000,000).

## 2.6 Criteria Used in other countries for Land-Use Planning

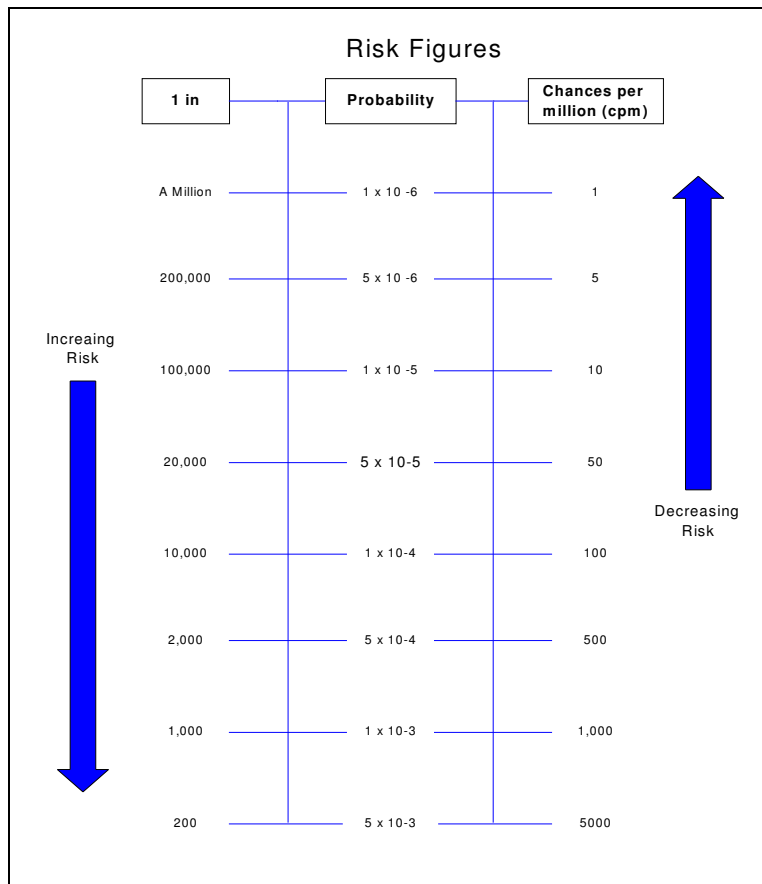
The following are some of the better-developed criteria:

<b>UK HSE</b>	
Maximum tolerable worker individual risk	1 in 1,000 per annum
Maximum tolerable public individual risk	1 in 10,000 per annum
Benchmark for new plant and developments	1 in 100,000 per annum
Broadly acceptable public individual risk	1 in 1,000,000 per annum
Land-use Planning - Residential development unrestricted	1 in 1,000,000 per annum (Dangerous Dose)
<b>Netherlands</b>	
Maximum tolerable public individual risk for existing situations	1 in 100,000 per annum
Maximum tolerable public individual risk for new developments	1 in 1,000,000 per annum
Maximum tolerable public individual risk around airports, above which re-housing is required.	1 in 20,000 per annum
Broadly acceptable public individual risk	1 in 1,000,000 per annum
<b>Australia</b>	
Acceptable risk to the public in residential zones from hazardous industries	1 in 1,000,000 per annum
Hospital, Schools, Child-care	0.5 in 1,000,000 per annum
Acceptable total risk within hazardous industrial zones	1 in 10,000 per annum

**Table 10: Various National risk criteria (fatality unless otherwise stated)**

## 2.7 Presentation of Risk

Risk figures can be confusing. The following figure shows some of the different ways that risk can be presented.



**Figure 2: Ways of Presenting Risk**

## 2.8 Classification of Development Types

In giving LUP advice, the HSA classify developments under one of the following categories:

- Residential
- Retail and catering
- Commercial
- Industrial
- Sensitive e.g. hospital, some schools, outdoor leisure complexes etc.: developments of this nature are subject to special analysis

The following table sets out the risk zones that are estimated for the purposes of offering land-use planning advice:

(figures are related to the individual risk of receiving a dangerous dose, per year)

Zone	Risk (R)
Zone 1.	$> 1 \times 10^{-5}$ (i.e. $> 10$ cpm)
Zone 2.	$1 \times 10^{-6} < R < 1 \times 10^{-5}$ (i.e. 1 - 10 cpm)
Zone 3.	$0.3 \times 10^{-6} < R < 1 \times 10^{-6}$ (i.e. 0.3 - 1 cpm)

**Table 11: Risk zones for LUP**

The LUP advice for the different zones is as follows:

<b>Zone 1:</b>	Advise against residential, office and retail, permit occasionally occupied developments e.g. pump houses, transformer stations. Consult with H.S.A re. Industrial development.
<b>Zone 2:</b>	Permit workplace development. Permit residential densities from 28 to 90 persons /ha., density increasing as risk decreases across the zone in developed areas and 22 to 70 persons/ha. in less developed areas. Permit modest retail and ancillary local services Advise against shopping centres, large-scale retail outlets, undue concentration of restaurant/pub facilities.
<b>Zone 3:</b>	No restrictions except for sensitive developments, which would be subject to consultation if inside the consultation range and should not be at a risk greater than $0.3 \cdot 10^{-6}$ Sensitive developments include crèches, schools, hospitals, and nursing homes. Locations of major public assembly will be subject to individual assessment.

**Table 12: LUP Advice zones based on Risk**

The advice with respect to housing density in Zone 2 is based on consideration of the analysis given in "A Worst Case" Methodology for Risk Assessment of Major Accident Installations" in Process Safety Progress [Vol. 19, No. 2].

Use of the criteria as outlined above will provide a basis for the advice on the acceptability of a new 'Seveso' establishment and for justifying a separation distance between Seveso establishments and off-site developments. These criteria do not guarantee an absence of risk but suggest a tolerable level, given that major accidents with offsite damage are relatively uncommon. They represent an attempt to balance a potential for harm against a social requirement that large tracts of land should not be unnecessarily sterilised for future development.

The criteria will be subject to on-going review and revised in the light of new knowledge and ongoing experience.

## 2.9 Societal Risk

The approach as set out above includes an element of societal risk in terms of the advice for each of the zones ('residential densities from 28 to 90 persons per ha.' 'modest retail', 'large-scale' etc.). In most cases no further assessment of societal risk is necessary. However, for very-high density or very sensitive developments or for developments in the vicinity of highly populated areas a separate societal risk assessment may be necessary.

### 2.10 Consequence-based approach

It is the view of the Authority that, for existing sites and for those sites presenting thermal or overpressure hazards only, it may be more appropriate to take a consequence-based approach (Note 2 of appendix 3 gives an overview of consequence and risk based assessments). This takes into account the additional physical damage to buildings and structures resulting from these types of hazards, over and above the direct harm to people that result from toxic exposure. It also reflects the omni-directional nature of these hazards. The following scenarios are considered:

- instantaneous loss of contents from tanks, drums or cylinders
- full-bore rupture of pipelines and smaller leaks
- bund overtopping
- pool, bund and building fires
- drum projectiles
- releases from reaction vessels in the event of loss of control
- road tanker failures leading to spillage , fire or explosion
- vapour cloud explosions
- solid-phase explosions

In general, the worst credible scenarios are selected.  
The advice zones for a consequence-based approach are as follows:

Thermal and Overpressure Effects:

Zone	Advice
Inner Zone Source-1800 TDU Source-600 mbar	Industrial [subject to consultation], Occasional occupation by small number
Middle Zone 1800-1000 TDU 600-140 mbar	Commercial & industrial <100 persons, retail & catering <250m <sup>2</sup>
Outer Zone 1000 -500 TDU 140-70 mbar	Commercial, retail & catering, industrial, small housing developments.

### **3. Major Accidents, Land-use Planning Advice and Environmental Effects**

The Authority's technical advice to the planning authority deals with the potential effects of major accidents. In relation to the environment the advice is concerned only with those environmental effects that are related to major accidents and it does not consider routine emissions, which are within the remit of the local authority or EPA, and subject to license.

Currently, there is no common approach within the EU on suitable scenarios or endpoints for the assessment of Major Accidents to the Environment (MATTEs) within the framework of the Seveso II directive. Consequently, such assessment tends to be more qualitative than the approach concerning major accidents and the potential effect on human receptors. This qualitative approach is due to the highly variable nature and sensitivity of environmental receptors, allied to the lack of suitable sensitivity data for all receptors, and the multiplicity of such receptors in the environment.

The approach of the HSA, in the consideration of environmental effects associated with Seveso II establishments, is also conscious of the requirements placed on operators (current or proposed) by Regulation 9 of S.I. No. 74 of 2006. In assessing the consequences of potential worst-case credible accidents and their impacts on the environment, the HSA concentrates on Regulation 9(2)(e), requiring operators to use best practicable means –

- to prevent a major emission of dangerous substances resulting from uncontrolled developments from any part of the establishment, into the environment, and
- for rendering harmless and inoffensive such substances as may be so emitted.

The Seventh Schedule to S.I. 74 of 2006 lists the criteria for notification of accidents to the Commission. Major accident hazards should have this type of potential in order to be considered.

More practical information on what might constitute a major accident to the environment is given in guidelines from the HSA in relation to major accidents to the environment [*Guidance on Interpretation of Major Accident to the Environment (rev 5)*- Oct 2003] which in turn is adapted from guidance issued by the UK Department of the Environment, Transport and the Regions.

A major accident to the environment will occur as a result of a major emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment and resulting in significant damage to the natural or man-made environment. This damage could be relatively long lasting but not necessarily irreversible. Recovery of habitats can take considerably longer depending on the dangerous substance in question. The assessment of major accidents to the environment focuses on the specific risks to sensitive receptors within the local environment, the extent of consequences to such receptors, and on the ability of such receptors to recover.

#### **HSA Approach**

The approach of the Authority, therefore, is to examine potential impacts to the environment from the identified credible major accident hazards and satisfy itself that appropriate 'best practicable means' are/will be in place to prevent such impacts. Best practicable means might constitute adequate bunding for storage tanks containing dangerous substances allied with tertiary containment to prevent migration off-site of any overtopping fraction, or contaminated fire fighting water, for example.

The potential for initiating a major accident due to natural phenomena is also examined. For example, the effect of flooding, storm damage, subsidence is considered in relation to the potential effect on storage tanks and storage areas, as well as important site utilities. The operator must demonstrate that other potential initiators have been considered (lightning for example) and control/mitigation measures employed where required



While the 'best practicable means' standard is also applied to control of gaseous loss of containment events (e.g. suitably-sized catch pots for reaction vessels), the consequences of such releases are examined as part of the general major accident scenarios for human receptors.

Article 12 of the amended Directive requires Member States to 'take account of the need, in the long term, to maintain appropriate distances between establishments covered by this Directive and residential areas, buildings and areas of public use, major transport routes as far as possible, recreational areas and areas of particular natural sensitivity or interest...'

Where the Authority notes such areas in the vicinity of an establishment it undertakes further analysis to satisfy itself that an appropriate distance can be maintained. Appropriate distances are not specified in the Directive. However a separation distance will be considered appropriate if it is sufficient to enable the installation and operation of suitable control and mitigation measures, and/or is such that the risk of serious damage is low in the event of a major release.

## 4. Petroleum Bulk Stores, Land Use Planning and Environmental Criteria

### Background

The earlier part of this appendix has set out the general approach of the Authority regarding the provision of Land Use Planning (LUP) advice and the previous section elaborated further in relation to the environment.

This document sets out the Authority's position in formulating land-use planning advice for new petroleum bulk store installations with particular consideration of appropriate environmental criteria.

In the case of new installations at existing establishments, a similar approach will be adopted. In some instances, due to spatial constraints on older sites, or other considerations relating to their layout, particular site-specific measures may have to be designed in order to fulfil the 'best practicable means' criteria. In these cases consultation with the Authority at an early stage in the design process with justification on how the proposed design in terms of meeting the 'best practicable means' criteria.

### Legislative basis

Under the Seveso II Directive [96/82/EC as amended by 2003/105/EC] there is a requirement to ensure that the objectives of preventing major accidents and limiting the consequences of such accidents are taken into account in the land use policy of member states. Furthermore, there is a requirement to take account of the need, in the long term, to maintain appropriate distances between establishments covered by the Directive and residential areas, areas of public use and areas of particular natural sensitivity or interest. Such appropriate distances are not specified in the Directive or transposing Regulations, but would generally be considered sufficient if they allow the installation of suitable control and mitigation measures to provide adequate protection to the environment, or if their extent is such that the risk of serious damage to the environment is low in the event of a major release. Under the EC (Control of Major Accident Hazards involving Dangerous Substances) Regulations, 2006 [SI 74 of 2006], which transpose the Seveso II Directive, and specifically relating to the general duties of operators, Reg. 9(1)(b) requires the operator to take all necessary measures to limit the consequences of any major accident to man and the environment, while 9(2)(c) further qualifies this by stating that such necessary measures shall include the making of arrangements to ensure that the use, handling, storage, and transport of dangerous substances in the establishment are, so far as is reasonably practicable, without risk for man and the environment, and 9(2)(e) that the use of best practicable means to prevent a major emission into the environment from any part of the establishment of dangerous substances resulting from uncontrolled developments in that establishment, and for rendering harmless and inoffensive such substances as may be so emitted.

### Petroleum Bulk Stores & Major Accidents to the Environment

The Directive specifically applies to "major accidents" as defined. That is to say, an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment, leading to a serious danger to human health or the environment, whether immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances. By definition therefore, a major accident can only be considered under the terms of the Directive, if it is caused by a dangerous substance as defined under Parts 1 and 2 of Annex 1 of the Directive. Automotive petrol and other petroleum spirits (including diesel) are listed as named substances in Part 1 of the First Schedule of S.I. 74 of 2006 and as such are dangerous substances. In addition, other relevant substances are classified under the generic category of Dangerous to the Environment, and are therefore also considered dangerous substances under the terms of the Directive. Materials not so classified as a dangerous substance, or not provisionally classified as a dangerous substance, though they may possess other properties that could cause ecological disruption, are outside the scope of the Seveso II Directive.

Many of the larger petroleum bulk stores are located adjacent to areas of natural sensitivity (ports, etc.). Such locations may also be designated as candidate Special Areas of Conservation (cSAC's), or by virtue of populations of significant bird populations, as Special Protection Areas (SPA's). As such, the potential consequence to the natural environment as a result of a major spillage event to that environment is likely to be severe. However, the long-term (and perhaps even short-term) consequences associated with some materials may be less significant. Non-persistent oils, such as kerosene for example, by virtue of their relatively quick degradation rate, will pose a lesser danger to the environment than the more persistent oils (crude oil for example). Along with spillage of inventory, the generation of contaminated firewater in the event of a major fire must also be considered.

### Bunds

Prevention of a major emission into the environment, in the context of petroleum bulk stores, is generally provided by bunding. The general requirement is for 110% of the largest tank, or 25% of the total tank volume, where more than one tank exists in the bund, whichever is the larger figure. The statutory requirements of S.I. No. 313 of 1979 (Dangerous Substances (Petroleum Bulk Stores) Regulations) must be complied with. In addition, the UK's HSE publication "The Storage of Flammable Material in Tanks (HSG 176)" provides further guidance on an appropriate approach to spillage containment.

### Risk Assessment

In terms of site-specific environmental risk assessment, the EPA's Guidance Note on the Storage and Transfer of Scheduled Activities provides a detailed approach (under Section 5 of that document). Additionally, it sets assessment criteria based on the German Environment Agency's approach of using water hazard classes – i.e. either non-hazardous or one of the following classes: WHC 1 – low hazard, WHC 2 – hazardous, or WHC 3 – severe hazard. Assignment of the WHC class is based on the risk phrases of the materials involved, and other considerations such as biodegradation rate, bioaccumulation etc. The full detail of how this class is assigned can be obtained directly from the German Environment Agency website at <http://www.umweltbundesamt.de/wgs-e/index.htm>, (where a search can be made using CAS numbers or the substance name). In addition, the downloads section demonstrates how substances and mixtures can be self-classified based on the risk phrases as applied by the Classification, Packaging and Labelling stream of legislation (Directive 67/548/EEC as amended and Directive 99/45/EC).

Furthermore, EPA's Guidance Note goes on to provide a simple risk category table based on this risk classification criteria and associated quantities stored -

WHC Class	1	2	3
Vol. (m <sup>3</sup> ) or mass T			
<0.1	A	A	A
0.1 – 1	A	A	B
1 – 10	A	B	C
10 – 100	A	C	D
100 – 1000	B	D	D
>1000	C	D	D

Generally, category A equates to low risk, B to medium risk, while categories C and D equate to higher risk. Particular consideration needs to be given in relation to sensitive environmental receptors in cases of overground facilities of category D and underground facilities of categories C and D. Section 5.3 of the guidance note provides detail on retention requirements associated with each WHC class while Section 6 provides guidance on the design and operation of retention facilities (bunds), which are categorised as Class

1, 2 or 3 on the basis of low, moderate, or high hazard potential. The EPA Guidance note should be consulted for further detailed information. It should be noted that the nature of dangerous substances and their associated volumes stored at petroleum bulk stores is likely to classify such sites as category C or D, that is to say possessing a high potential for pollution in the event of a major release, and would ordinarily require containment systems to be designed to a high standard. Provision for holding contaminated firewater should be facilitated into the overall containment design. Key activities with major accident potential should be provided with independent levels of protection (e.g. independent high level alarms and leak detection system, allied with physical secondary and tertiary containment). Again, referral is made to the EPA guidance for specific detailed design criteria appropriate to these categories.

### **Bund Overtopping**

The issue of bund overtopping is not dealt with specifically in the EPA guidance document. It is examined by the HSA as a potential scenario with respect to Seveso II establishments in terms of the provision of LUP advice. Such a scenario is considered highly unlikely but credible, and the consequences in terms of the Seventh Schedule of the Regulations (i.e. will a major accident to the environment ensue?) and the receptors that will be affected, have to be considered. Again, referring to those sites that would qualify as possessing a higher potential for pollution, then provision for containment of the overtopping fraction in the event of catastrophic failure must also be considered in the overall design to take account of this scenario. For example, the provision of tertiary containment and associated drainage systems to contain and hold up to 110% of the maximum calculated overtopping fraction is considered by the Authority to be an appropriate approach. How tertiary containment is provided will very much depend on site-specific conditions. Therefore, consultation should be made early at the design stage with the Authority in order to ensure that the proposed approach is satisfactory.

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### References Cited

1. 'Criteria for land-use Planning' – Appendix 3 of 'Land Use Planning Advice for Mayo Co. Council', HSA, April 2004
2. The Storage of Flammable Liquids in Tanks – HSG 176 – Health and Safety Executive
3. S.I. 74 of 2006 – European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations
4. Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances
5. S.I. 313 of 1979 – Dangerous Substances (Petroleum Bulk Stores) Regulations 1979
6. Environmental Protection Agency IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities, May 2003
7. Environmental Protection Agency (Draft) Guidance Note to Industry on the Requirements for Fire-Water Retention Facilities, 1995 ISBN 1 899965 165

## Appendix 3 – Software, approaches to risk assessment, weather

### 1. Software Models

#### (a) ALOHA:

ALOHA, available from the US Environmental Protection Agency, is an emergency response model intended primarily for rapid deployment by responders, as well as for use in emergency preplanning. It incorporates source strength, as well as Gaussian and heavy gas dispersion models and an extensive chemical property library. More than 700 pure chemicals and a small number of aq. Solutions are included in ALOHA's chemical library.

ALOHA quality assurance has been performed in two stages:

(1) ALOHA source and dispersion estimates have been systematically tested against output from similar models.

(2) ALOHA evaporation rate estimates have been compared against measured rates from both boiling and non-boiling pools. Neutrally buoyant gas concentration predictions have been compared against concentrations measured during Project Prairie Grass. Heavy gas dispersion predictions have been compared against DEGADIS predictions for six heavy gas field releases (Desert Tortoise, Goldfish, Maplin Sands, Burro, Eagle, and Thorney Island).

The latest version can also be used to model thermal and overpressure effects.

#### (b) PHAST

PHAST is a commercially available software package produced by DNV Technica. PHAST stands for Process Hazard Analysis Software Tool. PHAST is designed for use in assessing situations which present potential hazards to life, property and the environment and to quantify their severity.

It uses a built-in chemical and parameter database for 46 substances, with incomplete data for many more.

It uses the Unified Dispersion Model (UDM) to estimate dispersion of releases to the atmosphere. The model has been well validated.

PHAST can also be used to model thermal and overpressure effects.

### 2. Consequence and risk based hazard assessments

#### 2.1 Consequence based Approach:

The "consequence based" approach (for which sometimes the term "deterministic approach" is used) is based on the assessment of consequences of conceivable accidents, without quantifying the likelihood of these accidents. The concept behind the use of this approach is to avoid tackling the uncertainties related to the quantification of the frequencies of occurrence of the potential accidents.

The extent of consequences provides a measure of the severity of the potential accidents independently of their likelihood. These are used as a criterion in the "consequence based" approach. The consequences of the accidents are taken into consideration quantitatively by estimating the distance to which the physical magnitude describing the consequences reach (e.g. a threshold toxic concentration corresponding to the beginning of the undesired effect such as fatality), for a given exposure period.

Several conceptual approaches which are relevant to determining a consequence distance can be used, for example:

- for toxic releases, determination of a distance corresponding to a lethal toxic dose or serious injury (e.g. LC1%, that is the Lethal Concentration corresponding to the "first death" or lethality 1%);
- for thermal effects from fires, determination of a distance corresponding to a thermal radiation which, for a given exposure period, can cause burns likely to be lethal or cause serious injury;
- for explosions, determination of a distance corresponding to an overpressure likely to be lethal or cause serious effects.

#### 2.2 Risk based Approach:

Another category of approach used is the "risk based" approach (also known as the "probabilistic" approach). Various names have been used for this category, such as Probabilistic Risk Assessment (PRA), Probabilistic Safety Analysis (PSA), and Quantified Risk Assessment (QRA). Their purpose is to evaluate the severity of the potential accidents, and to estimate the likelihood of occurrence. For estimating the likelihood of

scenarios various methods are in use, ranging from simple selection of scenarios and frequencies from the relevant databases to the application of sophisticated tools, such as Event Tree and Fault Tree Analysis. In that sense, and since explicit calculation of the frequencies of possible accidents takes place, the "risk based" methods seem to be more complete in the analysis of risk than the methods previously described. However, they are more complicated, more time-consuming and more expensive.

In general, the "risk based" approaches define the risk as a combination of the consequences derived from the range of possible accidents, and the likelihood of these accidents. Therefore, they usually consist of five phases:

- identification of hazards,
- estimation of the probability of occurrence of the potential accidents (taking into account the safety/preventative measures and systems),
- estimation of the consequences of the accidents,
- integration into overall risk indices.
- comparison of the calculated risk with acceptance criteria.

Risk may be expressed in terms of (i) the individual risk, defined as the probability of fatality (or a specified level of injury) due to an accident in the installation for an individual being at a specific point, and (ii) the societal risk, defined for different groups of people, which is the probability of occurrence of any accident resulting at fatalities greater than or equal to a specific figure.

### 3. Weather Stability Classes

Weather conditions in hazard studies are generally described in terms of an atmospheric stability condition and a wind-speed e.g. D<sub>5</sub> indicates Pasquill stability class D with a wind speed of 5m/s. The Pasquill stability class (see table below) is a measure of the air turbulence which in turn is influenced by the level of solar radiation. The level of air turbulence influences the rate at which gas clouds dissipate to safe levels as they drift away from the source of the release.

Wind at 10m height	Solar Radiation			Night time cloud cover	
	Strong	Moderate	Slight	>=4/8	<=3/8
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

The classes A-F determine the stability is as follows:

- |                        |                      |
|------------------------|----------------------|
| A: extremely unstable  | D: neutral           |
| B: moderately unstable | E: slightly stable   |
| C: slightly unstable   | F: moderately stable |

## References

1. Position Paper on the provision of Land-Use Planning Advice in the context of the European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, 2000 (S.I. No. 476 of 2000).
2. Guidelines for Evaluating the Characteristics of Vapour Cloud Explosions, Flash fires and BLEVEs, AIChE, CCPS, 1994.
3. Guidelines for Consequence Analysis of Chemical Releases, AIChE, CCPS, 1999.
4. 'Guidelines for Quantitative Risk Assessment – CPR 18E', First Edition, 1999, Committee for Prevention of Disasters (Netherlands -'Purple Book').
5. 'Methods for the Calculation of Physical Effects – CPR 14E', Third Edition, 1997, Committee for Prevention of Disasters (Netherlands -'Yellow Book').
6. Guidelines for Evaluating the Effects of Vapour Cloud Explosions using a TNT Equivalency Method, FM Global, 1994.
7. Guidance on Land Use Planning as Required by Council Directive 96/82/EC (ISBN 92-828-5899-5)
8. Safety Cases for Consultation Distances for Major Hazard Installations, P97, RP Paper from Safety Cases within the CIMAH Regulations 1984, Edited by F.P. Lees & M.L. Ang, Butterworth 1989

## Appendix 4 - Ammonium Nitrate Fertilizer (ANF) Storage Plants – The HSA Approach to Technical LUP Advice

### 1. Introduction

This appendix sets out the approach of the HSA in relation to the provision of land-use planning advice in regard to establishments storing ANF.

### 2. Properties of Ammonium Nitrate

ZVG-Number : 3750  
 CAS-Number : 6484-52-2  
 EC-Number : 229-347-8

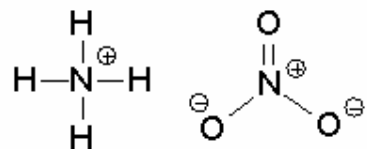
Substance classification :  
 128120 Ammonium salts  
 128500 Nitrates

State of aggregation : solid  
 at 1013 mbar/20 degrees C

Form : Crystals  
 Colour : colourless

Characterisation :  
 Oxidizing solid.  
 The substance itself does not burn, but in contact with combustible substances it increases the risk of fire and can fuel any existing fire substantially.  
 Very soluble in water.  
 Solves under cooling.  
 Hygroscopic.

FORMULA :



H4-N2-O3

Molecular weight : 80,04 g/mol



## EUROPEAN LABELLING

Hazard symbol :



O Oxidizing

Risk phrases (R-phrases) :

R 8

Contact with combustible material may cause fire

R 9

Explosive when mixed with combustible material

Safety advices (S-phrases) :

S 15

Keep away from heat

S 16

Keep away from sources of ignition - No smoking

S 41

In case of fire and/or explosion do not breathe fumes

The molecular weight of Ammonium Nitrate is 80. The atomic weight of Nitrogen is 14. Therefore, with 2 N atoms, the % Nitrogen in AN is  $28/80 = 35\%$ . So for 100% ANF, the Nitrogen content is 35%

Therefore when fertilizers with a nitrogen content as a result of AN is given as 28%, this corresponds to 80% AN ( $28/35$ ), and 15.75% AN corresponds to  $(15.75/35) = 45\%$  AN.

### 3. HSA Approach

Before deciding on an approach, the HSA reviewed an extensive list of publications covering aspects of the topic.

#### 3.1. Literature Review

##### 3.1.1 Hazard and Risk Assessment

A large number of articles have been published in reputable publications on the assessment of the risks from Ammonium Nitrate storage.

Among them:

- 'Safety Cases' by Ang & Lee (1989), which includes a description of how consultation distances are set by HSE, it notes that an upper limit of 300t is set for the permissible storage of bagged ammonium nitrate fertilizer, and looks at the detonation effects of this.
- The ILO publication 'Major Hazard Control A Practical Manual' (1993) suggests (in Appendix 8) that the separation distance (in metres) be set based on the formula  $[600 (\text{tonnes in stack}/300)^{1/3}]$ .
- The Loss Prevention Bulletin (Issue 132) has an article on the 'Assessment of Individual Risks from Fires in Warehouses Containing Toxic Materials' by Maddison, Atkinson and Kinsman.
- The UK HSE has published guidance on assessing Safety Reports for Chemical warehouses (including Ammonium Nitrate) which outlines methods for estimating heat and toxic release rates from warehouse fires. It indicates the use of a 'lift-off' criterion.
- Dechy et al.'s article 'First Lessons of the Toulouse Ammonium Nitrate Disaster 21 Sept 2001, AZF Plant France', (in the Journal of Hazardous Materials (111, 2004, 131-138)), noted the suspected role of contamination in Toulouse and refers to the new French law of 2002 which made it compulsory to take a value of 10% of the AN mass stored for the calculation of LUP scenarios.
- The INERIS report of October 2001 estimates that between 20 and 120 tonnes of AN were involved in the Toulouse explosion
- An EU workshop on AN at Ispra (Feb 2002) reviewed the possible causes of the Toulouse explosion and in general the hazards associated with AN, as well as some of the associated problems and concerns. The workshop identified the need to broaden the Seveso Directive to include Grades of ANF at less than 28% AN.
- Mr. David Adams of HSE's HID has written an article 'The Toxic Effects from a Fire Involving Ammonium Nitrate'. Although pre-Toulouse, it indicates the assessment should consider both the explosion of the stack and the toxic effects associated with a fire. It was presented to the EU JRC workshop on Ammonium Nitrate in 2002. It describes the results of HSE research work on Ammonium Nitrate fires and suggests a likely risk figure for those plants. It states that the frequency of an explosive event is very low.
- 'Safety and Security Issues Relating To Low Capacity Storage of AN-Based Fertilizers' by Marclair and Kordek in the J Haz Mat (A123, 2005, 13-28) gave an overview on this topic. It also notes the contamination potential of sawdust and wood shavings, among others.
- Atkinson & Adams presented a paper to the International Fertilizer Society at a meeting in London in 2002: 'Ammonium Nitrate: Toxic Risk from Fires in Storage'. This paper sets out a methodology for developing 'source terms' for modelling fires involving AN. It suggests that PHAST is a suitable dispersion code for modelling such an event. The paper also describes the HSE approach to LUP around AN stores. It notes the risks can be significant with the 1 cpm contour typically being at the 500m. This paper ("the HSL paper") forms the basis of the HSA approach to modelling the toxic effects of fire involving ANF. One of the authors, Mr. Graham Atkinson was engaged by the Authority in a consultancy role in the development of the detailed aspects of the approach.
- An HSL report by GT Atkinson on 'The Generation of NO<sub>x</sub> in Fires Involving Ammonium Nitrate and Other Chemicals' (2000) gives decomposition rates for AN exposed to thermal radiation.

- The PHAST 6.4 help system describes the steps required to model a warehouse fire and also suggests PHAST is suitable for events involving Ammonium Nitrate.
  - The existing UK HSE approach is described in the *Planning Case Assessment Guide* Chapter 6, which have been made available on a confidential basis to HSA. The HSE approach is specific to AN whereas the PHAST approach is suitable for all warehouse scenarios. It is understood that this approach is under review, based on the research indicated in the Atkinson & Adams paper.
  - Kersten & Mak in a presentation in Tokyo in 2004 (i.e. after Toulouse) titled '*Explosion Hazards Of Ammonium Nitrate, How to Assess the Risks?*' provides a table of the accident history of Ammonium nitrate since 1950 and concludes the hazards vary from toxic effects of fire-driven decomposition of AN to the occurrence of an explosion. The rest of the article focuses on the explosion aspect, looking at deterministic and probabilistic approaches, including the use of LOPA. It notes that the effects of fire dominate the risks because the risk of an explosive event is considered to be very low. It states that the effects of an explosion can be modelled by comparison with TNT (i.e. the 'TNT method' using Hopkinson's scale law). In looking at the equivalence of AN to TNT it quotes various company figures of 3% for fertilizer grade and 10% for 'technical' grade and a HSE figure of 14%. It concludes that while in general the risks are low, the consequences would be high.
- 3.1.2 Fire Modelling
- The SFPE *Handbook of Fire Protection Engineering* (3<sup>rd</sup> edition) Section 3 Chapters 1 and 11.
  - *Heat release rates from heavy goods vehicle trailer fires in tunnels*, Ingason & Lonnermark, Fire Safety Journal, 40 (2005) 646-668.
  - *Hazard Assessment for fires in Agrochemical warehouses, the role of combustion products*, Kinsman & Maddison, Process Safety and Environmental Protection 79(B3), IchemE, 2001
  - NFPA 204: *Standard for Smoke and Heat Venting*, 2002
  - *A Review of Models for Dispersion Following fires*, Hall et al, Envirobods 2005
  - *The fire and explosion at Cory's Warehouse*, HSE 1985.
- 3.1.3 Guidance on ANF Storage
- CS18 '*Storage & Handling of Ammonium Nitrate*' (1986), superseded by INDG 230 (2004), give good advice on the practices required at sites storing ANF.
  - Factory Mutual Data Sheet 7-89 '*Ammonium Nitrate and Mixed Fertilizers containing Ammonium Nitrate*' (2000) makes loss prevention recommendations. It suggests using 10% of the total AN quantity, up to a max of 45 tonnes, for explosion modelling.
  - Control of fire-water run-off is described in the HSE publication '*The control of firewater run-off from CIMAH sites to prevent environmental damage*' EH70 1995 and in the Fertiliser manufacturers Association '*COP For The Prevention Of Water Pollution From The Storage And Handling Of Solid Fertilisers*' (1998).
  - A USA EPA/CEPP publication '*Explosion Hazard from Ammonium Nitrate*' (1997) gives an overview of accident history and refers to NFPA 490 for standards on the storage of AN.
  - '*Handbook for the Storage of AN Based Fertilizers*', EFMA, 1992
  - '*Guidance for the Safe Handling and utilization of Non-Conforming Fertilizers and Related Materials for Fertilizer Producers*', EFMA, 2004. The advice contained in this document also applies to Blenders.

The HSA, as part of its inspection programme, will ensure good practice is being followed in relation the storage of ANF and the prevention of fire.

### **3.2 Scenario Selection**

Although not itself combustible, when exposed to an external source of heat AN can decompose to various oxides of Nitrogen, usually considered as NO and NO<sub>2</sub>.

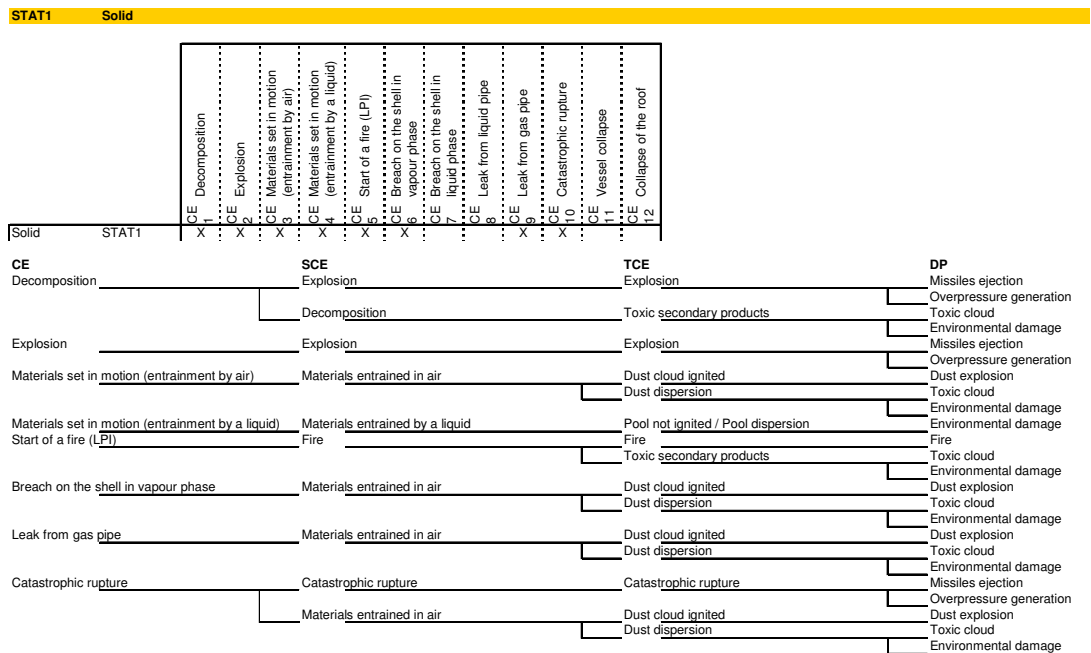
The Risk Hazard Assessment Database (RHAD) currently under development as part of an EU project on LUP at the request of the Commission, is based on the *Aramis (Accidental Risk Assessment Methodology for Industries)* in the context of the Seveso II Directive) risk assessment project methodology.

For mass solid storage, *Aramis* gives the following critical events

<b>EQ1</b>	<b>Mass solid storage</b>
<b>STAT1</b>	<b>Solid</b>

		CE 1 Decomposition	CE 2 Explosion	CE 3 Materials set in motion (entrainment by air)	CE 4 Materials set in motion (entrainment by a liquid)	CE 5 Start of a fire (LPI)	CE 6 Breach on the shell in vapour phase	CE 7 Breach on the shell in liquid phase	CE 8 Leak from liquid pipe	CE 9 Leak from gas pipe	CE 10 Catastrophic rupture	CE 11 Vessel collapse	CE 12 Collapse of the roof
Mass solid storage	EQ1	X	X	X	X	X							
Solid	STAT1	X	X	X	X	X	X			X	X		
<b>Results</b>		<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>							

The associated Event Tree is given as



i.e. it suggests the 'dangerous phenomena' to be considered are:

- o Fire and toxic cloud

- explosion overpressure,
- missiles
- environmental damage

Looking briefly at each of these in turn:

#### 3.2.1 Fire and toxic Cloud

Fire of ANF as such can be ruled out because ANF is not combustible.

As ANF is not combustible, other sources of combustibles must be looked for. If these are potentially present, the effects of fire must be considered. The effect of fire on ANF is to cause it to decompose, releasing toxic gases. Therefore the first consequence to look at is the off-site dispersion of these gases.

#### 3.2.2 Explosion

The most plausible (but very unlikely!) route to an explosion is firstly the formation of a pool of molten AN from a heat input source (e.g. following a very large fire), in a confined state, followed by initiation of an explosion from the falling of a high-energy object or some other source.

Explosion overpressure effects could then be considered.

A dust explosion was not included - AN fertilizer dust, being non-combustible in nature, does not give rise to a dust explosion such as those commonly associated with grain and organic dusts.

#### 3.2.3 Missiles

While missile generation is possible, the probability in terms of off-site effects is judged to be small and can therefore usually be neglected in these situations.

#### 3.2.4 Environmental accident

The most likely MATTE relates to a fire/fire-water run-off situation. This will only become an LUP issue for new establishments.

### **3.3 Established Approaches**

Examples of approaches to the modelling of warehouse fires have been described by the HSE and DNV (PHAST help system).

The HSE approach is a risk based one, starting out with various fire scenarios of different size in a 300t stack and looking at the toxic effects of this, and also assigning an explosion probability to each fire level. Account is taken of security and fire-fighting arrangements in place at the site.

The DNV/Phast approach is also risk-based. Depending on the fire-fighting arrangements in place, probabilities are assigned to fires of different surface area. These can then be modelled in PHAST and the combined data inputted to a suitable programme to calculate the overall risk profile. The DNV approach does not specifically deal with explosion probability or effects, and is probably more suited to a standard warehouse fire situation.

Neither approach deals with major environmental accidents (MATTE).

Both approaches are useful in that they allow the altering of some variables if the risk is found to be too high (fire response, security etc).

The approach of the HSA is substantially based on the experimental work carried out by HSL and reported as described above in Section 2.1.

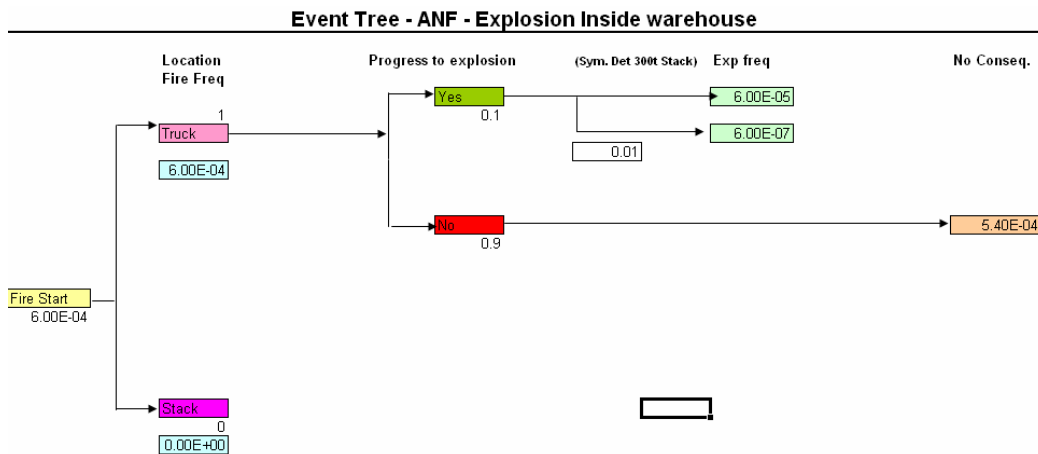
### **3.4 HSA Model**

For the purpose of generating LUP advice, the HSA assume the following:

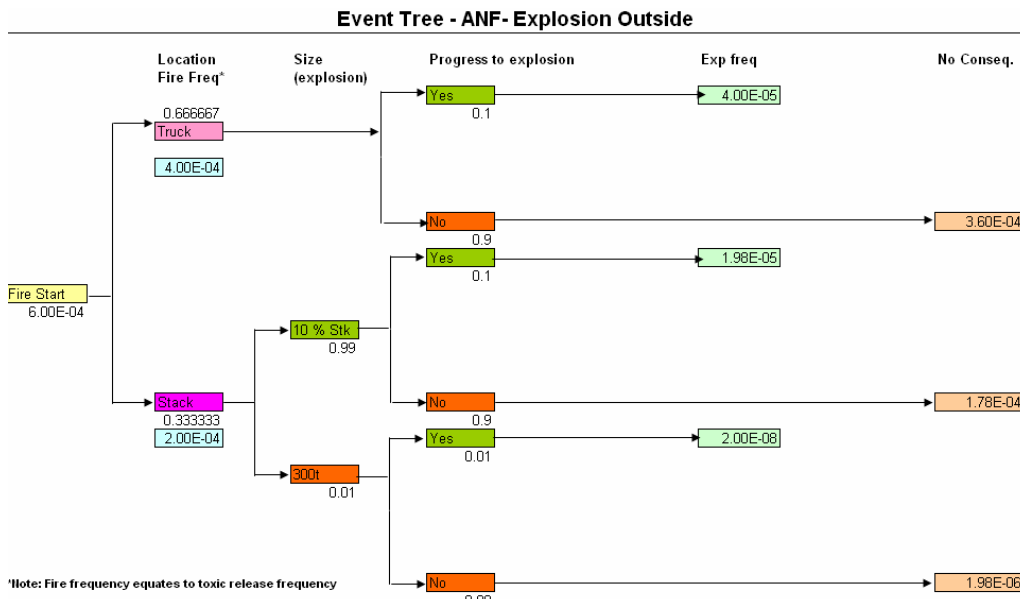
- All ANF, provided it is of the type set out in annex 1 of the Directive, is treated in the same way.

- Modelling of toxic fumes will be to the dangerous dose endpoint. Based on the current HSE DTL for NO<sub>2</sub> on their website, a value of 96000 ppm<sup>2</sup>min has been set as the dangerous dose, and this is equivalent to 56.6 ppm for 30 minutes.
- For Nitric Oxide a value of 697 ppm is used as the endpoint.
- 300t of ANF is equivalent to 41 tonnes of TNT, for explosion modelling purposes.
- The frequency of an explosion is related to the initial fire frequency, and is much more likely from a truck fire than from pallet or mass storage. In the case of pallet and mass storage, a smaller explosion (10% of the mass) is assumed to be more likely (by an order of magnitude) than an explosion involving the whole mass.
- If contaminated ANF is also stored at the establishment, a special assessment will be required.

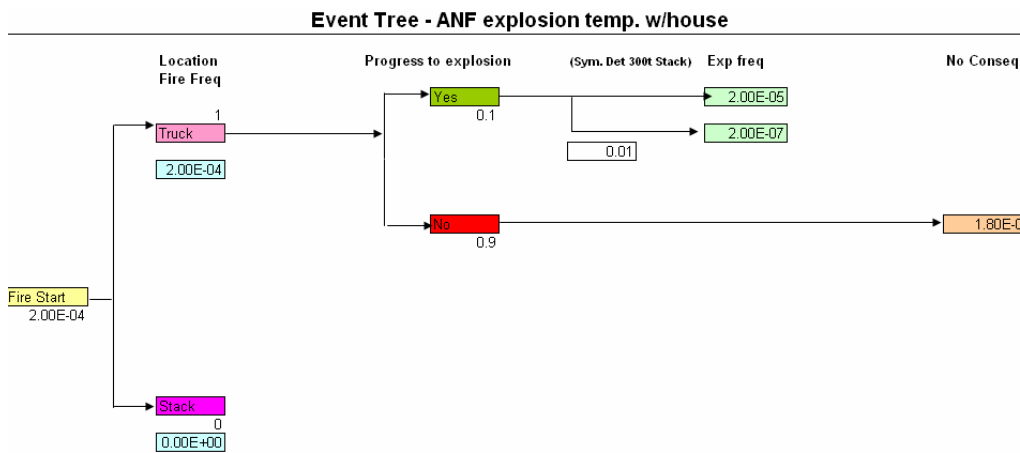
The model uses an initial fire frequency, which can be modified based on the factors such as co-storage with other dangerous substances, security, location, and fire response measures in place, either at the beginning of the assessment or during it. For a typical site, the fire frequency is taken as  $6 \times 10^{-4}$  per warehouse building per year. For simplicity, the whole outside storage area is treated as having the same fire frequency. Event Trees are then created to estimate the likelihood of the various downstream events. These are shown below:



**Fig.1 Event Tree for Fire/Explosion in Main Warehouse**



**Fig. 2 Event Tree for Fire/Explosion in Outside Storage Area**



**Fig.3 Event Tree for Fire/Explosion in Temporary Warehouse**

Therefore a typical set-up, involving storage in a warehouse and yard area, has an overall risk of fire of  $1.2 \times 10^{-3}$ , per year.

The likelihood of a truck catching fire is considered to be twice that for a stack. The probability that a fire will escalate to an explosion is considered to be an order of magnitude greater for a truck than for a stack. The probability that the quantity involved in the stack explosion is up to 10% of the nominal 300 tonne stack quantity is taken as being 100 times more likely than an event involving the full 300 tonnes.

The consequences of a fire involving AN in the outside storage area will be greater than that from the inside storage. In relation to the generation of fumes of toxic NO<sub>2</sub> from a fire inside a warehouse, the initial fire situation, before the roof collapses, is of most interest, because of the potential for higher ground-level concentrations. Because of the heat-

induced buoyancy, such concentrations are considered to be insignificant in the event of roof collapse, except in very high windspeed conditions.

The usual local wind-stability pairs of  $F_2$ ,  $D_{2.5}$ ,  $D_5$  and  $D_{10}$  are initially considered for modelling. Depending in the likelihood of the  $D_{15}$  condition, this could also be considered. A buoyancy check is carried out using the Briggs lift-off criterion equation, with the heat content of the plume and release height being required as inputs. In very many cases this will allow  $F_2$  conditions (and sometimes  $D_{2.5}$  and higher) to be discarded for modelling purposes. In any case the modelling of these scenarios in PHAST will show negligible consequences.

Although the data from Met Eireann is not exactly broken down into  $D_5$  and  $D_{10}$  categories, the '2.5 – 5.6 m/s'  $D$  weather can be taken as  $D_5$  and the '>5.6 m/s'  $D$  weather as  $D_{10}$ , for the purpose of modelling  $NO/NO_2$  releases from fire-induced ANF decomposition.

Generally, HSA selects 3 scenarios for modelling.

These are:

- Outside Stack Fire
- Outside Truck fire
- Inside Truck Fire

A fire frequency, as described above, is applied to each of these scenarios. Using the rates of  $NO/NO_2$  generation specified in the HSL paper, the extent of the dangerous dose zones are estimated in PHAST (or other suitable software programme).

This data is then inputted to Riskplot and the risk zones are visualised on a map of the area.

It is then conservatively assumed that these fires could result in an explosion at the probabilities set out in the event trees above (the existing HSE methodology suggests it is considerably less likely).

Factory Mutual suggest in *FM 7/89* that 10% of the stored quantity of ANF could be used for explosion modelling, up to a maximum of 45 tonnes of AN. HSE model a maximum of 300 tonne, based on the limiting stack size.

The HSA has chosen to model the full quantity up to 300t for bagged AN, as set out in the event trees.

In the case of bulk AN, the quantities subjected to heating and decomposition will be smaller than 300t, and these are selected for modelling purposes.

The overpressure effects are estimated using the TNT method, up to the dangerous dose of 140mbar. The efficiency of AN follows the HSE approach with 300 tonnes of AN being equivalent to 41 tonnes of TNT (based on 56% equivalence and 25% efficiency).

Given the low probability of explosion, the risk associated with missiles is so low as to be deemed not credible for modelling purposes.

The explosion risk contour extents and frequencies are inputted to Riskplot where they are summed with the toxic risks to generate the final risk contours that are overlaid on the local map.



#### 4. Data Collection

The first step in the actual assessment is to gather the following site-specific information:

Building Width (m):	
Building Height (m) (end of wall):	
Building Length (m):	
Building Orientation (o):	
Location - Urban or Rural:	
Site - Security Presence	
Site - Fenced or Unfenced:	
Construction - Flammable or Non-flammable:	
Use - Dedicated or Mixed:	
Sprinkler System - Yes or No:	
At Night - Manned or Unmanned:	
Roof - Frangible or Non-frangible:	
Skylights (location, Thermoplastic/GRP)	
Smoke vents (Location)	
Sawdust/other on floors	
Storage of Combustibles – pallets and packaging	
Locations/Qty of ANF Storage	
Location of timber structures within storage Building	
Location of fire sources within storage Building	
Location of flammable bulk liquid/gas storage	
Good Practice in storage of flammable bulk liquid/gas	
300t Packaged ANF stack limit observed	
Max qty ANF on truck	
% Storage Per Annum (>0 to 100%):	
% Fire-separated non-ANF Areas (0 to <100%):	

Inspectors of the Authority will visit the sites to ensure they are in compliance with legislation and following good practice as part of LUP advice generation. They will ensure the site is taking all necessary measures in relation to Major Accident Hazards. They will assess performance in relation to HSE, FM and NFPA standards, as described above. Information will also be collected on the level of housekeeping on site, the presence of timber/sawdust, storage location of transport machinery, height and nature of firewalls (whether to roof level etc.) The safe storage of pallets and packaging material in particular will be of interest, as will the fire prevention (including security) and fire-fighting arrangements.

The site should comply with the ANF storage guidance given in INDG 230.