Guidance on Technical Land-use Planning Advice

for planning authorities and operators of COMAH establishments

This guidance provides the current interpretation of Authority policy on the technical Land-use Planning advice requirements of the European 'Seveso' III Directive [2012/18/EU], on the Control of Major Accident Hazards, as implemented by the COMAH Regulations. It replaces the Policy & Approach document of 2010. It has been re-titled and streamlined, with greater emphasis placed on a more rigorous risk-based approach across all sectors. Clear guidance is given for scenario frequencies and modelling parameters. Sections on the Liquid Natural Gas, Recovered Natural Gas and Distillery/Warehouse sectors are also notable additions, as is a revised approach to societal risk.

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Part 1: Land Use Planning (LUP) Overview

1.1 GENERAL BACKGROUND

The Seveso Directive [2012/18/EU] requires that the objectives of preventing major accidents and limiting their consequences should be taken into account in land-use policy[1].

As implemented by the COMAH Regulations of 2015[2], the objectives are to be achieved through controls on:

- the siting and development of new establishments;
- modifications to existing establishments;
- development in the vicinity of establishments.

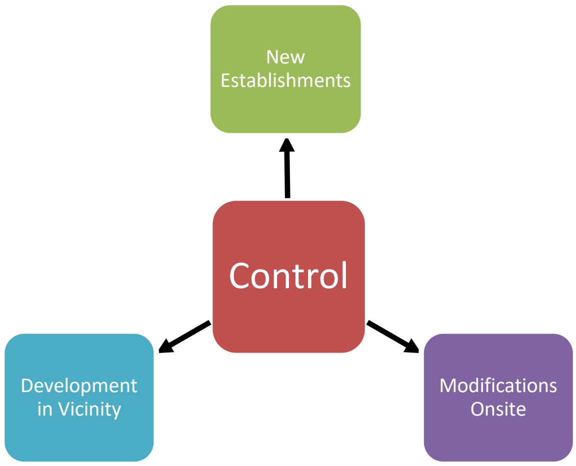

Figure 1: How the objectives of the Seveso III Directive are to be achieved

In applying these controls, account must be taken of the long-term requirement to maintain appropriate distances between establishments and residential areas, buildings and areas of public use, major transport routes, recreational areas and areas of particular natural sensitivity or interest.

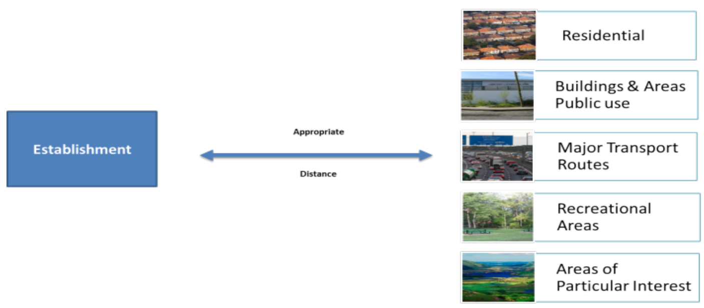

Figure 2: Necessary to maintain appropriate distances to identified receptors, in the long term

When decisions are being made in the planning process, publicly accessible technical advice must be available to a Planning Authority on the off-site risk from an establishment. The provision of this technical advice to a Planning Authority is referred to as *Technical Land-Use Planning* or 'TLUP'.

[1] Article 13 of the Seveso III Directive.

[2] Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations - SI 209 of 2015

This guidance addresses the policy and practice of the HSA in the provision of technical land-use planning advice to planning authorities.

The Seveso III Directive is implemented mostly through the Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations - SI 209 of 2015: the 'COMAH Regulations'. The TLUP requirements of the Directive are addressed by COMAH Regulation 24 (and also Regulation 12 for modifications to an establishment) and by the Planning and Development Regulations 2001-2019 (S.I. No. 600 of 2001).

COMAH Regulation 24 allows the Central Competent Authority ('CCA') for the Directive, which is the Health & Safety Authority, to set a protective Consultation Distance ('CD') around each establishment. This CD must be formally communicated to all relevant planning bodies. Planning bodies in turn are required to seek technical advice for any proposed development of the specified types (see fig. 2 above) within the Consultation Distance.

When the CCA receives an appropriate valid formal request from a planning body (see Appendix 1 for the referral form), it is legally obliged to provide technical land-use planning advice.

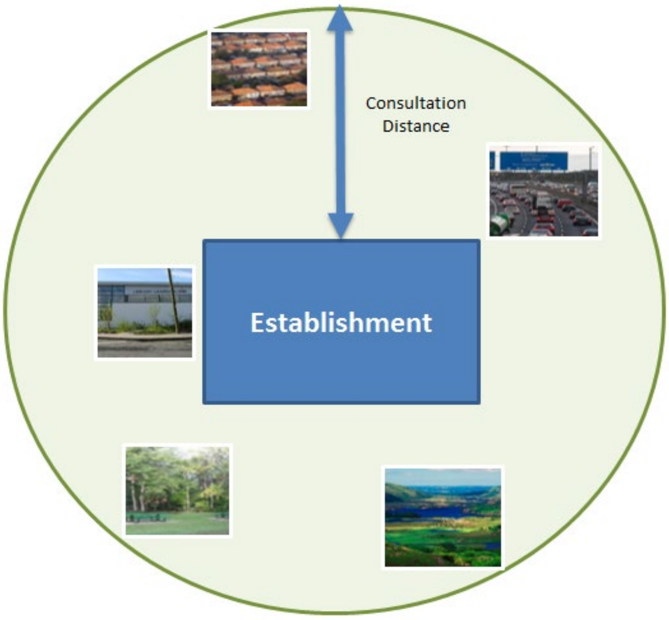

Figure 3: Within the consultation distance, the planning authority must seek technical advice for specified developments

The Planning & Development Regulations set out the overall timeframes for the planning process. Regulation 24 of the COMAH Regulations sets out the timeframes within which the CCA must provide technical advice to a referring planning body.

The Planning and Development Regulations specify the:

- circumstances in which planning authorities are to seek technical advice;
- information that must be supplied to the CCA when seeking technical advice.

1.2 BEST PRACTICE IN LUP

Best practice in technical LUP advice systems is described in the European Guidelines on LUP [3] (see section 4.3.1, pages 24 & 25 of the Guidelines). It advises that a technical LUP advice system should apply the principles of:

[3] Land use Planning Guidelines in the Context of Directives 96/82/EC and 105/2003/EC, Christou et al, 2006. ISBN 978-92-79-09182-7.

- consistency (*'Outcomes from broadly similar situations are broadly the same under similar conditions'*);
- proportionality (*'The constraint should be proportional to level of risk'*)
- transparency (*'Clear understanding of the decision-making process'*) .

The system of technical land-use planning advice set out in this guidance adheres to those principles and also takes into account the publication of the recent *Handbook of Scenarios for Assessing Major Chemical Accident Risks* (EUR 28518 EN, doi:10.2760/884152)[4] and the provision of ADAM[5] software to CCAs by the Major Accident Hazards Bureau.

The risk-based technical LUP advice methodology set out in this guidance will be used to develop the *ad hoc* technical LUP advice required by the Directive as well as the development of generic LUP zones around all establishments covered by the Directive. Where an external body is used to draw up such generic LUP zones, the approach set out in this document is to be followed. Under the *COMAH Regulations 2015*, provision of generic technical LUP advice by the CCA is a chargeable activity to COMAH operators (https://www.hsa.ie/eng/Your_Industry/Chemicals/Legislation_Enforcement/COMAH/Charging/).

1.3 ADVICE ON NEW ESTABLISHMENTS

COMAH Regulation 24 refers to the siting and development of new establishments. In this context, new establishments[6] include existing operations that intend to increase their inventory above the COMAH threshold.

Planning applicants for new establishments are expected to provide sufficient information to enable the CCA to apply the methods set out in this guidance, so that the technical advice may be generated for planning authorities.

In keeping with the longer-term aims for land-use planning under the Directive, technical advice in relation to new establishments will be more stringent than that for existing establishments. The individual location-based risk contours for new establishments, which are not to be exceeded, are:

1×10^{-6}/year	• Maximum tolerable risk at a public location
5×10^{-6}/year	• Maximum risk to offsite working population

Table 1: Criteria to be met for new establishments

The CCA may also bring to the attention of the planning authority the necessity to consult with the principal response agencies in relation to emergency planning and response arrangements.

1.4 ADVICE ON SIGNIFICANT MODIFICATIONS TO AN ESTABLISHMENT

The approach of the CCA to significant modifications has been addressed by the *Guidance on Significant Modifications under the COMAH Regulations* (published in 2019[7]).

In summary, the CCA regulates the on-site risk element, setting limits to the tolerable level of risk increase that will be permitted and then, generally, requiring the lowest level of increased risk through the use of additional technical measures. For off-site risk, the referral trigger is an off-site location fatality risk equal to or greater than 1×10^{-6} (per year).

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[4] https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/handbook_of_scenarios_for_assessing_major_chemical_accident_risksonlinepdf.

[5] Accidental Damage Analysis Module (https://adam.jrc.ec.europa.eu/en/adam/content).

[6] New establishment is defined in Regulation 2. It includes an establishment that enters into operation or is constructed on or after 1 June 2015 or a site of operation that falls within the scope of the Regulations, or a lower-tier establishment that becomes an upper-tier establishment, or vice versa, on or after 1 June 2015 due to modifications to its installations or activities resulting in a change in its inventory of dangerous substances.

[7] https://www.hsa.ie/eng/your_industry/chemicals/legislation_enforcement/comah/significant_modifications/guidance_on_significant_modifications_under_comah_regs.pdf.

It will then be referred to the Planning Authority, with technical advice consistent with the advice framework given in Section 1.5 (below) on developments in the vicinity of establishments.

1.5 GENERIC ADVICE ON DEVELOPMENTS IN THE VICINITY OF AN ESTABLISHMENT

Within the Consultation Distance around each establishment, as notified to the planning body, three zones of risk are derived based on the location, quantity and hazards of the dangerous substances present (according to the methodology set out in Part 2 of this document and elaborated further for each sector in Part 3).

The individual risk zones are:

10^{-5}/year	• Risk of fatality for Inner Zone (Zone 1) boundary
10^{-6}/year	• Risk of fatality for Middle Zone (Zone 2) boundary
10^{-7}/year	• Risk of fatality for Outer Zone (Zone 3) boundary

Increasing Risk

Table 2: Risk zones for technical LUP advice

Associated with these zones are 4 levels of development with increasing sensitivity to major hazards:

Level	Development Type
Level 1	**People at work, Parking**
Level 2	**Developments for use by the general public**
Level 3	**Developments for use by vulnerable people**
Level 4	**Very large and sensitive developments**

Increasing Sensitivity

Table 3: Development types (expanded on in Part 2 of this document)

Broadly, the Competent Authority's generic technical advice to Planning Authorities takes the form of 'Advises Against' (✘) or 'Does Not Advise Against' (✓) as illustrated in table 4 (based on the PADHI methodology [HSE UK], as elaborated in Appendix 2):

	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✘	✓	✓
Level 3	✘	✘	✓
Level 4	✘	✘	✘

Table 4: Nature of advice provided for each zone

So, for example, 'developments for use by the general public' (Level 2) would be advised against in the inner zone, but not in the other zones (Appendices 2 & 3 provide more detail of how developments fit into the matrix).

Generic Technical LUP advice generated by the CCA and provided to Planning Authorities will form part of the relevant public planning file.

1.6 SOCIETAL RISK

A system based on the computation of individual risk has been outlined up to this point; that is, the risk to a (possibly hypothetical) person permanently located outside the establishment. The advice matrix (Table 4 and Appendix 2) takes account, to a degree, of group risk and the varied receptor sensitivities. It is applicable for the specified developments in Appendix 2 near a single COMAH establishment, where the existing societal risk is well within the tolerable limit. However, there are times when the risk of multiple fatalities from an accident - Societal Risk – should be taken into account more explicitly. This might be when an application relates to a proposed significant off-site population density or where there is already a significant population within the risk zone or where the risk is from more than one establishment.

To take account of societal risk in such situations, the CCA will initially obtain an estimate of the *Expectation Value* (EV)[8]. For example, for a frequency of occurrence of an accident at 1 chance in a million years (=1 cpm) fatally affecting 120 people, the Expectation Value is the product of the two, that is, 120. Whereas, if the frequency of occurrence of the accident is once in 10,000 years, the Expectation value will be 100 * 120 = 12,000.

Expectation Value will be relevant for technical LUP advice concerning applications covering new establishments, for development near establishments and for significant modifications[9] to establishments.

The publication *R2P2*[10] [HSE 2001] provides an upper limit value for an intolerable societal risk criterion: for a predicted accident occurring no more frequently than once in 5,000 years , there should be no more than 50 fatalities. This has gained international acceptance as an anchor point for a line (of slope -1) to create an 'intolerable' societal risk criterion for single accidents. HSA 2010 recommended using points at (200 cpm/50 fatalities) and (1,000 cpm/10 fatalities) to create that line, drawing on the *R2P2* document. An 'acceptable' societal risk single risk criterion line can then be drawn at frequency values 2 orders of magnitude below the intolerable line.

Between the two lines, operators and potential operators will be required to demonstrate that, in relation to proposed changes, all practicable efforts have been made to reduce the risk to a level that is as low as reasonably practicable.

Some establishments will have the potential for fatalities to arise from a multiplicity of accident scenarios (or there may be other establishments in the vicinity adding to the Expectation Value). In such situations, the total offsite Expectation Value should not exceed the criterion upper limit Expectation Value of 10,000. Between Expectation Values of 100 and 10,000, it should be demonstrated that all practicable efforts have been made to reduce the risk to a level that is as low as reasonably practicable (above a developmental EV level of 450, an FN curve will be required as part of the demonstration).

For new developments near an establishment, where the calculated off-site Expectation Value at the development is greater than 2,000, further assessment of societal risk will be required and the creation of an *FN curve*[11] and calculation of the total Expectation Value will be necessary.

Where the EV exceeds 10,000, the technical LUP advice to the planning authority will always be 'Advises Against'.

Especially large-scale or sensitive development within the consultation distance[12] will likely require a societal risk evaluation.

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[8] Expectation Value is the product (multiplication) of accident frequency, expressed in chances per million, and the number of people suffering fatality in that accident.

[9] For significant modifications, an increase in Expectation Value has already been flagged as the trigger for more detailed analysis in the Guidance on Significant Modifications. HSA (2019).

[10] Para 136: HSE proposes that the risk of an accident causing the death of 50 people or more in a single event …. should be regarded as intolerable if the frequency is estimated to be more than one in five thousand per annum.

[11] An FN curve is a plot of cumulative frequency versus consequences (expressed as number of fatalities).

[12] Consultation Distance is the distance which was communicated to the planning authority at the time of notification or subsequently. See also section 1.9 below.

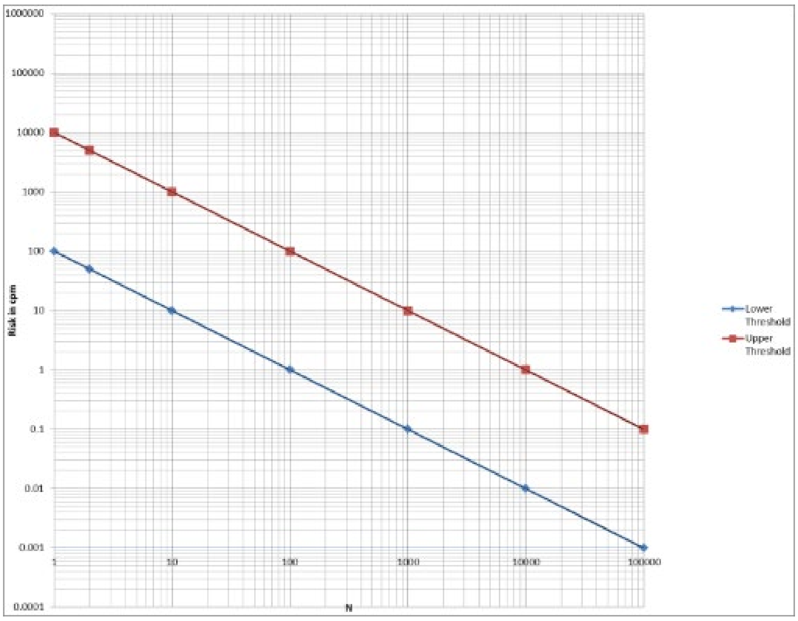


Figure 4: Upper and lower Societal Risk criterion lines (log scale)

The societal risk criterion is applied in addition to the individual risk criteria previously outlined.

Both the individual and societal risk criteria must be satisfied when considering new development. If the individual risk criterion is met, then the societal risk level has to be considered. If the societal risk is within the ALARP region, then an FN curve should be generated to evaluate the societal risk level (using the relevant scenarios from Section 3 of this document)

1.7 ENVIRONMENT & LAND-USE PLANNING

Article 12 of the Directive requires Member States to take account of the need, in the long term, to maintain appropriate distances between establishments and recreational areas and areas of particular natural sensitivity or interest. A separation distance for environmental purposes will be considered appropriate if it is sufficient to enable the operation of suitable control and mitigation measures, and/or is such that the risk of serious environmental damage is low.

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: environmental damage may be relatively long-lasting but is not necessarily irreversible. Recovery of habitats within a reasonable period of time is possible, depending on the dangerous substance.

While the system described in the previous sections focused on the risk to human health, it may also be applied to other environmental receptors, with a modification factor if necessary, in simple cases of airborne toxic releases or for the physical effects from fire and explosion. However, for accidental releases into waterways and in general, where the environmental receptors are more sensitive than human receptors, a different approach is taken.

Emphasis is initially placed on the prevention phase, the control of potential pollution routes and available response measures, rather than on the development of a quantitative risk assessment approach and use of risk-based criteria.

Assessment is based on a Source-Pathway-Receptor model. For new establishments, the Authority will focus on the removal of accident pathways to receptors (through the use of additional technical measures: appropriate containment, within the confines of current good practice and ALARP, for example). For significant modifications, the risk-based approach developed by the CDOIF[13] and outlined in the significant modification guidance document will be employed.

[13] Chemical and Downstream Oil Industries Forum publication : Guideline on Environmental Tolerability for COMAH Establishments, v2.0

Technical advice to a Planning Authority will address only the potential effects of major accidents, not routine emissions, which are within the remit of the Local Authority or Environmental Protection Agency (EPA) and subject to permit/license.

Whether the approach is qualitative or quantitative, the following are considered:

- Environmentally sensitive areas in the vicinity;
- Presence of endangered species;
- Protected water resources/biospheres;
- Types of accident that can cause environmental damage (firewater run-off, for example);
- Contamination routes (water courses, for example);
- Measures in place to protect the environment and their reliability;
- Hard/reliable measures in place to contain run-off in the context of internal and external emergency plans;
- Recovery periods with and without intervention;
- Clean-up and remediation plans and resources;
- Tolerability of assessed risk.

Under COMAH, operators are required to use best practicable means –

- to prevent a major emission of dangerous substances resulting from uncontrolled developments in an establishment into the environment, and
- for rendering harmless and inoffensive the substances emitted.

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 for example, allied with tertiary containment to prevent migration off-site of any overtopping fraction, or contaminated firefighting water.

The potential for a major accident to be initiated due to natural phenomena ('Natech') is also considered.

So, for example, the effect of flooding, lightning, storm damage and subsidence is considered in relation to the potential effect on storage tanks and storage areas, as well as on important site utilities. For new establishments, operators must demonstrate that other potential initiators have been considered and that appropriate prevention/control/mitigation measures will be employed.

The following events should be assessed in relation to their potential to cause or increase the likelihood of a major accident:

NATECH Event	Frequency (per year)
Storm	1 in 100 year event[14]
Snow	1 in 100 year event
Flood	1 in 1,000 year (river or coastal) event

Table 5: Frequency of naturally occurring potential initiators of major accidents (TRAS 2015)

For environmental hazards, good practice can be obtained from published sources, including relevant guidance or from BAT reference documents (BREFs) and the associated BAT conclusions (BATC) documents.

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

[14] Technical Rule on Process Safety 320: Precautions and Measures against the Hazard Sources Wind, Snow Loads and Ice Loads, 2015, German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

Risk levels to be attained for new establishments in relation to MATTEs (based on the CDOIF methodology) are:

MATTE Type	Broadly Acceptable Risk less than
A	1×10^{-4}
B	1×10^{-5}
C	1×10^{-6}
D	1×10^{-7}

Table 6: Broadly acceptable risk levels for MATTEs

For sites storing dangerous liquids in bulk, which will often be located near sensitive marine environments such as SACs and SPAs, the prevention of a major emission into the environment will be achieved through the use of appropriate primary, secondary and tertiary liquid containment.

A lower frequency of loss (by an order of magnitude – see Section 3.4.6, Table 42) will be used for double containment tanks, to reflect their contribution to prevention of damage to the environment; new establishments will be expected to avail of this, or equivalent, technology.

Appropriate bunds for containing spilled liquid and any applied extinguishing or cooling media will be required. 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. Regard will be had to EPA guidance [EPA 2019] on firewater retention.

Tertiary containment will be required where overtopping with potential to cause a MATTE is a credible event.

Information on flood mapping for the 1 in 1,000 year return period is available at http://www.floodinfo.ie/

Historical rainfall information is available from Met Eireann (https://www.met.ie/climate/services/rainfall-return-periods).

Some Historic wind gust storm data has been published:

Location	Gust (knots)
Belmullet	93
Birr	85
Casement	81
Claremorris	96
Clones	87
Cork Airport	94
Dublin Airport	75
Kilkenny	77
Malin Head	98
Mullingar	79
Roche's Pt	86
Rosslare	87
Shannon A/P	93
Valentia	88

Table 7: Historic wind gust data (Sweeney, 2000) [15]

To reflect the currently unquantified increased effect from climate change, the gust figures in Table 7 should be multiplied by 1.2 for technical land-use planning advice purposes.

[15] *From: A three-century storm climatology for Dublin 1715-2000, John Sweeney, Department of Geography, National University of Ireland, Maynooth.*

1.8 PUBLIC INFORMATION ZONE

Prior to 2015, the specified area was defined as an area at greater risk of being affected by a major accident and within which an upper-tier establishment had to supply information directly to persons in the area, on the appropriate action to take in an emergency. While this area still exists, the COMAH Regulations no longer refer to a 'specified area'. The requirement to provide this information still applies under the COMAH Regulations of 2015, but the area is now to be known as the **Public Information Zone (PIZ)** and will, at a minimum, coincide with the outer LUP zone as described in Section 1.5 above. The Authority will use its discretion as to whether it should be enlarged further, based on the consequences of the identified major accident scenarios.

Existing specified areas will continue in use as the Public Information Zone until they are replaced, as generic LUP advice is rolled out for each establishment. The HSA position paper on *Setting the specified area*, issued in 2003, no longer applies.

1.9 CONSULTATION DISTANCE

New establishments will be required to propose an appropriate consultation distance, in accordance with the methodology set out in this document, and submit it to the planning authority as part of a planning application.

When setting new consultation distances (or revising previously communicated consultation distances) the risk-based approach described in Part 3 of this document will be used to obtain a 1×10^{-9} (1-in-a-billion) fatality risk contour. Consequences to the thresholds specified in section 2 will also be obtained. The consultation distance will be set to whichever distance is greater.

Where the standard approach described above determines there are no off-site consequences then, rather than advising a Consultation Distance of zero to the planning authority, a distance of 50m from the establishment boundary will be advised if the major accident sources are located close to the boundary.

Part 2: Detailed Technical Approach

2.1 SECTORS

COMAH Establishments are assessed as being composed of distinct sectors, each of which has characteristic dangerous substances and types of major accident. The sectors are:

1) Liquid Petroleum Gas (LPG) installations
2) Liquid Natural Gas (LNG) installations
3) Renewable Natural Gas (RNG) installations
4) Flammable Liquid Fuel Storage installations
5) Gas Pipelines (within an establishment)
6) Fertilizer Storage sites
7) Dangerous Substance Warehouses
8) Chemical/Pharmaceutical installations
9) Gas Drum & Cylinder installations
10) Explosives Handling/Storage installations
11) Distilleries & Spirit Maturation Warehouses

For each of these, a method for generating generic TLUP risk zones is elaborated in this guidance: Part 3 will describe in detail how the generic advice will be generated, setting out the major accident scenarios, their frequencies and the consequences to be considered. In this part, the technical background underpinning Part 3 is described.

2.2 RISK OF FATALITY AND THE USE OF PROBIT EQUATIONS

The analysis requires an identification of credible major accident scenarios, then the likely accident consequences in terms of fatality. To estimate the fatal consequences of major accidents, established Probit[16] relationships for fatality are used: they are conservatively derived and help to ensure consistency in approach, resulting in a risk-based analysis that is robust and transparent.

Fatality risk increases as the level of consequence (increased concentration/intensity of effect and duration of exposure) increases. The relationship between the consequence level and the probability of fatality can be characterized by a Probit relationship. A range of consequences can be expected in a population exposed to an acute hazard [dose] which can be represented mathematically by a dose-response curve, with the number of people suffering fatal effects being the response. For computational purposes, it is better to fit the relationship into the form of a straight line. Probit equations do this and can be used to estimate the proportion of the population that may be affected by exposure to a particular harm.

Chlorine toxicity	• Probit = -4.81 + 0.5 ln ($C^{2.75}t$) with concentration, C, in ppm and time (t) in minutes
Thermal radiation	• Probit = -14.9 + 2.56 ln ($I^{1.33}$ t) with Intensity, I, in kW/m^2 and time (t) in seconds
Overpressure	• Probit = 1.47 + 1.35 ln (P) with pressure, P, in psi

Table 8: Examples of Probit equations

The number value obtained from the Probit equation can be looked up in a reference table to give the % of the population fatally affected: a Probit of 5 corresponds to 50% fatality, a Probit of 2.67 to 1% fatality, a Probit of 7.33 to 99% fatality and so on. So, Probit functions enable a consistent and transparent estimation of the fatality percentage in a standard exposed population.

[16] Probit-based models, derived from experimental dose-response data, are often used to estimate the health effect that might result based upon the intensity and duration of an exposure to a harmful substance or condition (for example, exposure to a toxic atmosphere, or a thermal radiation).

The next sections will describe the Probit equations to be used for estimating the consequences of specific types of major accident.

2.3 CONSEQUENCES OF THERMAL RADIATION

Thermal radiation exposure arises from fire-type events. Accidents that give rise to a thermal (heat) effect will impact differently on indoor and outdoor populations.

2.3.1 Thermal Effects on People Outside Buildings

The Probit used to determine the fatality proportion from a population exposed to thermal radiation is that of Eisenberg et al (1975):

$$\text{Probit} = -14.9 + 2.56 \ln (I^{1.33}\, t)$$

(with I in kW/m^2 and t in seconds: I is the incident heat flux and t the exposure duration).

This relationship applies to people out in the open when exposed.

For fires of long duration, such as pool fires and jet fires, it is reasonable for TLUP calculations to make allowances that, unless incapacitated, people will retreat from the hazard source: therefore the exposure time is the time required to reach a safe place. In this approach, the default exposure time is assumed to be 75 seconds at the maximum heat flux from the fire.

Using those parameters, the Eisenberg Probit relationship implies the following fatality proportions at these heat flux levels:

6.8 kW/m^2	• 1% fatality
9.23 kW/m^2	• 10% fatality
13.4 kW/m^2	• 50% fatality

Table 9: Heat flux and fatality levels, outside, for 75 second exposure

The threshold of fatality flux level of 6.8 kW/m^2 is often used as a screening distance for consequence modelling.

For Flash Fires, fatality levels of 100% are assumed inside the Lower Flammable Limit (LFL) envelope, with 0% fatalities outside that envelope.

2.3.2 Thermal Effects to People Inside Buildings

People inside buildings will have some protection from the effects of incident thermal radiation. Therefore a further refinement of the model is necessary. For persons indoor, the relevant thermal radiation landmarks[17] are:

>25.6 kW/m^2	• Building conservatively assumed to catch fire quickly and so 100 % fatality probability
12.7-25.6 kW/m^2	• People are assumed to escape outdoors, and so have a risk of fatality corresponding to that outdoors
<12.7 kW/m^2	• People are assumed to be protected, so 0 % fatality probability

Table 10: Heat flux levels relevant for people within buildings

[17] Source: Crossthwaite et al (1988)

For Flash Fire, indoor fatality levels are conservatively assumed to be 10% within the flashfire envelope.

2.3.3 Thermal Effects and Property Damage

Property damage may be a relevant element of the technical advice provided to a planning body (the Directive requires appropriate distances to 'buildings and areas of public use'). A mechanism is required to take into account the risks (including economic) to property, structures and businesses as part of any technical land-use planning advice, where relevant (see also 2.4.3 below).

The presence of blocking physical structures can be taken into account in determining the areas subject to thermal radiation.

For thermal radiation, the key contours for structural damage[18] will be:

37.5 kW/m^2	• Sufficient to cause damage to process equipment
25.6 kW/m^2	• Minimum heat flux to ignite wood at indefinitely long exposures (non piloted)
14.7 kW/m^2	• Minimum heat flux for piloted ignition of wood, melting of plastic tubing

Table 11: Heat flux levels and property damage

2.4 BLAST OVERPRESSURE

2.4.1 Blast Effects on People Outside Buildings

The Probit used for determining consequences from blast overpressure is that of Hurst, Nussey and Pape (1989). The relationship is:

$$\text{Probit} = 1.47 + 1.35 \ln (P)$$

with P in psi (NB 1 psi = 68.947573 mbar).

This relationship applies only to people exposed outdoors, and implies the following relationship between overpressure and fatality:

2.44 psi (168 mbar)	• 1% fatality
5.29 psi (365 mbar)	• 10% fatality
13.66 psi (or 942 mbar)	• 50% fatality

Table 12: Overpressure fatality thresholds for people outside

Caution: This Probit relationship should not be used for assessing the risk to indoor populations as it fails to take any account of factors such as building collapse, and therefore could lead to a significant underestimation of the risk.

Blasts also have the potential to generate projectiles, possibly capable of travelling several hundred metres. However, the available evidence is that the risk of a particular area being hit by a projectile is usually extremely low and is therefore generally not taken into account when using the methodology specified in this document.

[18] World Bank, 1985

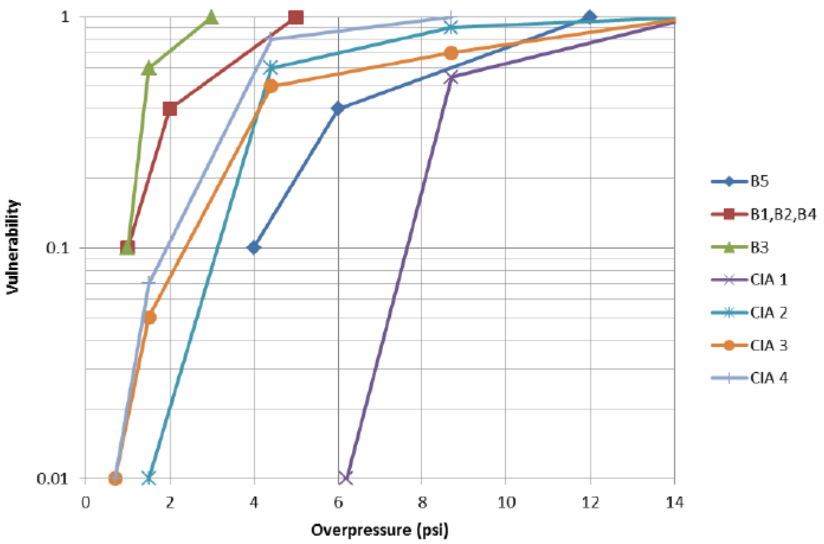
2.4.2 Blast Effects on People Inside Buildings

Persons indoor could be either more or less vulnerable to the effects of blast overpressure, depending on the blast resistance of the surrounding structure. The Chemical Industries Association (CIA, 2010) published relationships between the risk of fatality for occupants and the level of blast overpressure for 4 different categories of building:

Category 1	•Hardened structure building
Category 2	•Typical office block
Category 3	•Typical domestic building
Category 4	•'Portacabin' type timber construction

Table 13: Overpressure fatality thresholds for people inside buildings

The CIA Category 3 Curve (typical domestic building: two-storey, brick walls, timber floors) will in most circumstances provide a reasonably conservative basis for assessing the risk of fatality to most residential populations and is widely used for this purpose.



Graph Key:	
	CIA 1: Hardened structure building: special construction, no windows
	CIA 2: Typical office block: four story, concrete frame and roof, brick block wall panels
	CIA 3: Typical domestic buildings: two story, brick walls, timber floors
	CIA 4: Portacabin: timber construction, single story
	API B5: Reinforced concrete or reinforced masonry shear wall building
	API B3: Unreinforced masonry bearing wall building
	API B1, B2, B4: Wood frame trailer or shack, steel frame/metal siding or pre-engineered building, steel or concrete reinforced masonry infill or cladding
NOTE—Building key items 1 - 4 are defined by the CIA; items B1 - B5 are defined by API RP 752 (2003) [5, 3].	

Figure 5: Vulnerability of people in Buildings EIGA, 2014[19]

[19] Guideline for the Location of Occupied Buildings in Industrial Gas Plants, IGC Doc 187/14/E

2.4.3 Blast Effects on Buildings

The risks to physical structures will be taken into account as part of any technical land-use planning advice. Landmark overpressure damage values are:

Overpressure (kPa)	Overpressure (mbar)	Possible Damage Contours
1	>10	Glass Breakage
3.5	>35	Light
17	>170	Moderate
35	>350	Severe
83	>830	Total Destruction

Table 14: Blast effect on buildings (extracted from table 15, below)

If it is considered necessary by the CCA, the distance to some of these key contours could be plotted on a map as part of generic advice addressing consequences.

Overpressure (kPa)	Description of Damage
0.15	Annoying noise
0.2	Occasional breaking of large window panes 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
>3.5	Damage level for "Light Damage"
5	Minor damage to house structures
8	Partial demolition of houses, made uninhabitable
7 - 15	Corrugated asbestos shattered. Corrugated steel or aluminium 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
>17	Damage level for "Moderate Damage"
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
>35	Damage level for "Severe Damage"
50	Loaded tank car 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
>83	Damage level for "Total destruction"

Table 15: Levels of damage from overpressure - AIChE (1994)

While there are no generally accepted criteria for assessing the risk to the built environment (as opposed to the risk to human health), the results of an assessment using the above criteria will be an additional factor for planning authorities to consider, although that may be of less significance than the risk to people.

2.5 TOXICITY

2.5.1 Toxic Effects on People out in the Open

Probit equations are also used in estimating the fatal toxicity effects of dangerous substances (see Table 16 below). All probits take the form Probit = a + b ln ($V^n t$), where a, b and c are constants as given in Table 16, V is the concentration value by volume (in ppm) and t is the exposure duration (in minutes).

The exposure duration is generally taken to be equal to the release duration for vapour/gas releases, up to a maximum of 30 minutes and also a maximum of 30 minutes for toxic exposure from evaporating liquid pools or from fires (some scenarios will be of shorter duration than this maximum).

These Probit equations will be used for TLUP:

Substance	CAS #	a	b	n	Source
Ammonia	7664-41-7	-16.21	1	2	(BEVI 2009)
Bromine	7726-95-6	-8.54	1	2	(BEVI 2009)
Chlorine	7728-50-5	-4.81	0.5	2.75	(BEVI 2009)
Hydrazine	302-01-2	-13.452	1.676	1	(PHAST 8.21)
Phosgene	75-44-5	-7.69	2	1	(BEVI 2009)
Carbon monoxide	630-08-0	-7.21	1	1	(BEVI 2009)
Methyl bromide	74-83-9	-5.75	1	1.1	(BEVI 2009)
Methylisocyanate	624-83-9	-0.57	1	0.7	(BEVI 2009)
Methylmercaptan	74-93-1	-16.33	2.05	0.98	(BEVI 2009)
Nitrogen dioxide	10102-44-0	-16.06	1	3.7	(BEVI 2009)
Nitric oxide	10102-43-9	-150.838	15.432	1	(PHAST 8.21)
Hydrogen chloride	7647-01-0	-35.62	3.69	1	(BEVI 2009)
Hydrogen cyanide	74-90-8	-9.43	1	2.4	(BEVI 2009)
Hydrogen fluoride	7664-39-3	-8.62	1	1.5	(BEVI 2009)
Hydrogen sulphide	7783-06-4	-10.76	1	1.9	(BEVI 2009)
Sulphur dioxide	7446-09-5	-16.76	1	2.4	(BEVI 2009)

Table 16: Dangerous Substance Probits (concentration in ppm by volume)

Probits are available for other dangerous substances in the published literature; where there is more than one Probit, the CCA will use its discretion to select an appropriate value.

2.5.2 Toxic Effects on People Inside Buildings

The risk to persons indoor from a toxic vapour cloud depends on the effective ventilation rate of the building they are in. Air change rates, for passively ventilated buildings, of 2.5 and 2 air changes per hour are typically assumed for D_5 and F_2 conditions (F_2 and D_5 refer to the weather/stability sets typically used in modelling releases of dangerous substances into the atmosphere. D represents typical day-time conditions and F represents specific night-time conditions. The subscripts refer to the average wind speeds, in metres per second, associated with those atmospheric stability conditions).

The impact of a toxic release on an indoor population can be assessed using the same Probit equations as for outdoor exposure, but it is necessary to modify the effective concentration and duration of exposure to take account of gas infiltration into the building. If the modelling software does not calculate indoor concentration, the approach set out in Davies and Purdy (1986) will be followed.

2.5.3 Fraction Indoor/Outdoor

People are assumed to be indoor 90% of the time.

2.5.4 Probability of Weather Stability Sets

D_5 conditions are assumed to occur 80% of the time and F_2 for the remaining 20%.

2.5.5 Temperature Parameters

Loss of containment from storage vessels in the open are assumed to be at ambient atmospheric temperature. Ambient temperatures vary throughout the day and the seasons. For TLUP purposes, a temperature of 15 °C is used in D_5 conditions and 10 °C in F_2.

Raw temperature data is available from Met Eireann (https://www.met.ie/climate/available-data/historical-data).

2.5.6 Directional Probability

The probability of a gas/vapour release (or in some cases thermal flux) being blown in any direction by the wind is taken into account using data from the nearest weather station, typically allocating over 8 sectors.

2.5.7 Terrain

The terrain in the vicinity of the establishment, over which dispersion takes place, is carefully chosen from the table below.

#	Short description of the terrain	Roughness length (m)
1	Open water (at least 5 km)	0.0002
2	Mud flats, snow; no vegetation, no obstacles	0.005
3	Open, flat terrain; grass, a few isolated objects	0.03
4	Low vegetation; large obstacles here and there, x/h > 20	0.10
5	High vegetation; distributed large obstacles, 15 < x/h < 20	0.25
6	Park, bushes; many obstacles, x/h < 15	0.5
7	Strewn with large obstacles (suburb, wood)	1.0
8	Town centre with high-rise and low-rise buildings	3.0

Table 17: Roughness lengths (BEVI)

In default, for general terrain without defining features, a value of 0.1m will be used (a conservative approach).

2.5.8 Toxic Effects on the Environment

Where local fauna or flora is more sensitive to toxic exposure than humans, a more relevant toxic endpoint (than those described above) may be used to estimate consequences.

2.6 DOMINO EFFECTS

Domino effects are the effects arising when an accident event at one establishment initiates a major accident elsewhere in the establishment or at another establishment in the vicinity. Typical examples of where domino interactions may need to be explicitly considered include:

- Where the presence of a high frequency short-range hazard significantly increases the likelihood of a major failure of a relatively low frequency long-range hazard. For example, small LPG storage vessels located close to a large toxic gas storage tank.
- Where the initiating event on one site (or part of the same site) could trigger a more severe than expected event on a neighbouring site. For example, a loss of containment and fire involving highly flammables on one site could spread to involve a site storing Category 3 flammable liquids which would normally not be considered a major fire

risk (because of high flash point), but which are still very likely to be ignited and become involved in escalating the fire if the initiating event is a major fire from a nearby site.

- Where an event at one site (or part of the same site) could have unexpected indirect consequences on a neighbouring site. For example, a loss of power to control and emergency shutdown systems, or toxic vapours leading to incapacity/evacuation of vital staff controlling major hazards at a nearby site. Such unexpected indirect consequences could trigger or exacerbate a potential domino event.

In most cases, domino effects can be incorporated into the risk-based assessment by simply increasing the base case frequency for the likelihood of events on one (or both) sites.

Often it is found that domino effects are not significant for land-use planning, as the likelihood of an event at Site A triggering a major event at Site B is an order of magnitude less than the base case likelihood of the event at Site B. Nevertheless, as a general rule of thumb, the potential for domino effects will always be considered at establishments within 500 m of each other. The paper by Solzani & Cozzani (2005) informs the approach that will be taken in the analysis of domino effects.

2.7 UNBUNDED POOL SIZE

Unbunded pools are given an upper limiting radius of 50m. Where there are physical constraints (for example, a pool can form on only one side of the bund), then the constrained pool size is modelled and the frequency proportionally adjusted upwards.

In some cases, it may be that a pool is constrained to a particular direction, or there may be a possibility of larger pools (or even running pools). If such effects are considered to be significant, then the analysis will be adapted appropriately.

Overtop pools will be distributed over the potential overtop locations and the frequency assigned proportionately.

If the topography of the area surrounding the bund has any special features, such as tertiary containment, then this could be accounted for by modifying the potential location of fires outside the bund, possibly reducing the extent of the land use planning zones.

2.8 SURFACE EMMISSIVE POWER

The scientific literature describes a number of approaches to modelling the Surface Emissive Power (SEP) of heat radiated outwards from a flame, per unit surface area of the flame, in units of kW/m^2.

For pool fires, the solid flame model is considered to better represent the effects of pool fires than the single point model. However, there is quite a lot of variation in methods for determining flame height, effect of soot and the effective surface emissive power of flames.

For a consistency in the area of technical land-use planning advice, the following approach is taken to pool fires and their offsite effects (which is not valid for the assessment of on-site or near-field effects).

Maximum SEP values from the literature are:

Substance	**Emax** (kW/m^2)
Acetone	130
Crude oil	130
Diesel	130
Ethanol	130
Fuel Oil, Heavy	130
Gasoline	130
Heptane	200
Hexane	200
Hydrogen (Liq)	70
JP4	130
Kerosine	130
LNG/Methane	265
LNG/Methane (water)	265
LPG/Propane	250
LPG/Propane (water)	250
Methanol	70

Toluene	130
Xylene	130

Table 18: Maximum SEP values

In practice, the actual SEP is related to the pool diameter and the flame height.

Flame height is calculated using the Thomas equation. Using the data in CRR 96/1996, an average surface emitted flux can be estimated based on the sum of thermal fluxes from a lower and upper layer: it tends to decreases with increasing pool size. This is graphically represented below:

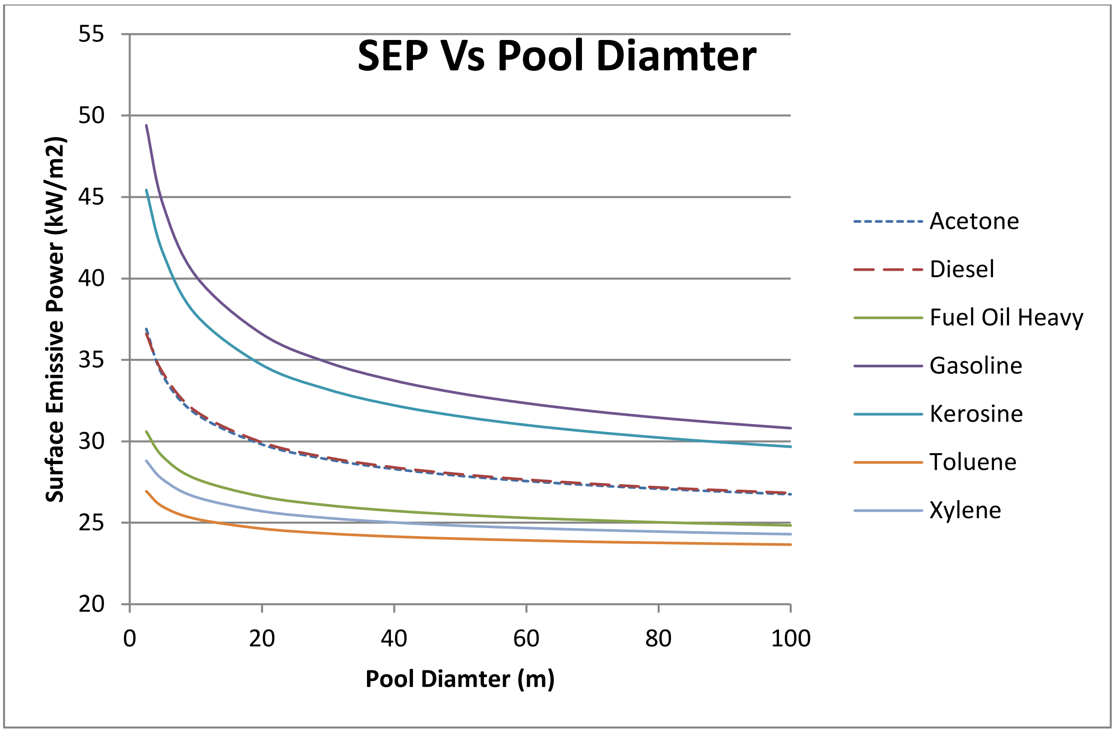


Figure 6: SEP Vs Pool Diameter (based on method & data in CRR 96/1996)

Exceptionally, an SEP for Ethanol of 130 kW/m^2 and for Methanol of 70kW/m^2 will be used for all pool fire diameters.

In Fireball calculations, a value of 250 kW/m^2 for LPG and 265 kW/m^2 for LNG and Methane gas will be used.

For jet fires, the maximum SEP values will be used in all cases.

2.9 IGNITION PROBABILITY

Unless otherwise indicated, the event frequencies used in the Part 3 tables include an assessment of the probability of ignition (that is where the scenario includes the word ‘fire’ or ‘explosion’), so a separate ignition probability assessment is not required in the standard model. Generally, ignition probabilities (below) and conditional event probabilities (in Part 3) are based on BEVI (2009), with a modification to take account of the changes to flammability categories introduced in the CLP Directive (1272/2008). If accident scenarios are not covered by the BEVI, then other sources or expert judgement will be used.

Ignition is considered to either happen immediately or to be delayed for a short period - the modelled accident consequences reflect these two possibilities.

Ignition probability depends on the flammability category of the dangerous substance, as illustrated in this table for fixed installations:

Ignition Cat.	Immediate Ign.	Delayed Ign.
0 (high reactivity)	0.7	0.3
0 (low reactivity	0.09	0.91
Liquid Cat 1	0.065	0.935
Liquid Cat 2	0.01	0
Liquid Cat 3	0	0

Table 19: Conditional ignition probabilities for fixed installations

Road Transport Units are treated as follows:

Flammability	Immediate Ign.	Delayed Ign.
0 (high reactivity)	0.4	0.6
0 (low reactivity	0.1	0.9
Liquid Cat 1	0.065	0.935
Liquid Cat 2	0.01	0
Liquid Cat 3	0	0

Table 20: Conditional ignition probabilities for road tankers

Note that in the above tables, for ignition categories 0 1nd 1 the total ignition probability is one.

For LPG/LNG at jetties, the following are used:

Release Type	Immediate Ign.	Delayed Ign.
Continuous, Large	0.7	0.3
Continuous, Small	0.5	0.5

Table 21: Conditional ignition probability for Gas (LPG or LNG) at a jetty

Conditional delayed ignition probability is split 0.4 for a VCE and 0.6 for a Flash Fire.

2.10 MORE COMPLEX ESTABLISHMENTS

For complex sites, the installation specific approaches as outlined in Part 3 can be combined. For example, a Pharma site may have a chemical warehouse, bulk flammable storage, toxic gas cylinders and a synthesis plant and therefore each of these may have to be accounted for in the development of generic advice.

2.11 LIMITATIONS OF A RISK-BASED APPROACH

While the risk-based approaches detailed in Part 3 are not as comprehensive as fully quantified risk analyses (QRA), they are judged to fulfil the principles of robustness, consistency and transparency required for a technical LUP advice system.

A risk-based approach inevitably involves assumptions concerning the frequency of accidents. However, this is preferable to the hazard-based approach, where it is implicitly assumed that the particular event chosen has a likelihood which is sufficient to be a cause for concern, but not so high as to make it unacceptable.

As the TLUP advice methodology focuses on off-site risk, it may underestimate the risk from lesser but more frequent events close to the source.

The field of risk assessment continues to develop, both in the understanding the major accident events themselves and the criteria that should be used to assess such accidents. This guidance cannot be expected to cover every situation. It is intended to provide the basis for robust assessment, but there will at times be a need to refine particular aspects and to generally adapt to technical progress or to take account of particular local conditions and the CCA reserves this right for itself.

Caution is advised in attempting to use the approach described in this document for purposes other than technical land-use planning advice because:

- the objective of the methodology relates to technical land-use planning advice, which is external to the establishment and future-oriented, the assessment methods presented here are not sufficiently detailed to address risk to on-site populations and should not be used for that purpose.

- the system is designed to be used in its totality and parts should not be mixed and matched with other systems or be used out of this TLUP context, without clear and sufficient justification.

Part 3: Method for Specific Sectors

3.1 LPG (LIQUID PETROLEUM GAS) INSTALLATIONS

3.1.1 Fixed storage installations

For fixed LPG installations, three loss-of-containment ('LOC') accident scenarios are modelled:

- an instantaneous loss of an entire vessel contents, resulting in a BLEVE, a VCE and a Flash Fire;
- loss of the entire vessel contents over 10 minutes, resulting in VCE, Flash fire and Jet Fire;
- loss (over 30 min) through a 10mm hole (or hole sized to largest connection) - VCE, Flash Fire and Jet Fire

The frequencies for each of these events (which include the ignition probabilities) are:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-7}	BLEVE/Fireball	2.45×10^{-7}	001
		VCE	4.2×10^{-8}	002
		Flash Fire	6.3×10^{-8}	003
Continuous leak over 10 minutes	5×10^{-7}	Jet Fire	3×10^{-7}	004
		VCE	9×10^{-8}	005
		Flash Fire	6×10^{-8}	006
10 mm pipe leak over 30 min	1×10^{-5}	Jet Fire	7×10^{-6}	007
		VCE	1.8×10^{-6}	008
		Flash Fire	1.2×10^{-6}	009

Table 22: Event frequencies for a single fixed LPG vessel

For TLUP purposes, the VCE and Flash Fire events are located at the release source. The TNO multi-energy method is use to determine overpressure levels in a VCE: typically 20% of the stoichiometric cloud volume is assumed to be in the congested area (where the ignition is assumed to occur) and is assigned Strength 7.

3.1.2 Road Tankers

For Road Tankers associated with onsite loading/unloading of LPG, two LOC events are considered:

- Instantaneous loss of entire contents, leading to a BLEVE/Fireball, VCE and Flash fire;
- Loss of entire contents through a 10 mm hose of 3 m length, resulting in a VCE, Flash Fire, Jet Fire.

The frequencies for each of these events (which include ignition probabilities) are:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous Failure	$5 \text{ X } 10^{-7}$	Fireball	$2 \text{ X } 10^{-7}$	010
		VCE	$1.2 \text{ X } 10^{-7}$	011
		Flash Fire	$1.8 \text{ X } 10^{-7}$	012
Loss over 10 minutes	$5 \text{ X } 10^{-7}$	Jet Fire	$5 \text{ X } 10^{-8}$	013
		VCE	$1.8 \text{ X } 10^{-7}$	014
		Flash Fire	$2.7 \text{ X } 10^{-7}$	015

Table 23: Event frequencies for road tankers (per active road tanker on site)

3.1.3 Jetties

If a jetty charging/discharging LPG is within or adjacent to the establishment, a major accident during loading/unloading operations will be taken into account. The scenarios modelled are for releases of 180 m^3 and 90m^3 LPG over 30min:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Continuous leak of 180 m^3 over 30 minutes	1.2×10^{-4}	Jet Fire	8.4×10^{-5}	016
		VCE	1.44×10^{-5}	017
		Flash Fire	2.16×10^{-5}	018
Continuous leak of 90 m^3 over 30 minutes	2.5×10^{-2}	Jet Fire	1.25×10^{-2}	019
		VCE	5×10^{-3}	020
		Flash Fire	7.5×10^{-3}	021

Table 24: Event frequencies for an LPG jetty

The LOC Frequency figures in Table 24 are to be multiplied by f_o [20].

The explosion volumes to be modelled in the multi-energy method are the stoichiometric volumes generated by these released gas volumes – 20% at strength 7 and 80% at strength 2.

3.1.4 Buried and Fully Mounded Vessels

It is implicitly assumed in these figures that an establishment meets all the good practice standards required for an LPG installation (for example, by having water deluge system or protective vessel coating) and there may be few, if any, cost-effective additional technical measures that will significantly reduce the extent of LUP risk-based zones. One possible risk reduction measure is to fully mound (or bury) the LPG vessels. In such circumstances, the likelihood of a BLEVE from an instantaneous failure is eliminated:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-7}	No BLEVE	2.45×10^{-7}	022
		Flash Fire	6.3×10^{-8}	023
		VCE	4.2×10^{-8}	024
Continuous leak over 10 minutes	5×10^{-7}	Jet Fire	3.5×10^{-7}	025
		VCE	9×10^{-8}	026
		Flash Fire	6×10^{-8}	027
10 mm pipe leak over 30 min	1×10^{-5}	Jet Fire	7×10^{-6}	028
		VCE	1.8×10^{-6}	029
		Flash Fire	1.2×10^{-6}	030

Table 25: Scenarios for mounded/buried LPG vessels

3.1.5 Uncertainties in LPG Risk-based Approach

The risk analysis method as described is somewhat simplistic and neglects smaller but more probable events such as smaller vessel leaks and pipe leaks. Because the risk values generated are being used for off-site control purposes, this is considered to be a reasonable approach (and is also a reason why this methodology is not suitable for detailed on-site risk analysis).

[20] fo = N*T*t*6.7x 10-11 , where T is the total number of ships on the transport route annually, t is the average unloading/loading duration (hours) and N is the number of transhipments per year.

3.2 LNG (LIQUID NATURAL GAS) INSTALLATIONS

3.2.1 Fixed installations

LNG may be stored on its own or in association with LPG (see section 3.1). Although LNG can be stored as a liquid (-161°C) at just above atmospheric pressure, it is more likely to be stored under significant pressure (up to 8-10 bar). The modelling scenarios are therefore similar to LPG, but greater allowance is made for pool fires because they are more probable when a loss of containment of cryogenic methane occurs.

This section does not address jetty operations, FSUs, or FSRUs.

For fixed LNG installations (including ISO containers when removed from a Road Tanker cab), the following scenarios are modelled:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-7}	BLEVE/Fireball	4.5×10^{-8}	031
		VCE	9.1×10^{-8}	032
		Flash Fire	1.37×10^{-7}	033
		Pool fire	2.28×10^{-7}	034
Continuous leak over 10 minutes (total inventory)	5×10^{-7}	Jet Fire	4.5×10^{-8}	035
		VCE	9.10×10^{-8}	036
		Flash Fire	1.37×10^{-7}	037
		Pool fire	2.28×10^{-7}	038
10 mm pipe leak over 30 min	1×10^{-5}	Jet Fire	9×10^{-7}	039
		VCE	1.82×10^{-6}	040
		Flash Fire	2.73×10^{-6}	041
		Pool fire	4.55×10^{-6}	042

Table 26: Event frequencies for fixed LNG installations (per storage unit)

For LUP purposes, the VCE and Flash Fire events are located at the source.

Consideration must be given to any associated regasification units, if present. These are treated as heat exchangers:

LOC Scenario	Frequency (yr^{-1})	#
Rupture of 10 pipes at the same time	1×10^{-6}	043

Table 27: Regasification Unit Scenario

3.2.2 Road Tankers

For ISO Road Tankers associated with delivery and transport of LNG, the scenarios are:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous Failure	5×10^{-7}	Fireball	2.00×10^{-7}	044
		VCE	6.00×10^{-8}	045
		Flash Fire	9.00×10^{-8}	046
		Pool fire	1.50×10^{-7}	047
Continuous leak over 10 minutes	5×10^{-7}	Fireball	5.00×10^{-8}	048
		VCE	9.00×10^{-8}	049
		Flash Fire	1.35×10^{-7}	050
		Pool fire	2.25×10^{-7}	051

Table 28: Event frequencies for road tankers (per active road tanker on site)

3.2.3 Uncertainties in LNG Risk-based Approach

The risk analysis method described above is somewhat simplistic and neglects smaller but more probable events such as smaller vessel leaks and pipe leaks. Because the risk values generated are being used for off-site control purposes, this is considered to be a reasonable approach.

3.3 BIOMETHANE (RNG) STORAGE

This includes the activity of generating methane from Digesters (Biomethane).

Digesters are considered to have failure frequencies equivalent to atmospheric storage vessels, since the pressure load is much less than 0.5 bar above atmospheric.

Some sites compress the up-scaled gas into small pressurised containers for transport off-site and these are also included in the scenarios used for the development of generic TLUP contours.

If LPG or LNG are present on a site, then the methodology in the previous sections must also be applied.

3.3.1 LOC Scenarios

The following scenarios are modelled for each Digester:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-6}	Fireball*	4.5×10^{-7}	052
		VCE	1.64×10^{-6}	053
		Flash Fire	2.46×10^{-6}	054
		None	4.55×10^{-7}	055
Continuous leak over 10 minutes	5×10^{-6}	Jet Fire?	4.5×10^{-7}	056
		VCE	1.64×10^{-6}	057
		Flash Fire	2.46×10^{-6}	058
		Pool fire	4.55×10^{-7}	059

Table 29: Scenarios for bulk Biomethane storage

*For the instantaneous failure, the contents of Digester are assumed to be in a fireball centred on the digester - as the pressure drops from the initial jet fire, the flame propagates back to the Digester.

The pressure vessels containing the up-scaled gas are treated as follows:

LOC Scenario	Frequency (yr^{-1})	#
Instantaneous Release	5×10^{-7}	060
Release over 10 minutes	5×10^{-7}	061
Release through 10mm pipe	1×10^{-5}	062

Table 30: Scenarios for pressurised drums of up-scaled biogas.

3.4 FLAMMABLE LIQUID STORAGE SITES

The non-environmental scenarios considered are Pool Fire, VCE and Flash Fire. The environmental scenario is a loss of containment affecting environmental receptors.

According to the CLP[21], Flammable liquids consist of 3 categories:

Category	Criteria
1	Flash point < 23 °C and initial boiling point ≤ 35 °C
2	Flash point < 23 °C and initial boiling point > 35 °C
3	Flash point ≥ 23 °C and ≤ 60 °C (1)
(1) For the purpose of this Regulation gas oils, diesel and light heating oils having a flash point between ≥ 55 °C and ≤ 75 °C may be regarded as Category 3.	

Table 31: CLP classification of flammable substances

Ignition probabilities were given in Part 2 for flammable liquids at ambient temperature (Tables 19 & 20). These ignition categories and limits are:

Ignition Category	Limits
0	FP < 0°C and BP ≤ 35 °C [22]
1	FP < 23°C, but not in Ignition Category 0
2	FP ≥ 23°C and ≤ 60 °C *
3	FP > 60°C and ≤ 100 °C
* *For the TLUP ignition probability purposes, diesel and light heating oils having a flash point between 60 °C and 75 °C (incl.)may be regarded as Ignition Category 2*	

Table 32: Ignition Categories with limits

CLP 1 flammable liquids will fall into Ignition Categories 0 or 1, depending on the specific flash point and boiling point. CLP 2 flammable liquids will fall into Ignition Category 1, while CLP 3 liquids will go into Ignition Category 2. The connection between ignition category and CLP category is represented in the following table:

CLP Cat.	Ignition Cat.
CLP 1	**0** [FP < 0°C]
	1 [FP ≥ 0 °C , < 23 °C]
CLP 2	**2**
CLP 3	**3**

Table 33: Relationship of ignition category to CLP flammability category

3.4.1 Ignition Category 0 Substances and Mixtures

Crude oil and Gasoline are examples of substances that fall into this category.
Sites are expected to comply with good practice and to have implemented all the recommendations arising from the Buncefield Final Report.[23]
For a single containment atmospheric storage tank storing Ignition Category 0 product, the LOC event frequencies are:

[21] The Classification, Labelling and Packaging Regulation, (EC) No 1272/2008.
[22] Including where the boiling range commences at 35°C
[23] Buncefield (2007)

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-6}	Pool Fire	4.50×10^{-7}	063
		VCE	1.82×10^{-6}	064
		Pool Fire late	5.46×10^{-7}	065
		Flash Fire	5.46×10^{-7}	066
		None /Toxic	1.64×10^{-6}	067
Failure over 10 minutes	5×10^{-6}	Pool Fire	4.50×10^{-7}	068
		VCE	1.82×10^{-6}	069
		Pool Fire late	5.46×10^{-7}	070
		Flash Fire	5.46×10^{-7}	071
		None /Toxic	1.64×10^{-6}	072
10 mm pipe leak over 30 min	1×10^{-4}	Bund Fire	9.00×10^{-6}	073
		VCE	3.64×10^{-5}	074
		Pool Fire late	1.09×10^{-5}	075
		Flash Fire	1.09×10^{-5}	076
		None /Toxic	3.28×10^{-5}	077

Table 34: Event frequencies for Ignition Category O flammable liquids

The toxic events in Table 34 are only relevant if the substance carries a H300/310/330/370 classification.

Instantaneous tank failure will lead to bund overtopping, which means the scenarios in Table 34 occur both inside and outside the bund. Overtopping % is based on site conditions, with 50% assumed by default. The overtop pool size is based on site conditions and modelling parameters, but the pool diameter modelled is never greater than 100m.

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure - overtop	5×10^{-6}	Pool Fire	4.50×10^{-7}	078
		VCE	1.82×10^{-6}	079
		Pool Fire late	5.46×10^{-7}	080
		Flash Fire	5.46×10^{-7}	081
		None /Toxic	1.64×10^{-6}	082

Table 35: Event frequencies for overtop scenarios, Ignition Category 0 flammable liquids

The magnitude of the overpressure generated by the VCE is that arising from a cloud volume based on a stoichiometric burning ratio of the vapourised liquid, by default with ignition strength of 7 for 20% of the volume and a combustion energy of 3.5 MJ/m^3, using the TNO multi-energy method (Van den Berg, 1985) .

3.4.2 Ignition Category 1 Substances and Mixtures

Operators are expected to comply with good practice and to have implemented all the recommendations arising from the Buncefield Final Report.

There are many flammable liquids with flash points less than 23°C and a boiling point above 35°C.

The ignition probability for a Category 1 spill is lower than for Category 0, so the frequency of the events are slightly less than in the preceding section .

The scenarios to be modelled are:

LOC Scenario	LOC Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5×10^{-6}	Pool Fire	3.25×10^{-7}	083
		VCE	1.87×10^{-6}	084
		Pool Fire late	5.61×10^{-7}	085
		Flash Fire	5.61×10^{-7}	086
		None /Toxic	1.68×10^{-6}	087
Failure over 10 minutes	5×10^{-6}	Pool Fire	3.25×10^{-7}	088
		VCE*	1.87×10^{-6}	089
		Pool Fire late	5.61×10^{-7}	090
		Flash Fire	5.61×10^{-7}	091
		None /Toxic	1.68×10^{-6}	092
10 mm pipe leak over 30 min	1×10^{-4}	Bund Fire	6.50×10^{-6}	093
		VCE	3.74×10^{-5}	094
		Pool Fire late	1.12×10^{-5}	095
		Flash Fire	1.12×10^{-5}	096
		None /Toxic	3.37×10^{-5}	097

Table 36: Event frequencies for Ignition Category 1 flammable liquids

Instantaneous tank failure will lead to bund overtopping, which means the scenarios occur both inside and outside the bund. Overtopping % is based on site conditions, with 50% assumed by default. The overtop pool size is based on site conditions and modelling parameters, but the pool diameter modelled is never greater than 100m.

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure - overtop	5×10^{-6}	Pool Fire	3.25×10^{-7}	098
		VCE	1.87×10^{-6}	099
		Pool Fire late	5.61×10^{-7}	100
		Flash Fire	5.61×10^{-7}	101
		None /Toxic	1.68×10^{-6}	102

Table 37: Event frequencies for overtop scenarios, Ignition Category 1 flammable liquids

3.4.3 Category 2 Substances and Mixtures

Ignition probabilities for Category 2 substances are very low. Pool fire is the only scenario of relevance for these sites. For TLUP purposes, accidents to the environment must also be considered. Other fire and explosion events are not considered for Category 2 substances unless they are co-located with Category 0 or Category 1, in which case they will be modelled as Category 1.

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous failure	5 x 10^{-6}	Pool Fire	5 x 10^{-8}	103
		VCE	0.0 x 10^{+0}	104
		Pool Fire late	0.0 x 10^{+0}	105
		Flash Fire	0.0 x 10^{+0}	106
		None /Toxic	4.95 x 10^{-6}	107
Failure over 10 minutes	5 x 10^{-6}	Pool Fire	5 x 10^{-8}	108
		VCE	0.0 x 10^{+0}	109
		Pool Fire late	0.0 x 10^{+0}	110
		Flash Fire	0.0 x 10^{+0}	111
		None /Toxic	4.95 x 10^{-6}	112
10 mm pipe leak over 30 min	1 x 10^{-4}	Bund Fire	1 x 10^{-6}	113
		VCE	0.0 x 10^{+0}	114
		Pool Fire late	0.0 x 10^{+0}	115
		Flash Fire	0.0 x 10^{+0}	116
		None /Toxic	0.0 x 10^{+0}	117

Table 38: Event frequencies for Ignition Category 2 flammable liquids

3.4.4 Category 3 Substances and Mixtures

Ignition probabilities for Category 3 substances are zero. Fire and explosion events are not considered for Category 3 substances, unless they are co-located in the same bund as Category 0 or Category 1, in which case they will be modelled as Category 1.

Failure to retain spilled material on site means that prevention of ignition will no longer be within the control of the operator of an establishment and therefore the approach outlined above, in relation to ignition probability, doesn't apply. Operators generally do not have control of areas outside the establishment, so a release off-site means that control of ignition sources, physical effects, and effects on third parties require consideration.

3.4.5 Road Tankers

Road tankers are taken into account in the analysis as follows:

For Ignition Category 0:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous Failure	1 x 10^{-5}	Pool Fire	4.00 x 10^{-6}	118
		VCE	2.40 x 10^{-6}	119
		Flash Fire	2.88 x 10^{-6}	120
		Pool Fire	3.60 x 10^{-7}	121
		None /Toxic	3.60 x 10^{-7}	122
Leak from largest connection	5 x 10^{-7}	Pool Fire	5.00 x 10^{-8}	123
		VCE	1.80 x 10^{-7}	124
		Flash Fire	2.16 x 10^{-7}	125
		Pool Fire	2.70 x 10^{-8}	126
		None /Toxic	2.70 x 10^{-8}	127

Table 39: Event frequencies for Ignition Category 0 liquid road tankers (per loading bay/gantry)

For Ignition Category 1:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous Failure	1×10^{-5}	Pool Fire	6.50×10^{-7}	128
		VCE	3.74×10^{-6}	129
		Flash Fire	4.49×10^{-6}	130
		Pool Fire	5.61×10^{-7}	131
		None /Toxic	5.61×10^{-7}	132
Leak from largest connection	5×10^{-7}	Pool Fire	3.25×10^{-8}	133
		VCE	1.87×10^{-7}	134
		Flash Fire	2.24×10^{-7}	135
		Pool Fire	2.81×10^{-8}	136
		None /Toxic	2.81×10^{-8}	137

Table 40: Event frequencies for Ignition Category 1 liquid road tankers (per loading bay/gantry)

For Category 2, events like VCE and Flash Fire not being credible, only the pool fire risk is considered:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Instantaneous Failure	1×10^{-5}	Pool Fire	1×10^{-7}	138
Leak from largest connection	5×10^{-7}	Pool Fire	5×10^{-9}	139

Table 41: Event frequencies for Ignition Category 2 flammable liquid road tankers (per loading bay/gantry)

3.4.6 Key Technical Measures for New Installations

It is expected that any new flammable liquid storage installation (or when replacing existing vessels tanks at establishments) will install double-skin or cup tanks.

LOCs frequencies and scenarios for cup tanks are given below:

LOC Scenario	Frequency (yr^{-1})	Consequence	#
Instantaneous failure of primary container and outer shell	1.25×10^{-8}	Release of the entire contents	140
Instantaneous failure of primary container	5×10^{-8}	Release of the entire contents into the intact outer shell	141
Failure of the primary container and outer shell	1.25×10^{-8}	Release of the entire contents in 10 min. in a continuous and constant stream	142
Failure of the primary container	5×10^{-8}	Release of the entire contents in 10 min. in a continuous and constant stream into the intact outer shell	143
Failure of primary container	1×10^{-4}	Continuous release from a hole with an effective diameter of 10 mm into the intact outer shell	144

Table 42: LOC's for cup tanks

3.4.7 Major Accidents to the Environment in this sector

In addition to the measures in place to minimize the risks to people, adequate tertiary containment should be provided, so that the contents of the largest tank and all the expected extinguishing media can be contained in the event of a major fire[24].

CLP Category 2 and 3 flammable liquids are generally more likely to carry an environmental hazard rating than Category 1 flammables. The most important major accident consideration for Category 3 storage is a loss of containment leading to a release of the dangerous substance into the environment.

Where the referral for TLUP advice relates to an application in the vicinity of these establishments, the applicant should consult with the operator on the consequences of a major accident and include an assessment in the application.

So, provided that there are no other flammable substances on the site or in the vicinity close enough to initiate a major accident and it is clear that any credible spill will remain on site, the probability of a Category 3 fire will not be considered credible.

[24] EPA (2019) provides guidance on Firewater retention.

3.5 PRESENCE OF INTERNAL NATURAL GAS PIPELINES

For some establishments the most significant major accident risk is associated with releases from on-site natural gas pipelines.

3.5.1 LOC Scenarios and frequencies

This table gives the loss of containment frequencies associated with pipework that will be used to develop generic technical LUP advice:

	Frequency (m^{-1} yr^{-1})			#
LOC Scenario	**D < 75mm**	**75 ≤ D ≥ 150mm**	**D>150mm**	
Pipeline Rupture	1×10^{-6}	3×10^{-7}	1×10^{-7}	145
Pipeline leak of 0.1D (max 50mm)	5×10^{-6}	2×10^{-6}	5×10^{-7}	146

Table 43: LOCs for over-ground pipes of varying diameter

For underground pipes an order of magnitude reduction is applied and the following values are used:

	Frequency (m^{-1} yr^{-1})			#
LOC Scenario	**D < 75mm**	**75 D ≥150mm**	**D>150mm**	
Pipeline Rupture	1×10^{-7}	3×10^{-8}	1×10^{-8}	147
Pipeline leak of 0.1D (max 50mm)	5×10^{-7}	2×10^{-7}	5×10^{-8}	148

Table 44: LoCs for underground pipes of varying diameter

For toxic pressurised gases, the concern is primarily toxic effects on humans, but environmental effects should not be disregarded. Modelling will use typical atmospheric stability conditions (D_5 / F_2) with appropriate Probits to calculate the limits of indoor and outdoor fatality.

The consequences associated with the LOCs are Jet Fires, Flashfires and VCEs. Their conditional probabilities are:

Event	Cond. Probability
Jet Fire	0.1
Flashfire	0.36
VCE	0.54

Table 45: Conditional probabilities for fire and explosion

3.6 FERTILIZER BLENDING AND STORAGE

The main sources of off-site risk are associated with the blending/storage of Fertilizer Grade Ammonium Nitrate (named substances 1 to 4 in Part 2 of Schedule 1 of the COMAH Regulations). The main events to consider are major fire, leading to a plume of toxic smoke capable of travelling some distance offsite and also, if the fire leads on to a detonation, from the blast overpressure effects.

Fertilizer Grade Ammonium Nitrate (FGAN) is not combustible, so a major accident would have to be initiated by other sources: this could be a fire involving wood or other combustible material or a road transport vehicle, for example. The effect of fire on FGAN causes it to decompose, releasing toxic gases. Therefore, the first scenario addresses off-site dispersion of these fire–generated gases.

FGAN detonation requires the formation of a pool of molten ammonium nitrate, caused by the heat input from a fire, a confined state and the initiation of an explosion by some mechanism (for example, from impact by a high energy object). Because of the explosion resistance of FGAN, a route to detonation is extremely improbable and the accident frequencies reflect this. While missile generation following detonation is credible, the off-site risk of missile impact in any single location is judged to be small and will usually be neglected in generic TLUP advice.

The most likely MATTE relates to a fire/fire-water run-off scenario. For new establishments, appropriate retention facilities should be in place.

3.6.1 Approach to source terms

For explosion modelling purposes, 300t of FGAN (the maximum stack size recommended by good practice) is taken to be equivalent to 42 tonnes of TNT (so 30 t FGAN is equivalent to 4.2t TNT). Generally, smaller fires (10% of total mass) are considered to be almost two orders of magnitude more likely than fires involving the full inventory. Progression to detonation is considered to be almost two orders of magnitude less likely for the full inventory stack (300t) than for 10% of the stack.

Fertilizer truck fires are considered to involve the maximum possible inventory (~30t).

Where FGAN is stored in stacks in the yard, then a fire scenario is considered. A FGAN fire in a fertilizer establishment's yard may have more significant consequences than a fire in a warehouse building. When modelling the generation of fumes of toxic NO_2 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. Once the fire develops and the roof collapses, the heat-induced buoyancy means ground-level concentrations will be insignificant, except in very high winds.

The wind-stability pairs of F_2, D_5 are typically used for modelling. However buoyancy calculations - Briggs lift-off criterion equation (Hannah (1998)) – generally allow F_2 conditions to be discarded for modelling purposes. While D_{10} conditions could be added to account for high winds, a somewhat simpler approach is taken, which provides a degree of conservatism to the resulting risk figures: the release is modelled as a passive dispersion in D_5 conditions, using a Gaussian model.

The 1% fatality footprint is also be considered to be equivalent to the particle deposition area.

3.6.2 Scenarios and Frequency of Occurrence

The two main accident scenarios considered are:

For the Yard:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Fire in Truck	4.02×10^{-4}	30 t Detonation	4.02×10^{-5}	149
		30 t Fire	3.62×10^{-4}	150
Fire In Stack	1.98×10^{-4}	30t fire	1.96×10^{-6}	151
		30 t Explosion	1.96×10^{-6}	152
		300t fire	1.94×10^{-4}	153
		300 t Explosion	1.98×10^{-8}	154

Table 46: FGAN Yard scenarios (per year)

Fire in truck is per truck per year, in the presence of FGAN (default fraction is 1).

For a Warehouse:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency	#
Fire In Stack	4.56×10^{-4}	30t fire	4.47×10^{-4}	155
		30 t Explosion	4.51×10^{-6}	156
		300t fire	4.51×10^{-6}	157
		300 t Explosion	4.56×10^{-8}	158

Table 47: FGAN Warehouse Scenarios

Risks sources are centred on the centre of the FGAN storage and operation areas.

3.7 CHEMICAL WAREHOUSES

Generally, the off-site risks associated with the most foreseeable accidents in chemical warehouses are negligible, as the quantities involved in any loss of containment tend to be limited (for example, single inventory containments up to about 0.2 m^3 for a single drum or 1 m^3 for an Intermediate Bulk Container or IBC). ISO Road containers can be treated as in Sections 3.1, 3.2, 3.4 etc. Particularly toxic substances (gases or volatile liquids) may require additional consideration (see Section 3.9).

Therefore, the most common off-site risk, for technical land-use planning advice generation, is the risk associated with a major fire, involving the release of hazardous substances from multiple containers. This could lead to a plume of toxic smoke capable of travelling some distance.

Where there is significant storage of flammable substances, the near-field thermal effects of a fire are also considered.

3.7.1 Approach to source terms

Assuming that the warehouse does not contain any particularly toxic materials (such as pesticides or toxic agrochemicals capable of being released unburned in the fire plume), then the main risk will be associated with dispersion of toxic combustion products.

However, it is difficult to predict the precise mix and quantity of each toxic combustion product: the approach taken is to assume that the toxicity of the fire plume can be represented by an equivalent release rate of the most significant toxic combustion product. This could be, for example, Nitrogen Dioxide, Hydrogen Chloride, Sulphur Dioxide, depending on the chemical substance composition within the warehouse.

Carbon Monoxide and Carbon Dioxide could also be released in significant quantities, as they could in all fires involving organic substances, so no weight is placed on assessing CO or CO_2 levels.

For warehouses storing complex mixtures of dangerous substances, representative release rates for NO_2, HCl, SO_2 and any other dominant toxic combustion products have to be determined. Porter et al (2000) make the following useful general assumptions:

Contains	Toxic Combustion Product	Conversion Rate
N	NO_2	5%
N	HCN	1.5%
Cl	HCl	100%
S	SO_2	100%
Br	HBr	100%

Table 48: Toxic combustion conversion rates

So, in a fire involving a dangerous substance containing nitrogen, the release rate of NO_2 can be estimated by assuming that 5% of the nitrogen content (see table 48) of the dangerous substances stored in the warehouse is combusted to form NO_2 which is then dispersed.

Example: for a large warehouse storing 2,500 tonnes of Ammonium Chloride (NH_4Cl, Molecular Weight = 53.49), the release rates of NO_2 (MW = 46) and HCl (MW = 36.46), from a major fire involving 100% of the inventory, can be calculated as follows (assuming 5% of N converted to NO_2, and 100% Cl converted to HCl as in table 48):

$$NO_2 \text{ release rate} = 2{,}500{,}000 \times (14/53.49 \times 0.05) \times (46/14) = 108{,}000 \text{ kg}$$

$$HCl \text{ release rate} = 2{,}500{,}000 \times (35.45/53.49 \times 1.0) \times (36.46/35.45) = 1{,}699{,}200 \text{ kg}$$

In most weather conditions, the hot plume of smoke from the fire will be buoyant, and is likely to rise into the atmosphere, resulting in relatively little risk at ground level. Therefore, for the purposes of TLUP risk assessment, it is necessary only to consider relatively high wind speed conditions, which generally occur for a small percentage of the time. However, as with fertilizer fires, the simpler and more conservative approach taken is to model as a passive dispersion in D_5 conditions, using a Gaussian model.

The model therefore assumes that for a large warehouse, the fire inventory is released over 2 hours, but only the first 30 minutes of this are modelled, using a standard Gaussian plume model, with no plume rise.

So for our example, a fire in a large warehouse involving 100% of the inventory gives the following release rates:

NO_2 release = (108,000/(2 X 60)) X 30 = 27,000 kg =15 kg/sec

HCL release = (1,699,200/(2 X 60)) X 30 = 442,800 kg =118 kg/sec

Where several toxic combustion products arise from a fire, it will be necessary to consider the relative release rates and toxicities to determine if a particular component is clearly dominant. Otherwise, it may be necessary to calculate an increased 'equivalent' release rate for the most significant component.

3.7.2 Fire Frequency

The likelihood of fire starts in typical warehouses has been estimated at about 10^{-2}/year, based on historical evidence (see Hymes and Flynn (1982) and Hockey and O'Donovan (1997)). However, the majority of such fires are relatively minor or are rapidly controlled and only a small proportion escalate to become major fires, with data from Hockey and O'Donovan suggesting a frequency of about 10^{-3}/year for a large fire in a typical warehouse. However, for the warehouse type holding hazardous substances, it is assumed that the more stringent controls would result in a reduction in the likelihood of such major events (involving the entire warehouse) being typically an order of magnitude lower still, at about 10^{-4} per year. The higher frequency of 10^{-3}/year is assigned to a lesser fire involving just 10% of the source term, that is:

Scenario	Frequency (yr^{-1})	#
Fire (10% of Inventory)	1×10^{-4}	159
Fire (100 % of Inventory)	1×10^{-5}	160

Table 49: Fire Frequency for Warehouse

Warehouses with sprinklers are considered to have a reduced frequency for small fires by one-half order of magnitude and of large fires by one order of magnitude (Frank et al, 2013)

3.8 CHEMICAL/PHARMACEUTICAL PLANTS

Chemical/pharmaceutical manufacturing/processing plants are likely to contain multiple hazard sources, often distributed around a large site. Hazards are likely to include those related to:

- Bulk Flammable storage;
- Dangerous Substance Warehousing;
- Bulk storage and processing of toxics and flammables;
- Overpressure and explosion related to processing;
- Releases from pressurised drums of toxic and flammable gases.

The risks associated with flammable storage and warehousing generally can be assessed using the methods described elsewhere in this document (such as sections 3.2 & 3.5), so it is only process hazards which are considered in more detail in this section. For sites with multiple hazards, the risks should be aggregated.

A key point to note for chemical processing sites, is that the dangerous substances in-process may be at elevated temperatures and pressures, so the likelihood of relatively small releases leading to a significant major accident is considerably increased. Furthermore, the hazardous substances that could be released from a process may include reaction products (and by-products) and not simply the raw materials or intended final products.

The general methods outlined here can also be applied to other establishment types with process hazards and /or multiple hazards.

3.8.1 Approach

3.8.1.1 Risks from Bulk Storage of Toxic (and Water Reactive) Liquids

Section 3.4 addressed loss of containment scenarios related to the bulk storage of flammable liquids. For sites with atmospheric bulk storage of non-flammable toxic (or water-reactive) liquids, the same base LOC figures can be used, with modified consequences, as follows:

LOC Scenario	LOC Frequency (yr^{-1})	Consequence	Frequency (yr^{-1})	#
Instantaneous failure	5×10^{-6}	Pool Evaporation + vapour dispersion (bund)	5×10^{-6}	161
		Pool Evaporation + vapour dispersion (overtop)	5×10^{-6}	162
Failure over 10 minutes	5×10^{-6}	Pool Evaporation + vapour dispersion	5×10^{-6}	163
10 mm pipe leak over 30 min	1×10^{-4}	Pool Evaporation + vapour dispersion	1×10^{-4}	164

Table 50: LOC scenarios and frequencies for bulk toxic storage

Adequate bunds are assumed to be present, as would be required by good practice. For instantaneous failure, it is assumed a pool forms outside the bund, by default this is assigned 50% of the tank contents. Overtop pools are assigned an upper radial limit of 50m.

Evaporation release rates from pools can be calculated using standard evaporation models (in D_5 and F_2 conditions). More detailed calculations may be required for water-reactive chemicals or fuming acids.

3.8.1.2 Process Risks

A full QRA to consider every process and every vessel individually would entail considerable effort and analysis which is not considered necessary for the purposes of generating generic technical land-use planning advice. Many of the possible loss of containment events will have immediate impacts within the process building which are not relevant to land-use planning. So, the approach taken is to identify the process step with the greatest potential for off-site consequences and to assume that this inventory bounds all other potential toxic and flammable events from the process building. This may require detailed analysis of the toxicity, flammability, volatility, temperature and inventory for various cases in order to ensure that the worst case toxic release is identified. The frequency of this event is then multiplied by the number of process reaction vessels to get the overall frequency for the loss of containment event. The locus of the releases are spread across the vessels.

Processes may be at elevated temperature and /or pressure and so the quantity of material that may be dispersed could be much greater than for an ambient release at atmospheric pressure. In some cases, it may be appropriate to assume that 100% of the available inventory in the largest vessel is released. In other cases it may be possible to determine a smaller 'worst-case' source term.

In the absence of more detailed information, the likelihood of such a major releases from a process vessel, allowing that other items of equipment (pipes, pumps, compressors, heat exchangers etc.) could also be sources of loss of containment events, is assumed to be equivalent to the 10 minute or 10mm hole releases, as given in this table:

LOC Scenario	Frequency	#
Instantaneous Release	5×10^{-6}	165
Release over 10 minutes	1×10^{-5}	166
Release through 10mm pipe	5×10^{-4}	167

Table 51: LOC scenarios for Process vessels (per vessel per year)

The figures are derived from the LOC frequencies in Table 31 of the BEVI. The frequencies for the 10-minute release and the 10mm release have been increased by half an order of magnitude to compensate for releases from associated process equipment which are not being separately modelled.

The LOCs from the table above will be multiplied by the number of reactor vessels in the hall or building as appropriate. Dispersion will be modelled in D_5 and F_2 weather conditions. In most cases, a standard Gaussian plume model will be sufficient for modelling the dispersion.

For flammable substances, fire and explosion risk must be accounted in the event tree. To be considered:

- Associated risks of VCE due to release of flammables in semi-confined regions.
- Flash Fire

These will be included in the analysis unless it is clearly evident that such events are not applicable for the facility.

So the event assumed is a vapour or 2-phase release external to the process building. If flammable, a flash fire is considered. If significant confinement is possible, a VCE is considered. If the substance also has toxic properties, then some of the flash fire probability is assigned to the toxic arm. For toxic only substances, all the risk is assigned to toxic dispersion.

A major accident to the environment could also be an outcome. While not usually relevant in setting LUP zones or consultation distances, this would be relevant for a new establishment and the requirement for suitable barriers to eliminate possible pathways.

The risk associated with failure of pressure vessels can be calculated by assessing the blast overpressure that would be produced in the event of the worst case pressure vessel failure (taking into account the volume and failure pressure). The failure pressure is typically taken as 3 times the design pressure. The overpressures will be determined using a simple TNT equivalence model, based on the release of stored energy in the vessel.

The risk associated with potential VCEs in semi-confined areas, such as might occur due to a leak of hot solvent, can be estimated simply by using the TNO vapour cloud explosion model, where the size of the flammable cloud is taken to correspond to the volume of the semi-confined region where the release may occur (often taken as the building volume). The ignition strength is taken as 7.

Where the potential for exothermic runaway exists, the instantaneous release LOC in table 51 should be increased by one half an order of magnitude, to 1×10^{-5} per year.

3.9 PRESSURISED GASES IN DRUMS & CYLINDERS

The risks associated with dangerous substance gas drum & cylinder stores (including Acetylene, Chlorine, Hydrogen Chloride (HCl), Ammonia (NH_3), LPG), arise from the toxic and /or flammable gas and vapour that is generated from any loss from the pressurised containment. The released inventory is limited to that of the containing cylinder or drum (a drum could contain up to 1 tonne). The likelihood of release can be relatively high due to the nature of the manual operations involved in handling drums.

BEVI (2009) suggests the following scenarios and frequencies for pressurised containment of water volume up to 150l:

Scenario	Frequency (yr^{-1})	#
Instantaneous Release	5×10^{-7}	168
Release through hole D=3.3mm	5×10^{-7}	169

Table 52: LOC Scenarios and event frequencies for pressurised Cylinders (per cylinder per year)

For a multiple cylinder array with N cylinders, the following applies:

Scenario	Frequency (yr^{-1})	#
Instantaneous Release	$N \times (5 \times 10^{-7})$	170
Release through hole D=3.3mm	$(N-1) \times (5 \times 10^{-7})$	171

Table 53: LOC Scenarios for pressurised Cylinder array with N cylinders (per year per array)

Dispersion of the toxic releases will be modelled in D_5 and F_2 weather conditions, using an appropriate dispersion model (ADAM, ALOHA, EFFECTS, PHAST, etc.).

For pressurised flammable gas cylinders, fire/explosion events will be modelled. Conditional probabilities are taken as:

Event	Cond. Probability
Fireball/Jet Fire	0.1
Flashfire	0.36
VCE	0.54

Table 54: Conditional probabilities for fire and explosion events

Drums are mobile pressurised containers of greater than 150l water volume. Drum scenarios considered are:

Scenario	Frequency (yr^{-1})	#
Instantaneous Release	5×10^{-6}	172
Contents released over 10 min	5×10^{-6}	173
Release through pipe D=10mm	1×10^{-4}	174

Table 55: LOC Scenarios and event frequencies for pressurised drums (per drum per year)

3.10 STORAGE / HANDLING / MANUFACTURING OF EXPLOSIVES

This section applies to sectors manufacturing, storing or using explosives. This includes actual explosives manufacturing sites and sites using explosives (underground mines, for example).

The major accident scenarios associated with such sites are accidental detonation, giving rise to blast overpressure. Such explosions can also generate flying debris and cause window damage, which may sometimes be important in determining the LUP risk.

3.10.1 Approach to Modelling

The risk based approach considers the worst case event for each explosives inventory and assumes the following:

LOC Scenario	Frequency (yr^{-1})	#
Fire in process Building	1×10^{-4}	175
Fire in Storage Area	1×10^{-5}	176

Table 56: Scenarios for explosives

Processing, storage and transport locations are considered as potential fire locations.

Fires involving 10% of the inventory are considered to be an order of magnitude more likely than those involving the full inventory.

Fires are considered to always lead on to an explosive event. The TNT equivalence model is used to determine the overpressure. The ESTC (HSE 2002) model's indoor and outdoor fatality fractions are applied.

Otherwise, fatality and damage levels are calculated as described in section 2.4.

3.11 DISTILLERIES & SPIRIT MATURATION WAREHOUSES

This section applies to sectors manufacturing and/or storing potable spirit.

Processing, storage and transport locations are considered as potential fire locations. The major accident scenarios associated with such sites are spirit warehouse fires, fires and explosions in Still Houses or at bulk loading/unloading points.

3.11.1 Approach to Modelling

As the spirit is predominantly composed of ethanol, the SEP for ethanol (130 kw/m2 - see p 22) is be used for ethanol fire modelling.

However, for fires in warehouses containing wooden casks, the flux used is increased to 250 kw/m2 (HSE 2001), because of the substantial co-burning of wooden casks which substantially adds to the fire load.

Ethanol has a FP of 12 °C and boils at 78.4 °C and is therefore located in CLP category 2: according to Table 32, this means it falls into ignition category 1.

Ethanol releases at the boiling point (from Stills) are treated as CLP category 1, meaning they fall into ignition category 0.

The event frequencies in Tables 36 and 34, respectively, apply.

In accord with Table 36, flash fires and vapour cloud explosions are also possible scenarios where the alcohol is present in bulk – in the Still House or at bulk tanker loading/unloading operations.

Potential MATTEs are spills or firewater getting into watercourses.

Bulk road tanker loading/unloading are assumed to involve inventories up to 30m^3. Spills during loading/unloading are credible and therefore fire, VCE and Flash fire are included. For such pool fires, the area of the largest possible pool is used (bearing in mind that this may be severely limited through kerbing and drainage). The event frequencies in Table 40 apply to bulk loading/unloading of spirit.

Spirit warehouses are typically well protected against vandalism and arson. In addition, they are compartmented and contain sprinklers.

For those reasons and provided those measures are in place, the major fire frequency is set at:

LOC Scenario	Frequency (yr^{-1})	#
Full compartment Warehouse Fire	5 x 10^{-6}	175

Table 57: Spirit Warehouse Fire Frequency

GLOSSARY

AIChE	American Institute of Chemical Engineers
ALARP	As Low As Reasonably Practicable
ADAM	Atmospheric Dispersion Accident Model
ARAMIS	Accidental Risk Assessment Methodology for IndustrieS
BLEVE	Boiling Liquid Expanding Vapour Explosion
CBA	Cost Benefit Analysis
CD	Consultation Distance
CIA	Chemical Industries Association
COMAH	Control of Major Accident Hazards
cpm	Chances per million (years)
EV	Expectation Value
HSA	Health and Safety Authority
Flash Fire	Combustion of flammable gas/vapour – air mixture, with no significant overpressure generated
F-N curve	A Frequency-Number curve (for Societal Risk)
HSE	Health and Safety Executive (UK)
LUP	Land-use Planning
Natech	Major Accidents initiated by a natural hazard or disaster
PA	Planning Authority
PADHI	Planning Advice for Developments near Hazardous Installations
PLL	Potential Loss of Life
Pool Fire	Surface fire involving a pool of flammable liquid
QRA	Quantified Risk Analysis
R2P2	Reducing Risks, Protecting People (UKHSE publication, 2001)
TLUP	Technical Land-use Planning Advice
TOR	Tolerability of Risk
VCE	Vapour Cloud Explosion

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APPENDIX 1: REQUEST FOR TECHNICAL LUP ADVICE FROM A PLANNING AUTHORITY

Send to HSA LUP mailbox: LandUsePlanning@hsa.ie

Planning Authority area (select):

This development type is (tick):

a. related to a modification to an existing establishment or
b. external, within the consultation distance notified to us by HSA or
c. for a new establishment

Relevant Establishment (select)

If development refers to type b, tick one of the following: the development type is

1	a. Provision of hotel, hostel or holiday accommodation	
	b. Provision of housing.	
2	Provision of schools, crèches or other educational or childcare facilities, training centres, hospitals, convalescent homes, homes for the elderly or sheltered accommodation.	
3	Retail development greater than **250 m²** in gross floor space.	
4	Structures for community and leisure facilities, greater than **100 m²** in gross floor space.	
5	Provision of facilities or use of land for activities likely to attract occasionally more than **1,000 people** at any one time.	
6	Commercial, industrial or office development designed to accommodate **20 or more** employees.	
7	Provision of parking facilities (on its own) for more than **200 motor vehicles**.	
8	A major transport link (including a public road).	
9	Any development adjoining or separated only by a road from an establishment, posing an above-normal risk of fire or explosion.	
10	Modifications to any of the above, which will increase the number of persons present by **10 or more**.	

The generic advice provided by the Authority is insufficient for the planning authority in this case because (if applicable):

The centre of the proposed development is located at:

Latitude (decimal degrees):

Longitude (decimal degrees):

Planning authority reference:

Link to location of all documents relevant to planning application:

Date request submitted:

Date by which decision is due:

APPENDIX 2: DEVELOPMENT SENSITIVITY LEVELS

SENSITIVITY LEVEL 1: People at work, Parking

Level 1

DT1.1 – Workplaces

DT1.2 – Parking Areas

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
WORKPLACES (DT 1.1)	Offices, factories, warehouses, haulage depots, farm buildings, non-retail markets, builder's yards.	Workplaces (predominantly non-retail), providing for less than 100 occupants in each building **and** less than 3 occupied storeys – **Level 1**	Places where the occupants will be fit and healthy, and could be organised easily for emergency action. Members of the public will not be present or will be present in very small numbers and for a short time.
	EXCLUSIONS		
		Workplaces (predominantly non-retail) providing for 100 or more occupants in any building **or** 3 or more occupied storeys in height **(DT 1.1.1)** Level 2 (except where the development is at the major hazard site itself, where it remains Level 1).	Substantial increase in numbers at risk with no direct benefit from exposure to the risk.
	Rehabilitation and training services for people with disabilities	Workplaces (predominantly non-retail) specifically for people with disabilities **–(DT 1.1.2)** Level 3	Those at risk may be especially vulnerable to injury from hazardous events and / or they may not be able to be organised easily for emergency action.
PARKING AREAS (DT 1.2)	Car parks, truck parks, lock-up garages.	Parking areas with no other associated facilities (other than toilets) – **Level 1**	
	EXCLUSIONS		
	Car parks with picnic areas, or at a retail or leisure development, or serving a 'park and ride' facility.	Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development. **(DT 1.2.1)**	

SENSITIVITY LEVEL 2: Developments for use by the general public

Level 2

DT2.1 – Housing

DT2.2 – Hotel/Hostel/Holiday Accommodation

DT2.3 – Transport Links

DT2.4 – Indoor Use by Public

DT2.5 – Outdoor Use by Public

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
HOUSING (DT 2.1)	Houses, apartments, retirement flats/ bungalows, residential caravans, mobile homes.	Developments up to and including 30 dwelling units **and** at a density of no more than 40 per hectare - Level 2	Development where people live or are temporarily resident. It may be difficult to organise people in the event of an emergency.
		EXCLUSIONS	
	Infill, backland development (development of land at rear of existing property).	Developments of 1 or 2 dwelling units (DT 2.1.1) - Level 1	Minimal increase in numbers at risk.
	Larger housing developments.	Larger developments for more than 30 dwelling units (DT 2.1.2)– Level 3	Substantial increase in numbers at risk.
	Developments at high density.	Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare – (DT 2.1.3) Level 3	High-density developments.
HOTEL/HOSTEL/ HOLIDAY ACCOMMODATION (DT 2.2)	Hotels, motels, guest-houses, hostels, youth hostels, holiday camps, holiday homes, student accomodation, accommodation centres, holiday caravan sites, camping sites.	Accommodation up to 100 beds or 33 caravan / tent pitches – Level 2	Development where people are temporarily resident. It may be difficult to organise people in the event of an emergency.
		EXCLUSIONS	
	Smaller guest-houses, hostels, youth hostels, holiday homes, student accomodation, holiday caravan sites, camping sites.	Accommodation of less than 10 beds or 3 caravan / tent pitches – (DT 2.2.1) Level 1	Minimal increase in numbers at risk.
	Larger hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites.	Accommodation of more than 100 beds or 33 caravan / tent pitches – (DT 2.2.2) Level 3	Substantial increase in numbers at risk.
TRANSPORT LINKS (DT 2.3)	Motorway, dual carriageway.	Major transport links in their own right; i.e. not as an integral part of other developments –	Prime purpose is as a transport link. Potentially large numbers exposed to risk, but exposure of

		Level 2	an individual is only for a short period.
	EXCLUSIONS		
	Estate roads, access roads.	Single carriageway roads – (DT 2.3.1) Level 1	Minimal numbers present and exposed to risk for a short time period (mostly). Associated with other development.
	Any rail or tram track.	Railways – (DT 2.3 x2) Level 1	Transient population, exposed to risk for short time periods. Times with no population present.
INDOOR USE BY PUBLIC (DT 2.4)	**Food & Drink:** Restaurants, Cafes, drive-through fast food, pubs. **Retail:** Shops, petrol filling station (total floor space based on shop area, not forecourt), vehicle dealers (total floor space based on showroom/sales building not outside display areas) retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public. **Community & adult education:** Libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. Adult education, 2nd level exam colleges, colleges of FE. **Assembly & leisure:** Coach / bus / railway stations, ferry terminals, airports. Cinemas, concert/ bingo/ dance halls. Conference centres. Sports / leisure centres, sports halls. Facilities associated with golf courses, flying clubs (e.g. changing rooms, club house), indoor go-kart tracks.	Developments for use by the general public where total floor space is from 250 m² up to 5,000 m² – Level 2	Developments where members of the public will be present (but not resident) Emergency action may be difficult to co-ordinate.
	EXCLUSIONS		
		Development with less than 250 m² total floor space – (DT 2.4.1) Level 1	Minimal increase in numbers at risk
		Development with more than 5,000 m² total floor space – (DT 2.4.2) Level 3	Substantial increase in numbers at risk
OUTDOOR USE BY PUBLIC (DT 2.5)	**Food & Drink:** Food festivals, picnic area. **Retail:** Outdoor markets, car boot sales, funfairs. **Community & adult education:** Open-air theatres and exhibitions. **Assembly & leisure:** Coach / bus / railway stations, park & ride facilities, ferry terminals. Sports stadia, sports fields / pitches, funfairs, theme parks, viewing stands. Marinas, playing fields, children's play areas, BMX/go- kart	Principally an outdoor development for use by the general public i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time – Level 2	Developments where members of the public will be present (but not resident) either indoors or outdoors. Emergency action may be difficult to co-ordinate.

	tracks. Country parks, nature reserves, picnic sites, marquees.		
	EXCLUSIONS		
	Outdoor markets, car boot sales, funfairs. Picnic area, park & ride facilities, viewing stands, marquees.	Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1,000 at any one time – (**DT 2.5.1**) Level 3	Substantial increase in numbers at risk and more vulnerable due to being outside.
	Theme parks, funfairs, large sports stadia and events, open-air markets, outdoor concerts, pop festivals.	Predominantly open-air developments likely to attract the general public in numbers greater than 1,000 people at any one time – (**DT 2.5.2**) Level 4	Very substantial increase in numbers at risk, more vulnerable due to being outside and emergency action may be difficult to co-ordinate.

SENSITIVITY LEVEL 3: Developments for use by vulnerable people

Level 3

DT3.1 – Institutional Accommodation and Education

DT3.2 – Prisons

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
INSTITUTIONAL ACCOMMODATION AND EDUCATION **(DT3.1)**	Hospitals, convalescent homes, nursing homes. Housing for elderly with warden on site or 'on call', sheltered housing. Nurseries, crèches. Schools and academies for children up to school leaving age.	Institutional, educational and special accommodation for vulnerable people, or that provides a protective environment – **Level 3**	Places providing an element of care or protection. Because of age, infirmity or state of health the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult.
	EXCLUSIONS		
	Hospitals, convalescent homes, nursing homes, sheltered housing.	24-hour care where the site on the planning application being developed is larger than 0.25 hectare (**DT3.1.1**) Level 4	Substantial increase in numbers of vulnerable people at risk.
	Schools, nurseries, crèches.	Day care where the site on the planning application being developed is larger than 1.4 hectare (**DT3.1.2**) – Level 4	Substantial increase in numbers of vulnerable people at risk.
Places of detention **(DT3.2)**	Prisons, detention facilities, remand centres.	Secure accommodation for those sentenced by court, or awaiting trial etc. – **Level 3.**	Places providing detention. Emergency action and evacuation may be very difficult.

SENSITIVITY LEVEL 4: Very large and sensitive developments

Level 4

DT4.1 - Institutional Accommodation

DT4.2 - Very Large Outdoor Use by Public

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
[Note: All Level 4 developments are exceptions to Level 2 or 3. They are reproduced here for convenience]			
INSTITUTIONAL ACCOMMODATION (DT4.1)	Hospitals, convalescent homes, nursing homes, sheltered housing.	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided. And where the site on the planning application being developed is larger than 0.25 hectare : **Level 4.**	Places providing an element of care or protection. Because of age or state of health, the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult. The risk to an individual may be small but there is a larger societal concern.
	Nurseries, crèches. Schools for children up to school leaving age.	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided. And where the site on the planning application being developed is larger than 1.4 hectare : **Level 4.**	Places providing an element of care or protection. Because of age, the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult. The risk to an individual may be small but there is a larger societal concern.
VERY LARGE OUTDOOR USE BY PUBLIC (DT4.2)	Theme parks, large sports stadia and events, open air markets, outdoor concerts, and pop festivals.	Predominantly open air developments where there could be more than 1000 people present **Level 4.**	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings. Large numbers make emergency action and evacuation difficult. The risk to an individual may be small but there is a larger societal concern.

Notes

1. Where a development straddles zones, the development will be considered to belong to the zone that gives rise to the greatest Expectation Value (a societal risk assessment may be necessary if there is significant expectation contribution from the other zone(s)).
2. For developments consisting of multiple Development Types, a societal risk evaluation will likely be necessary.

APPENDIX 3: DEVELOPMENT TYPE BY ZONE

Developments not advised against for each zone are presented in this appendix.

The overall scheme is:

	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Inner Zone (individual risk > 10^{-5} per year):

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	Development Type	Dev type ref
1	Developments of 1 or 2 dwelling units	Infill, backfill development (development of land at rear of existing property).	Housing	2.1.1
1	Accommodation of less than 10 beds or 3 caravan / tent pitches –	Smaller - guest houses, hostels, youth hostels, holiday homes, student accommodation, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday Accommodation	2.2.1
1	Single carriageway roads –	Estate roads, access roads.	Transport Links	2.3.1
1	Railways –	Any railway or tram track.	Transport Links	2.3.2
1	Development with less than 250 m^2 total floor space		Indoor Use by the Public	2.4.1
1	Workplaces (predominantly non-retail), providing for less than 100 occupants in each building **and** less than 3 occupied storeys –	Offices, factories, warehouses, haulage depots, farm buildings, non-retail markets, builder's yards.	Workplaces	1.1
1	Parking areas with no other associated facilities (other than toilets) –	Car parks, truck parks, lock-up garages.	Parking Area	1.2

Middle Zone (individual risk between 10^{-5} and 10^{-6} per year):

Level	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	Development Type	Dev type ref
2	Developments up to and including 30 dwelling units **and** at a density of no more than 40 per hectare -	Houses, apartments, retirement flats/ bungalows, residential caravans, mobile homes.	Housing	2.1
2	Accommodation up to 100 beds or 33 caravan / tent pitches –	Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, student accommodation, accommodation centres, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday Accommodation	2.2
2	Major transport links in their own right; i.e. not as an integral part of other developments –	Motorway, dual carriageway.	Transport Links	2.3
2	Developments for use by the general public where total floor space is from 250 m^2 up to 5,000 m^2 –	**Retail: Restaurants, Cafes, drive-through fast food, pubs. Food & Drink:** Shops, petrol filling station (total floor space based on shop area, not forecourt), vehicle dealers (total floor space based on showroom/sales building not outside display areas) retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public.	Indoor Use by the Public	2.4
2	Developments for use by the general public where total floor space is from 250 m^2 up to 5,000 m^2 –	**Community & adult education:** Libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. Adult education, 2nd level exam colleges, colleges of FE.	Indoor Use by the Public	2.4
2	Developments for use by the general public where total floor space is from 250 m^2 up to 5,000 m^2 –	**Assembly & leisure:** Coach / bus / railway stations, ferry terminals, airports. Cinemas, concert/ bingo/ dance halls. Conference centres. Sports / leisure centres, sports halls. Facilities associated with golf	Indoor Use by the Public	2.4

		courses, flying clubs (e.g. changing rooms, club house), indoor go-kart tracks.		
2	Principally an outdoor development for use by the general public i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time –	**Food & Drink: Food festivals, picnic area.**	Outdoor Use by the Public	2.5
2	Principally an outdoor development for use by the general public i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time –	**Retail: Outdoor markets, car boot sales, funfairs.**	Outdoor Use by the Public	2.5
2	Principally an outdoor development for use by the general public i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time –	**Community & adult education: Open-air theatres and exhibitions.**	Outdoor Use by the Public	2.5
2	Principally an outdoor development for use by the general public i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time –	**Assembly & leisure**: Coach / bus / railway stations, park & ride facilities, ferry terminals. Sports stadia, sports fields / pitches, funfairs, theme parks, viewing stands. Marinas, playing fields, children's play areas, BMX/go- kart tracks. Country parks, nature reserves, picnic sites, marquees.	Outdoor Use by the Public	2.5
2	Workplaces (predominantly non-retail) providing for 100 or more occupants in any building **or** 3 or more occupied storeys in height	(Except where the development is at the major hazard site itself, where it remains Level 1).	Workplaces	1.1.1

Outer Zone (individual risk between 10^{-6} and 10^{-7} per year):

Level	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	Development Type	Dev type ref
3	Larger developments for more than 30 dwelling units	Larger housing developments.	Housing	2.1.2
3	Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare –	Developments at high density.	Housing	2.1.3
3	Accommodation of more than 100 beds or 33 caravan / tent pitches –	Larger – hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday Accommodation	2.2.2
3	Development with more than 5,000 m^2 total floor space		Indoor Use by the Public	2.4.2
3	Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1,000 at any one time	Outdoor markets, car boot sales, funfairs. Picnic area, park & ride facilities, viewing stands, marquees.	Outdoor Use by the Public	2.5.1
3	Workplaces (predominantly non-retail) specifically for people with disabilities	Rehabilitation and training services for people with disabilities	Workplaces	1.1.2
3	Institutional, educational and special accommodation for vulnerable people, or that provides a protective environment –	Hospitals, convalescent homes, nursing homes. Housing for elderly with warden on site or 'on call', sheltered housing. Nurseries, crèches. Schools and academies for children up to school leaving age.	Institutional Accommodation and Education	3.1
3	Secure accommodation for those sentenced by court, or awaiting trial etc. –	Prisons, detention facilities, remand centres.	Places of Detention	3.2

Developments requiring special assessment:

Level	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	Development Type	Dev type ref
4	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided. And where the site on the planning application being developed is larger than 0.25 hectare	Hospitals, convalescent homes, nursing homes, sheltered housing.	Institutional Accommodation	3.1.1
4	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided. And where the site on the planning application being developed is larger than 1.4 hectare :	Nurseries, crèches. Schools for children up to school leaving age.	Institutional Accommodation	3.1.2
4	Predominantly open air developments where there could be more than 1000 people present	Theme parks, large sports stadia and events, open air markets, outdoor concerts, and pop festivals.	Very Large Outdoor Use By Public	2.5.2