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An Coimisiún um Rialáil Fuinnimh

ALARP Demonstration Guidance Document

Part of the Petroleum Safety Framework

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The Commission for Energy Regulation,
The Exchange,
Belgard Square North,
Tallaght,
Dublin 24.
www.cer.ie

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List of Abbreviations

Abbreviation	Meaning
(the) Act	The Electricity Regulation Act, 1999 as amended, inter alia, by the Petroleum (Exploration and Extraction) Safety Act 2010
ALARP	As Low As is Reasonably Practicable
CBA	Cost Benefit Analysis
CER	Commission for Energy Regulation
FN	A measure of societal risk where F is the cumulative frequency of N or more fatalities
HSA	Health and Safety Authority
HSE	UK Health and Safety Executive
ICAF	Implied Cost of Averting a Fatality
NSAI	National Standards Authority of Ireland
QRA	Quantitative Risk Assessment

List of Defined Terms in this Paper

Words and phrases defined in Section 13A of the Act shall, unless the context otherwise requires, have the same meanings when used in this Paper.

Term	Definition or Meaning
ALARP Demonstration Guidance Document	This guidance document, as amended from time to time, which details CER's expectations on ALARP demonstration under the Framework. The ALARP Demonstration Guidance Document forms part of the Framework.
Defined ICAF	The Defined ICAF is a pre-defined monetary value for use in a cost benefit analysis that can be compared to a calculated ICAF for a risk reduction measure. If the calculated ICAF is greater than a multiple (defined as the Gross Disproportion Factor) of the Defined ICAF, the cost of the risk reduction measure is said to be grossly disproportionate to the risk reduction it provides. The Defined ICAF may be published by CER from time to time, is indexed linked and is at least €2,400,000 in 2013 prices.
FN curve	An FN curve plots the cumulative frequency of N or more fatalities over the range of fatalities possible.
Framework	The Petroleum Safety Framework established under Section 13I of the Act which comprises the collection of regulations, written regulatory documents and procedures which, taken together, describe the system the CER uses to regulate the activities of petroleum undertakings with respect to safety.
General Duty	The duty placed on petroleum undertakings under section 13K of the Act to ensure that: a) any petroleum activity is carried on in such a manner as to reduce any risk to safety to a level that is As Low As is Reasonably Practicable (ALARP); and b) any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in such a manner as to reduce any risk to safety to a level that is ALARP.
Good Practice	The recognised risk management practices and measures that are used by competent organisations to manage well-understood hazards arising from their activities.
Gross Disproportion Factor	The minimum factor by which the calculated ICAF of a risk reduction measure must exceed the Defined ICAF for the cost of the risk reduction measure to be in gross disproportion to its safety benefit and therefore for it to be considered not reasonably practicable to implement the measure.
Hazard	Source of potential harm.

Term	Definition or Meaning
High Level Design	The CER *Decision Paper on the High Level Design of the Petroleum Safety Framework* (the High Level Design[1]) as amended from time to time.
Implied Cost of Averting a Fatality (ICAF)	The ICAF is the cost of a risk reduction measure divided by the reduction in Potential Loss of Life that it provides over its lifetime.
Lower Tolerability Limit	The boundary between risks that are broadly tolerable and tolerable if ALARP.
Major Accident	An event, such as a major emission, fire, explosion, impact or structural failure of petroleum infrastructure, resulting from uncontrolled developments in the course of petroleum activities that could lead to a serious danger to human health whether immediate or delayed. Serious danger implies events which could impact multiple persons, including members of the public and/or workforce.
Major Accident Hazard	A hazard that if realised could result in a Major Accident.
Potential Loss of Life	The sum across all hazardous events and scenarios being considered of the average annual fatalities, where the average is calculated as the annual frequency of an event multiplied by the number of fatalities resulting from it.
Residual risk	The risk that remains once a risk reduction measure has been implemented.
Risk	The likelihood of a given consequence.
Risk assessment or risk analysis	The process used to assess and comprehend the risk from a hazard, or number of hazards. Risk analysis provides the basis for comparison of the risk with the Risk Tolerability Limits.
Risk reduction measure	A measure that reduces the risk from a hazard.
Risk Tolerability Limits	The Upper Tolerability Limit and / or Lower Tolerability Limit for individual, or societal risk, as the context requires.
Safety Case Guidelines	Guidelines, as amended from time to time, prepared by the CER under section 13L of the Act relating to the preparation and appropriate contents of safety cases for petroleum undertakings. The Safety Case Guidelines form part of the Framework.
Upper Tolerability Limit	The boundary between intolerable risks and risks which are tolerable if ALARP.

[1] See Reference 1 in Appendix A.

1 Introduction

1.1 The Petroleum Safety Framework

The *Electricity Regulation Act 1999*, as amended *inter alia* by the *Petroleum (Exploration and Extraction) Safety Act 2010* (the Act) gives the Commission for Energy Regulation (CER) responsibility for the safety regulation of petroleum exploration and extraction activities in Ireland. The Act specifically includes a requirement for the CER to "establish and implement a risk-based Petroleum Safety Framework" referred to in this document as the Framework. The Framework can be understood as the entire system that the CER uses to regulate the safety of petroleum activities[2], and in particular designated petroleum activities[3], carried out by petroleum undertakings[4]. The Framework established by the Act is risk-based, recognising that hazards may be presented by the activities to be regulated and it requires petroleum undertakings to reduce risks to a level that is as low as is reasonably practicable (ALARP).

The CER *Decision Paper on the High Level Design of the Petroleum Safety Framework*[5] (the 'High Level Design') sets out, at a high level, how the Framework operates. This *ALARP Demonstration Guidance Document* forms part of the Framework.

1.2 Purpose of ALARP Demonstration Guidance Document

The purpose of the *ALARP Demonstration Guidance Document* is to provide detailed guidance to petroleum undertakings on the CER's expectations on what is required in an ALARP demonstration under the Framework.

It is the responsibility of the petroleum undertaking to ensure that the risk from its activities is reduced to a level that is ALARP and to demonstrate this through its safety case (or cases). The petroleum undertaking must decide how best to demonstrate that the risks from their activities are ALARP through its safety case. The CER will assess whether it considers the demonstration to be adequate or not given the full array of information provided, and having regard to the requirements of the Act and of the Safety Case Guidelines. The ALARP demonstration will form a central part of the safety case or safety cases submitted by the petroleum undertaking under the Act.

The *ALARP Demonstration Guidance Document* is intended to reflect best international practice in this field. In preparing the ALARP Demonstration Guidance Document, the CER has drawn on guidance issued by statutory bodies regulating safety in the petroleum exploration and extraction industries in the UK and Australia. The CER may amend the *ALARP Demonstration Guidance Document* from time to time to take account of changes in national or international practice.

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[2] As defined in Section 13A(2) of the Act.
[3] A designated petroleum activity is a petroleum activity designated as such by the CER by regulation pursuant to Section 13D of the Act.
[4] As defined in Section 13A(1) of the Act.
[5] See Reference [1].

1.3 Structure of the Document

The *ALARP Demonstration Guidance Document* is divided into four further sections:

- **Legal Context** (Section 2), provides an overview of the legal context relevant to the application of the ALARP principle in Ireland;

- **The ALARP Principle and ALARP Demonstration** (Section 3), provides an overview of the ALARP principle and sets out the general requirements for ALARP demonstration under the Framework;

- **ALARP Assessment** (Section 4), provides guidance on how ALARP assessment is to be carried out by petroleum undertakings and how this is incorporated into an overall hazard management process which incorporates the ALARP principle; and

- **Risk Tolerability Limits** (Section 5), provides advisory guidance on the upper and lower individual and societal risk limits that petroleum undertakings will be expected to abide by.

2 Legal Context

Under the Act, petroleum undertakings are subject to a General Duty which requires them to ensure that:

a) any petroleum activity is carried on in such a manner as to reduce any risk to a level that is as low as is reasonably practicable, and
b) any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in a manner as to reduce any risk to a level that is as low as is reasonably practicable[6].

The concept of what is 'reasonably practicable' was considered by the Court of Appeal in the UK in the case of *Edwards v National Coal Board 1949*[7] where Asquith L.J. held:

> "*'Reasonably practicable' is a narrower term than 'physically possible', and seems to me to imply that a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them*"

The definition of "reasonably practicable" espoused in the *Edwards* case is followed in Ireland and was applied by the Supreme Court in the case of *Boyle v Marathon Petroleum (Irl) Ltd* 1999[8]. The Supreme Court, in dealing with the concept of "reasonably practicable", indicated that the approach involved three elements. First, the onus of proving that all that is reasonably practicable has been done lies on the duty holder; second, the duty is higher than the common law duty of care; and third, cost is not always to be a factor in determining whether "reasonably practicable" precautions have been taken but equally a balance has to be considered between the risk removed by a particular precaution and any risk created by the implementation of that measure.

The courts in Ireland have accepted the UK position that in applying the ALARP standard, a risk reduction measure must be adopted unless the sacrifice involved in implementing that measure is grossly disproportionate to the risk reduction gained. The ALARP principle arises from the fact that boundless time, effort and money could be spent in the attempt to reduce a risk to zero and some limit must be placed on how far a duty holder must go to discharge their duty and this limit is defined to be one of reasonable practicability. What is reasonably practicable in any given situation will be determined by the facts of the case.

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[6] Section 13K of the Act.
[7] See *Edwards v National Coal Board* [1949] 1.K.B. 704.
[8] See *Boyle v Marathon Petroleum (Irl) Ltd* [1999] 2 I.R. 460.

3 The ALARP Principle and ALARP Demonstration

3.1 Overview of ALARP Principle

The fundamental obligation placed upon petroleum undertakings under the Act is to reduce all risks to safety to a level that is as low as is reasonably practicable (ALARP). This obligation is based on the principle that those who create and have control over risks have responsibility for their management and must actively assess them in order to ensure that sufficient risk reduction measures are implemented such that the residual risk is ALARP. A key regulatory goal of the Framework is to ensure that petroleum undertakings fulfil this obligation.

The fundamental principle of risk-based hazard management is that whilst risks cannot always be completely eliminated, it should be possible to reduce them to a level that is ALARP, where they are tolerable to society because all reasonably practicable risk reduction measures have been implemented. The management of hazards such that the risk is ALARP needs to be demonstrated and in industries where there is a possibility of Major Accident Hazards, such as the petroleum exploration and extraction industry, the mechanism for such a demonstration is through a safety case.

Within the Framework, a petroleum undertaking's safety case must contain the petroleum undertaking's ALARP demonstration that all risks, including non-Major Accident Hazards, are reduced to a level that is ALARP.

The ALARP principle is illustrated in Figure 1. The triangle represents an increasing level of cumulative risk (all risks that a person, or population are exposed to) from a low risk situation in green at the base of the triangle to a high risk, red region at the top.

Figure 1 shows an upper risk level, the Upper Tolerability Limit, above which risks are intolerable and will only be permitted for exceptional reasons. Below the Upper Tolerability Limit, the risk is only tolerable if it is ALARP, which means that all reasonably practicable measures must have been identified and implemented. As introduced in Section 2, the term reasonably practicable indicates a narrower range than all physically possible risk reduction measures: if the cost of a risk reduction measure, whether in terms of money, time or trouble, can be demonstrated to be grossly disproportionate to the risk reduction gained from the measure, taking account of the likelihood and degree of harm presented by that risk, then it may not be required to adopt such a measure. Where the risk(s) in question are between the Upper and Lower Tolerability Limits in Figure 1, a detailed ALARP demonstration will be required. This must show that Good Practice has been followed and that all reasonably practicable measures have been implemented.

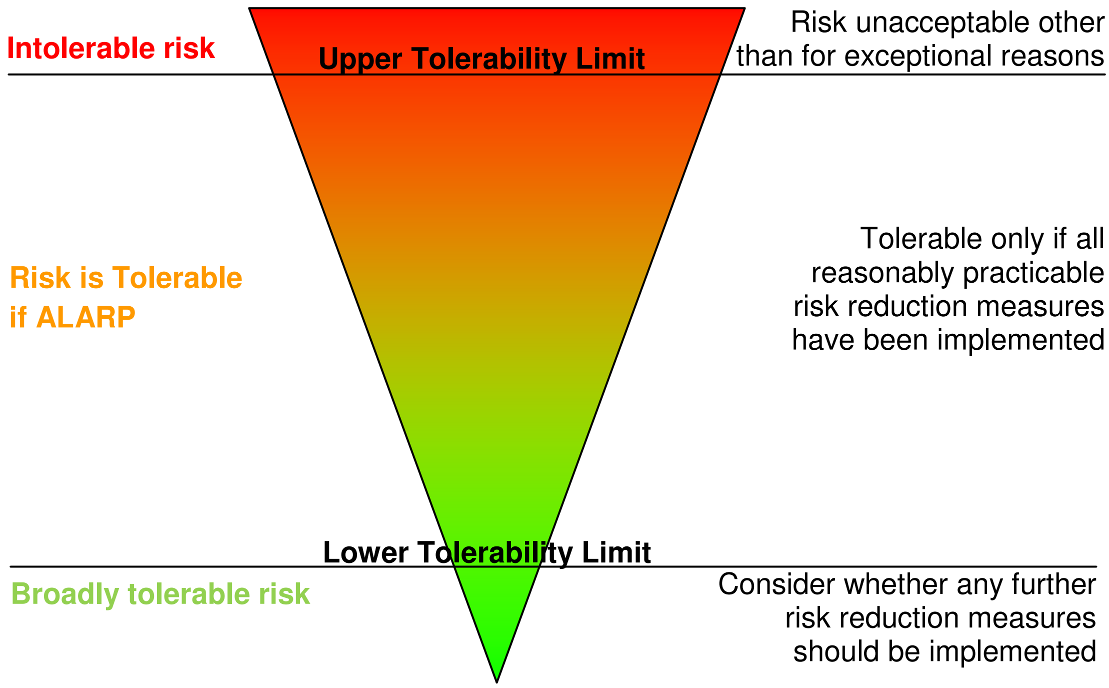

Figure 1: Schematic of the ALARP principle

Figure 1 also illustrates a lower risk limit (the Lower Tolerability Limit) below which the risks are broadly tolerable to society and comparable to everyday risks faced by the general public (denoted by the Broadly Tolerable Risk region in Figure 1). If the cumulative risk is below the Lower Tolerability Limit, the ALARP demonstration is likely to be straightforward. However although these risks are generally managed by the application of Good Practice, there is still the requirement to identify and implement any further reasonably practicable measures.

Values for the Risk Tolerability Limits and further guidance on them are given in Section 5.

3.2 ALARP Demonstration

A petroleum undertaking's safety case must demonstrate that all risks are reduced to a level that is ALARP. Specific requirements for the documented demonstration of ALARP within the different safety cases in the Framework are set out within the *Safety Case Guidelines*. However, there are a number of general requirements for an ALARP assessment and subsequent ALARP demonstration across all safety cases under the Framework.

1. The ALARP assessment carried out by petroleum undertakings must involve an overall hazard management process which incorporates the ALARP principle. The CER's expectations for such a process are outlined in Section 4. Petroleum undertakings should follow this process, or a process that achieves the same objectives. The processes used for ALARP assessment, including hazard identification, must be described in the ALARP demonstration.

2. The cumulative risk that persons are exposed to must be placed in the correct region on the ALARP diagram so as to invoke the correct assessment of the hazards that

are affecting those persons. Between the tolerability limits, a detailed ALARP demonstration is required to provide sufficient evidence that all reasonably practicable measures have been identified and implemented. Provided Good Practice has been followed (and is duly evidenced), where the cost of further risk reduction measures is grossly disproportionate to the safety benefit achieved, such further measures can be rejected. The ALARP demonstration for cumulative risks below the Lower Tolerability Limit will often be met by demonstration of adherence with Good Practice.

3. As well as describing the measures that have been implemented, an ALARP demonstration needs to describe those measures that have not been implemented and the reasons for this. This is especially important where circumstances or hazards change, as previously discarded measures might need to be implemented to maintain the risk ALARP.

4. It is expected that the group of persons involved in the ALARP assessment process will have competency as a group in:
   - The operation or design of the plant in relation to the hazard and activity being considered;
   - The risk reduction measures; and
   - Hazard identification, risk and ALARP assessment.

   The hazard identification, risk assessment and ALARP assessment processes should be undertaken by competent professionals and, where appropriate, for example, in relation to hazard identification and identification of risk reduction measures, as a team activity.

As stated in Section 1, it is the responsibility of the petroleum undertaking to decide how best to demonstrate in its safety case that the risks from their activities are ALARP. The CER will assess whether it considers the demonstration to be adequate or whether additional information / assurances are required.

4 ALARP Assessment

4.1 Overview

The ALARP assessment carried out by a petroleum undertaking involves applying an overall hazard identification and risk management process, which incorporates the ALARP principle. This section describes the CER's expectations of such a process. This process, or a process that achieves the same objectives should be followed. Figure 2 is a schematic overview of the process, which has the following steps:

1. A comprehensive identification of all hazards associated with the activities of the petroleum undertaking including specific identification of Major Accident Hazards (Section 4.2);

2. Where Good Practice exists, this or its equivalent must be implemented (Section 4.3);

3. If there is a risk of a Major Accident Hazard:
   a) A quantitative evaluation of the cumulative risk to the person(s) with specific evaluation of the Major Accident Hazard(s) is carried out
      - In circumstances where the risk of an identified Major Accident Hazard cannot be evaluated with sufficient certainty to be reliably compared with the Risk Tolerability Limits, recourse is made to the precautionary principle (see Section 4.5.8);
      - If the risk can be evaluated with sufficient certainty, follow the next step.

   b) Compare the cumulative risk from all hazards that the person(s) is exposed to against the Upper Tolerability Limit (see Section 4.4)
      - If the cumulative risk from all hazards is intolerable, the activity is not permitted except for exceptional reasons and so risk reduction measures must be implemented regardless of whether they are reasonably practicable or not until the risk is below the Upper Tolerability Limit. Once this has been achieved, the assessment carries on as for risks that are initially below the Upper Tolerability Limit.
      - If the cumulative risk is below the Lower Tolerability Limit, the assessment proceeds as for the case where there are no major hazards (4 below), following from (2) above where Good Practice needs to be met.

   c) Identify all physically possible risk reduction measures (Section 4.2.3) and
      - Implement the measure unless it is demonstrated and documented that it is not reasonably practicable to do so (Section 4.5).
      - If the safety benefit of a risk reduction measure cannot be evaluated with sufficient certainty to determine if it is reasonably practicable, recourse is made to the precautionary principle (see Section 4.5.8).

4. If the person(s) cannot be affected by a Major Accident Hazard, or the risk is below the Lower Tolerability Limit:
   i. Identify any further risk reduction measures that could be implemented; and
   ii. Consider whether any of these risk reduction measures should be implemented.

5. Ensure that all risks continue to be ALARP throughout the lifecycle of the infrastructure/activity (See Section 4.6) by periodic review of the above process.

It is the responsibility of the petroleum undertaking to decide how best to demonstrate that the risk from their activities is ALARP. The CER will assess whether they consider the demonstration to be adequate or not given the full array of information provided.

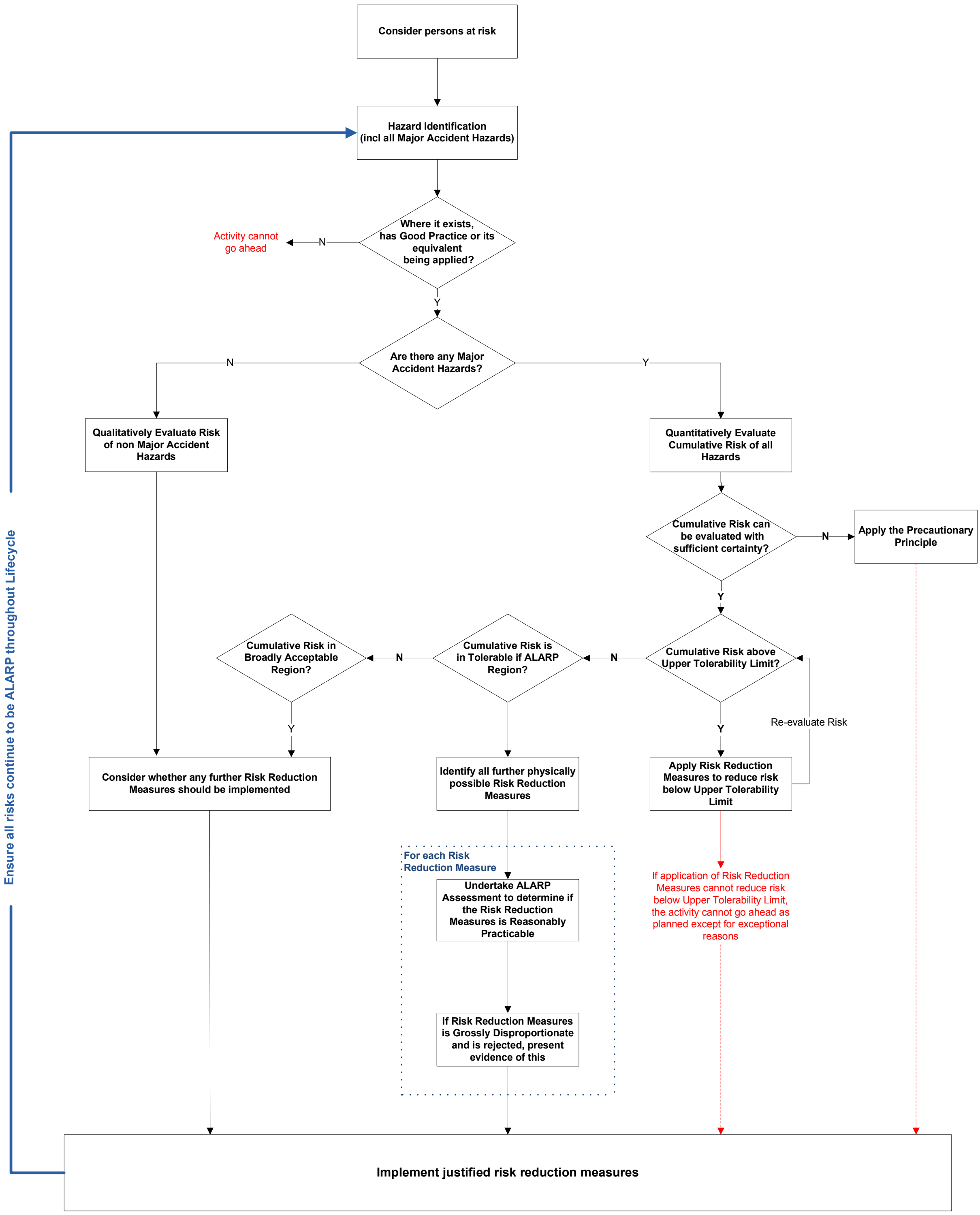

Figure 2: Hazard management process incorporating the ALARP principle

4.2 Hazard and Risk Reduction Measures Identification

4.2.1 Hazard Identification

The first stage in the hazard identification and risk management process is the comprehensive identification of hazards that could have an immediate or long term safety impact to people. The identified hazards are then fed into the ALARP assessment.

Hazard identification is usually a brainstorming workshop process undertaken by a group of skilled and experienced people with knowledge of the particular site, project and/or activities being undertaken. Most hazard identification techniques involve a team approach, since an individual generally cannot have the depth of experience and expertise on all aspects of the site, activity and hazards, and group interactions are more likely to stimulate consideration of hazards that even well-informed individuals might overlook. Operational staff who will be exposed to the hazards can make a valuable contribution to the hazard identification process.

Hazards and their causes are diverse, and many different methods are available for hazard identification. The hazard identification methodology should be chosen to match the situation, activity and hazards that are being considered and information appropriate for the technique must be available. It may be a standard technique, following an established protocol, a modification of one, or a combination of several[9].

Hazard identification requires careful consideration of the ways in which an activity could fail and create a hazard to persons. In all cases the key requirement is for careful consideration of the faults that may occur, which may include:

- **Persons:** Accidental or intended human intervention with unintended consequences;
- **Procedures:** Incorrect procedures leading to an error; and
- **Plant:** Mechanical failure due to factors such as corrosion.

When considering how a hazard may occur, it is not sufficient to just consider the direct past experience of the persons undertaking the hazard identification, or experience of the activity, or site being considered. Every effort must be made to think how failures might occur, identify their causes, potential consequences and the risk reduction measures that are needed to remove or reduce the risk from these failures. The risk reduction measures can either lower the possibility of the hazard occurring or its consequences, or both.

Hazard identification must be managed in a formal process with accurate recording of the scope and the outcome of the process. Defining the scope of the hazard identification is important as it must be clear that the identification process(es) cover the totality of the activity being considered, otherwise the full range hazards associated with it may not be identified. In addition, the information that is provided to the hazard identification team must be accurate and up-to-date.

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[9] For source see Reference [7].

4.2.2 Major Accident Hazard Identification

In the hazard identification process, all Major Accident Hazards should be specifically identified. As illustrated in the diagram below[10], these hazards have a low frequency, but high consequence, making them more difficult to manage. For this reason, they are a particular focus of the Framework and ALARP assessment.

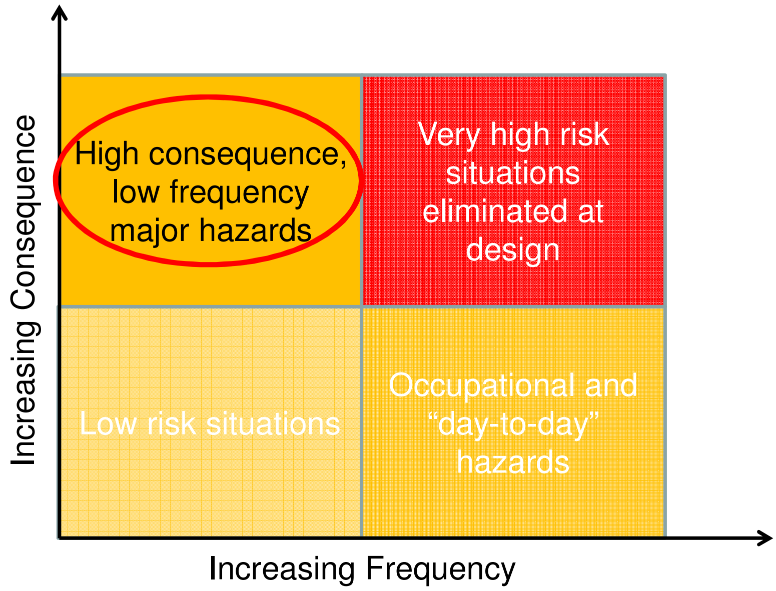

Figure 3: Schematic of different classes of hazard

The hazard identification process becomes more critical as the complexity of the activity increases. For well understood activities with little complexity, the hazards have often already been identified and the risk reduction measures needed to manage these hazards will be detailed in appropriate codes and standards. A more complex activity will require the hazards associated with all component parts of the activity and, for example, interactions between different equipment items to be identified and the associated risks assessed.

4.2.3 Risk Reduction Measures

As part of the hazard identification process, risk reduction measures already implemented need to be identified such that the residual risk can be assessed. In addition, all physically possible risk reduction measures need to be identified such that those that are deemed reasonably practicable can be implemented. Identification of risk reduction measures is often best carried out at the same as hazard identification and the guidance for hazard identification also applies to risk reduction measure identification.

This process should typically identify risk reduction measures that are new, or are improvements to existing measures already installed, either in terms of equipment, improved maintenance, or operations.

[10] For source see Reference [7].

4.3 Good Practice

For all identified hazards, the adoption of available Good Practice or its equivalent is the first requirement in the hazard management process. Therefore, the initial stage in determining whether a risk is ALARP is to determine whether Good Practice or its equivalent is being met.

4.3.1 What do we mean by Good Practice?

Good Practice is defined to be:

> *The recognised risk management practices and measures that are used by competent organisations to manage well-understood hazards arising from their activities*.

These methods are found in a variety of forms including:

- Guidance or codes of practice from national regulators;
- Standards from standards-making organisations (e.g. NSAI);
- Guidance produced by a body such as a professional institution or trade federation representing an industrial or occupational sector; and
- Lessons learned from previous accidents, not yet incorporated into standards, but accepted as an improvement.

Good Practice also requires that the management of hazards is considered in a hierarchy, with the concept being that it is inherently safer to eliminate a hazard than manage its consequences or reduce its frequency. Therefore, the hazard management process must adhere to the following hierarchical approach to risk reduction, with measures that are classed in the categories at the top of the list preferred to those below.

Elimination:	Complete removal of a hazard;
Substitution:	Replacement of one part of an activity, process or design by another that is inherently less hazardous;
Control:	A system that controls a hazard so that the consequences are minimised or removed;
Mitigation:	Action taken or systems that reduce the consequences of a hazard; and
Emergency Response:	Risk reduction through action such as removal of persons from the place of danger or use of personal protective equipment such as smoke hoods, immersion suits and fireproof gloves.

This means that elimination of a hazard should be considered before substitution, control, mitigation, and emergency response in that order.

4.3.2 Applying Good Practice as part of an ALARP Assessment

1. Good Practice in the management of hazards should be considered in the hierarchy set out in Section 4.3.1.

2. Good Practice evolves as knowledge and experience improves over time, and it is **current** Good Practice that forms the basis of an ALARP demonstration. This affects the assessment of ALARP in three ways:
    a. Codes and standards that are current and relevant to the activity being considered must be used for new designs, or activities;
    b. If there is a choice of codes, a justification as to why the selected code is the most appropriate is needed; and
    c. If a code or standard is updated such that an existing activity has a safety critical deficiency with respect to the new code, there is a need to assess whether it is reasonably practicable to make changes in order to meet the new code.

3. In assessing Good Practice, it is important to consider whether all aspects of an activity are covered by Good Practice. It may be possible for each individual aspect of an activity or design to be covered by a prescriptive code that defines Good Practice, but no guidance given for the sum of all of them. In this case, an ALARP assessment must be undertaken for the totality of the activities.

4. If Good Practice is defined by a number of risk reduction measures for a particular hazard (or activity or design etc), Good Practice can either be achieved by adherence to them, or implementing equivalent measures that reduce the risk from the hazard to at least the same degree.

5. Some codes and standards are risk-based and therefore do not give an absolute test of Good Practice. However the methodology in the code, or standard should be followed as long as it complies with the remainder of this guidance.

Where Good Practice exists, activities that do not meet it, or an equivalent, will <u>not</u> be approved by the CER.

4.4 Comparison of Risks against Tolerability Criteria

4.4.1 Overview

If person(s) are exposed to a Major Accident Hazard, the cumulative risk to them must be evaluated using quantitative risk assessment[11] to allow explicit comparison with the Risk Tolerability Limits and to enable the appropriate assessment of whether the risk is ALARP according to:

- If the risk is intolerable (above the Upper Tolerability Limit), risk reduction measures must be implemented, regardless of whether they are reasonably practicable, until the risk drops below the Upper Tolerability Limit, except where

[11] See Section 4.5.6 for high level guidance on quantitative risk assessment.

there are exceptional reasons.

- If the risk is between the Risk Tolerability Limits, a detailed ALARP demonstration is required to provide sufficient evidence that all reasonably practicable measures have been identified and implemented and only those measures where the costs are grossly disproportionate to the safety benefit provided have been rejected.
- If the risk is below the Lower Tolerability Limit a less detailed process is needed to demonstrate that the risk is ALARP (see Section 4.5.2.2).

A similar risk evaluation process is not required for persons that are only exposed to non-Major Accident Hazards, but it must be shown that the risk does not threaten the Upper Tolerability Limit by, for example, showing adherence to Good Practice and direct reference to historical data for the activity.

4.4.2 Assessment Guidance

When considering the societal risk criteria (see Section 5.3), which are applicable to the public only (i.e. not workers), all Major Accident Hazards must be included in the assessment, which means that if two or more designated petroleum activities can affect the same public population, the cumulative risk from these sources should be evaluated and compared against the Risk Tolerability Limits.

For risk to workers, non-major hazards (e.g. occupational hazards) have to be included in the cumulative risk calculation in addition to all Major Accident Hazards, though less is expected in the assessment of such risks compared to Major Accident Hazards.

The risk criteria are for fatalities and the risk assessment must calculate the fatalities that may occur as a result of the hazards. A conservative approach should be taken in the use of harm criteria to calculate fatalities.

For some activities with the potential for Major Accident Hazards, the risk may be well understood. For example, a pipeline built to a specific code for which the maximum risk (of building to the limit of the code) is known. If this risk is known to be below the Upper Tolerability Limit, this calculation does not need to be repeated to show this for the particular pipeline, as long as it meets <u>all</u> aspects of the relevant code. Compliance with such a pipeline code is also Good Practice and, if it is know that no other risk reduction measures are reasonably practicable, this will also demonstrate ALARP.

If the risk of the activity cannot be evaluated with sufficient certainty to be reliably compared with the Risk Tolerability Limits, recourse is made to the precautionary principle (see Section 4.5.8).

To assess a particular activity against the tolerability criteria, the evaluation needs to encompass the *entire risk that persons are exposed to*. In many cases this will be the same as the risk from the activity under consideration, but in some cases (for example, where persons may be exposed to risks from a variety of activities from different or adjacent sources), these will need to be aggregated to determine the aggregate risk exposure.

Similarly, even if the risk from each one of a large number of different hazards is small, the cumulative risk may be above the Upper Tolerability Limit and so needs to be carefully evaluated.

For a situation where an activity is itself low risk, but where the cumulative risk to the person(s) from all sources is not necessarily low (for example carrying out domestic maintenance in the accommodation of an offshore platform), the cumulative risk will need to be assessed using Quantitative Risk Assessment (QRA), but the determination of risk reduction measures for the simple task (domestic maintenance) will itself be straightforward and can follow the guidance for broadly acceptable risks below. However, there is the potential for the simple task to be affected by the higher risk activities and so the hazard identification undertaken as the foundation of the ALARP demonstration must be comprehensive and robust to identify any such interaction.

4.5 Determining what is Reasonably Practicable

4.5.1 Introduction

The following sections provide guidance on how a petroleum undertaking should determine and demonstrate whether it is reasonably practicable to implement a risk reduction measure. The approach needed will vary according to the hazard, risks and risk reduction measure being considered. It is always the responsibility of the petroleum undertaking to determine the correct methodology to make this judgement.

In order of increasing complexity, the approaches that are described are:

- **Engineering judgement**, whereby previous applicable experience is used in conjunction with other tools;
- **Qualitative risk assessment**, in which frequency, severity and risk are qualitatively determined;
- **Semi-quantitative risk assessment**, in which frequency, severity and risk are approximately quantified within ranges; and
- **Quantitative risk assessment**, in which full quantification of the risk occurs.

The above list provides a hierarchy of approaches with the top two approaches generally being more amenable where the implications of the decision on whether to implement the corresponding risk reduction measure are relatively low, or the situation is well-understood, or the risk is broadly tolerable as described in Section 4.5.2.2.

If the decision is made to implement a risk reduction measure as opposed to not implementing it, the justification of this does not need to be included in the ALARP demonstration as the critical decisions which do require justification are those where a risk reduction measure is <u>not</u> implemented.

The test of whether the cost of implementing a measure is grossly disproportionate to the cost of the risk reduction benefit will require to be considered for each circumstance in which a petroleum undertaking asserts that it is not reasonably practicable for a particular measure to be implemented.

Figure 4 outlines this hierarchy with three illustrative categories of risk reduction measures positioned to indicate the technique that is likely to be applicable to them.

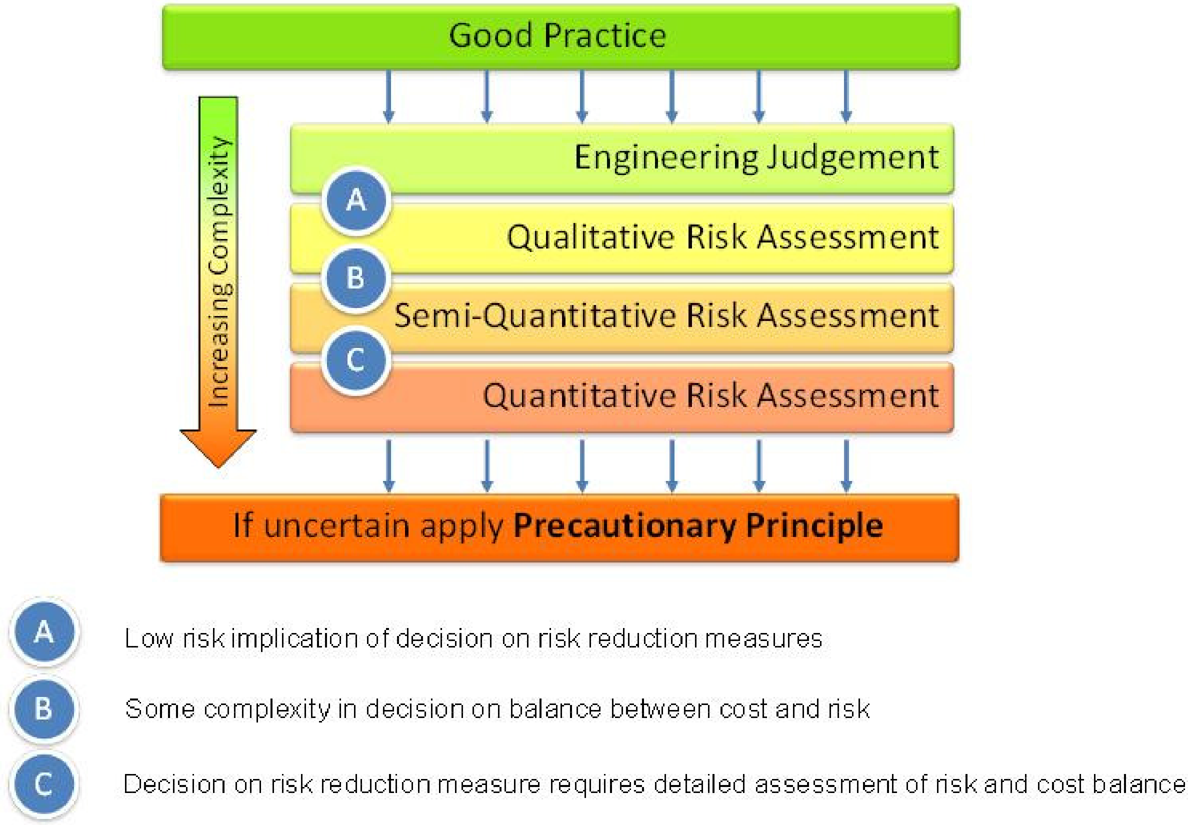

Figure 4: Schematic of methods to determine reasonable practicability

Petroleum undertakings can determine the reasonable practicability of a risk reduction measure using any of the above methods. However, whatever technique is used to determine whether or not to implement a particular risk reduction measure, it must provide confidence that a decision not to implement it, or to implement a measure that does not give as a high a risk reduction as another measure, can be made with sufficient certainty that the risk is reduced to a level that is ALARP. If a particular technique does not give sufficient certainty, a more sophisticated technique should be used. If no technique can give sufficient certainty in the decision not to install a risk reduction measure, the precautionary principle should be invoked.

Guidance on each of the different approaches in assessing reasonable practicability is set out in sections 4.5.3 to 4.5.6.

4.5.2 General Guidance

4.5.2.1 Ranking of Risk Reduction Measures

All of the approaches outlined in the following sections can be used to determine whether or not it is reasonably practicable to implement a particular risk reduction measure as long as the technique is sophisticated enough to give sufficient certainty in the result. Additionally, the techniques may be used to rank risk reduction measures so that, combined with costing information, the most effective risk reduction measures can be identified and implemented.

The process used to define a ranking must be sufficiently robust so that any decisions that are dependent on the ranking achieve sufficient certainty. For example, if a semi-quantitative process is used to rank risk reduction measures (potentially with cost information), this process needs to be sufficiently robust such that a decision not to implement any particular risk reduction measure, or implement a risk reduction measure that gives a lower risk reduction than another measure, is made with sufficient certainty that the outcome achieves reduction of the risk to a level that is ALARP. The method used must allow any 'cut-off point' below which measures are not implemented to be well enough defined such that there is a robust justification for all measures not implemented.

In the case of ranking risk reduction measures that have a variety of costs and risk reduction benefits, quantified risk assessment can be used if appropriate data is available, but less sophisticated tools can only be used if the differences in cost or risk are so large as to make the comparison certain. Thus, in the sections below, cost benefit analysis is described in the context of QRA; the application of other techniques is only possible for large and clear differences in costs or risk between different risk reduction options (or the option of not implementing a measure).

In summary, if risk reduction measures, potentially with cost information, are ranked, this process needs to apply the same rigour as decisions on individual risk reduction measures, with the diagram in Figure 4 also being applicable.

4.5.2.2 Broadly Tolerable Risk

In the case where persons are not exposed to a Major Accident Hazard, or the risk is below the Lower Tolerability Limit, meeting Good Practice where available will generally achieve the reduction of risk to a level that is ALARP. In this case, the petroleum undertaking still needs to be vigilant in considering whether Good Practice is improving and relevant, or whether there are any additional hazards present which need to be considered. This means that further risk reduction measures should be identified and considered. In considering the risk reduction measures required to reduce broadly tolerable cumulative risk or the risk from non-major hazards to a level that is ALARP, the assessment of what may be grossly disproportionate in relation to the risk reduction measures proposed and the safety benefits achieved will take account of the level of risk identified. This does not mean that a petroleum undertaking should not implement measures that are of low cost and provide a clear risk reduction. The petroleum undertaking still has to go through a process of hazard identification and risk assessment in order to carry out this process.

Due to the relatively low risk associated with broadly tolerable risks, it is unlikely that the more complex assessment techniques outlined below will be required to determine whether a risk reduction measure should be implemented or not. It is likely that a simple technique such as engineering judgement, qualitative risk assessment or a simplified, but conservative, quantitative analysis can be used to assess the risks and determine whether the cost of a risk reduction measure is grossly disproportionate to its safety benefit or not.

4.5.3 Engineering Judgement

A particular aspect of a proposed activity or design may be such that Good Practice cannot be directly applied, does not exist, or there are variables or complexities that do not allow any clear definition of Good Practice. For example, the precise location of escape routes on an offshore platform is not defined in Good Practice.

In these circumstances, the first approach can be to conduct high-level[12] engineering analysis and assessment, without using risk assessment techniques, in order to assess potential means of managing the hazards. This would generally require a good understanding of the mechanisms that might lead to the realisation of the hazard and the potential consequences and is broadly termed "engineering judgement". Within this process, the selection of analysis and assessment methods and interpretation of the results relies on the assessor's experience of similar situations and knowledge of the hazards and associated risk reduction measures.

As activities become more complex, recourse to engineering judgement may not be sufficient or possible as the combination of factors can be complex and the nature of the hazards outside the experience of the persons whose engineering judgement is being sought. Engineering judgement cannot then be relied upon and qualitative, semi-quantitative or quantitative risk assessment should be used.

4.5.4 Qualitative Risk Analysis

4.5.4.1 The Technique

Qualitative risk analysis is a method of evaluating risks without assigning any absolute values to the consequence, frequency, or risk. Consequence and frequency are typically assigned into bands described as, for example, very low, low, medium, or high. The overall risk then varies from very high (when both consequence and probability are high) to very low (when both are low).

The technique splits frequency, consequence and risk into a relatively small number of discrete bands, which are not assigned numerical values, and so the accuracy of the technique is limited and it should not be used to make many of the decisions that are key to an ALARP demonstration for Major Accident Hazards.

4.5.4.2 Assessing Risk Reduction Measures

The technique is most suitable for risk assessment of operational tasks in connection with the General Duty to maintain the risk from non-Major Accident Hazards ALARP. However, even in this case, the qualitative nature of the tool and coarseness of assessment means that it can only be used to assess well-understood hazards with well-understood safeguards.

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[12] Note that a detailed consequence analysis could be undertaken to assess whether to implement a risk reduction measure without the need to refer to frequency and hence risk data. This is an inherently more conservative type of assessment than risk assessment. Such an analysis using high-level consequence information is described here under engineering judgement, though there is of course a continuum of techniques from the less to the more sophisticated.

4.5.5 Semi-quantitative Risk Analysis

4.5.5.1 The Technique

Semi-quantitative risk analysis is similar to qualitative risk analysis, but with the addition of numerical bandings of consequence and frequency, which are combined together to give a risk banding. There are a number of standard methodologies for this approach, including a risk matrix and layers of protection analysis. Each of these techniques uses numerical bands (often orders of magnitude) to describe frequencies and consequences associated with the hazard being considered and define one of a number of risk bands to each combination of frequency and consequence. It provides a more sophisticated basis for assessing risk reduction measures than qualitative risk analysis, but is less accurate than quantitative risk assessment.

For semi-quantitative risk analysis to be used as part of an ALARP demonstration, the numerical bands that are used in the technique must be well defined. Possible ways to quantify the bands for the frequency side of the risk assessment include bands for events likely to occur include measures such as:

- Every N years, where N varies between the bands;
- Once in a site's lifetime; or
- Once each year in the worldwide oil and gas industry.

Whatever bandings are chosen they must be well-defined and not open to interpretation by the persons undertaking the risk assessment.

In order to be used successfully, the frequency, consequence and risk banding must have sufficient resolution to allow for an ALARP demonstration for the full range of scenarios intended to be covered by the technique. The frequency of a Major Accident Hazard should be many orders of magnitude less than the frequency of a lost time injury and if both types of hazard are covered by the same matrix, multiple frequency bandings will be required. It is unlikely that the technique can be used successfully if a frequency band covers more than an order of magnitude in terms of years between events.

Equally, the consequence bandings must be well-defined, with sufficient resolution for the decision that is being made using the technique. There may be many cases where the consequences (or frequency) are reduced, but the banding and hence risk does not change, or where one of two risk reduction measures shows a decrease in risk banding whereas the other risk reduction measure may actually give the larger risk reduction. These limitations need to be considered when making decisions using the technique.

The definition of the risk bandings used must also be well thought through and consistent such that a particular risk reduction measure is not favoured solely due to a particular choice of risk banding resulting from the combination of frequency and consequence.

In assessing risks using this technique, the potential for a number of different scenarios to arise from the same hazard should be considered. The most likely outcome rarely corresponds to the highest consequence outcome and therefore, before the assessment is undertaken, it may not be obvious which is the highest risk scenario. In this case, a number of scenarios must be assessed in order to find the highest risk. However, the assessment must avoid the potential for “salami slicing” of the risk picture, whereby too many scenarios are used with the risk from each one being low, but the overall risk being higher. If a large number of scenarios (say greater than six) are needed to either well-define the highest risk event, highest frequency or consequence event or differentiate between the cases being considered (with and without a risk reduction measure in place), then the technique is at the limits of its applicability and it points towards the need for a more sophisticated quantitative risk assessment. Semi-quantitative risk assessment cannot be used for cumulative risks where the total risk arises from many different hazards unless there is no interaction between the hazards. However, it can be used as a screening tool to identify those hazards or risk reduction measures that need to be considered for more detailed analysis and in this case, the risk ranking guidance applies.

4.5.5.2 Assessing Risk Reduction Measures

To use semi-quantitative risk assessment to assess whether a single risk reduction measure needs to be implemented for the risk to be ALARP, calibration of the technique needs to have been undertaken beforehand such that the cost of a risk reduction measure that constitutes gross disproportion for a particular reduction in risk is known.

The approach can also be used to determine which of two risk reduction measures should be implemented (if it is physically not possible to implement them both), if the difference in risk reduction between them clearly favours the one with a lower cost (i.e. the more expensive measure actually gives less risk reduction). If the measure providing a greater risk reduction also costs more, the comparison may not be as clear and if insufficient certainty can be gained from the semi-quantitative assessment, quantitative risk assessment may be needed to determine which one to implement.

The introduction of some quantification in assessing ALARP means that more complex scenarios can be assessed and the decision basis is more transparent. If qualitative risk analysis is unable to distinguish the risk difference between two scenarios (generally one with and one without a particular risk reduction measure), semi-quantitative risk analysis may be able to do this. If semi-quantitative risk analysis cannot differentiate between them, then quantitative risk analysis may be able to show the difference.. However, where the potential consequences are more severe, or there is a need to assess the combined risk from many hazards, then semi-quantitative risk analysis is unlikely to be appropriate.

4.5.6 Quantitative Risk Analysis and Cost Benefit Analysis

QRA is required to be carried out if person(s) are exposed to Major Accident Hazards in order to determine the cumulative risk they are exposed to in order to compare risk levels with quantified Risk Tolerability Limits. The detail required in the QRA must be such that the cumulative risk is calculated with sufficient certainty to initiate the correct type of ALARP assessment. Further detail on QRA is given in the *Safety Case Guidelines*.

Quantitative Risk Analysis (QRA) can also be used to calculate a numerical value for the risk reduction achieved by a risk reduction measure and, with cost benefit analysis, to determine whether it is reasonably practicable to implement or not.

4.5.6.1 The QRA Technique

In a quantitative risk assessment, the frequency and consequence of a hazard are assessed in detail over the range of hazardous scenarios that can occur in order to ascribe numerical values to each, allowing a numerical value of risk to be calculated. QRA will typically consider the development of any hazardous scenario in detail, with the frequency and consequences of many outcomes being evaluated. It therefore provides a much more detailed picture of the associated risks allowing for the difference in safety benefits between different risk reduction measures to be assessed more accurately as long as appropriate data sources are available.

The level of detail required in the assessment will vary between hazards. Risks that do not contribute significantly to the cumulative risk and for which decisions on risk reduction measure are not based on QRA may be assessed more conservatively and in less detail than higher risk hazards. The risk assessment should be commensurate with the complexity and risk of the hazard and so, for example, for occupational hazards, may just refer to generic data for the broad type of activity being undertaken.

To use QRA to determine whether a measure should be implemented, the QRA process must be rigorous, robust and transparent. As far as possible, the frequency of the event should be calculated from a basis of historical data that is modified for the actual situation being considered, or combined with other relevant probabilistic data. The consequences of each potential outcome are then analysed, often using some form of mathematical model, to determine the risks associated with the event.

The quality of the modelling and the input data will affect the accuracy of the numerical estimate and so the uncertainties associated with the QRA must always be borne in mind in hazard management decisions.

In order that the risk assessment models the situation at hand, rather than a hypothetical, or idealised situation, it must encompass engineering and operational understanding of the hazard being modelled.

Where significant decisions are required with regard to major hazards, the QRA must be subject to *sensitivity analysis* to gauge the potential for plausible changes in basic assumptions, or, for example, a foreseeable change in working pattern, to invalidate the conclusions and decisions taken from the risk analysis.

4.5.6.2 Assessing Risk Reduction Measures

The benefit provided by a risk reduction measure is the difference between the risk calculated with and without the risk reduction measure in place. The risk benefit per unit cost can then be determined in order to rank the risk reduction measure. This ranking allows the most preferential risk reduction measures to be identified, but, apart from those for which the cost is clearly grossly disproportionate to the risk benefit, it does not identify the cut-off point in the ranking below which measures are grossly disproportionate. To do this, the assessment process needs to use cost benefit analysis.

4.5.6.3 Assessing Risk Reduction Measures through Cost Benefit Analysis

Cost benefit analysis (CBA) is the numerical assessment of the cost of implementing a particular risk reduction measure, such as a design change or modification and the comparison with the likely risk reduction that this would be expected to achieve.

The way that this is done is to:

(1) Calculate the Implied Cost of Averting a Fatality (ICAF) for the risk reduction measure, which is the cost of the risk reduction measure divided by the risk reduction achieved (the reduction in Potential Loss of Life over the lifetime of the risk reduction measure) and

(2) Compare this to a Defined ICAF criterion.

A risk reduction measure will then be reasonably practicable to implement unless the calculated ICAF is grossly disproportionate to the Defined ICAF. Lower ICAF values are less likely to be grossly disproportionate and therefore the corresponding risk reduction measures more likely to be implemented because of lower costs, or greater risk reduction.

The Potential Loss of Life is defined to be the sum across all hazardous events and scenarios being considered of the average annual fatalities, where the average is calculated as the annual frequency of an event multiplied by the number of fatalities resulting from it.

In order for CBA to be used as part of the demonstration of reasonable practicability, a Defined ICAF value of at least **€2,400,000** is advised (at 2013 prices and index-linked). An explanation as to why this figure is advised is given in Appendix B. However, in using this figure a range of factors, including sensitivity and uncertainty, need to be taken into account in the decision making process. Ultimately, it is for the petroleum undertaking to determine the measures required to reduce the risk to a level that is ALARP and that a decision not to implement a particular measure on the grounds that the cost is grossly disproportionate to the achieved safety benefits (and therefore not reasonably practicable), takes account of all relevant factors and circumstances.

4.5.6.4 Gross Disproportion Factor

In order for CBA to be used as part of the demonstration of why the implementation cost of a risk reduction measure is grossly disproportionate to the safety benefit it delivers, a Gross Disproportion Factor must be shown between the calculated and defined ICAF (effectively the cost and the safety benefit). A factor of at least two is required and a robust justification will be required for any value less than ten. An explanation of why these figures are advised is given in Appendix C. Thus, if the difference between the calculated and defined ICAF is less than this factor, gross disproportion is not normally shown and the risk reduction measure will require to be implemented.

4.5.7 Guidance on General Issues relevant to assessing Reasonable Practicability

4.5.7.1 Range of Consequences to be Considered

If a hazard is realised, the consequences that develop will vary depending on the details of the event, environmental conditions and the reaction of persons and safety systems. Due to the large number of possible outcomes, it is appropriate to model a reduced range of consequences in the ALARP assessment and if this is done, consequences that at least cover the worst-case credible and most likely events need to be modelled. In modelling different scenarios, it must be ensured that the total frequency of the hazardous event is accounted for.

Alternatively, just the worst-case credible consequences could be modelled assuming that every time the hazard is realised it leads to this worst-case. Being a conservative assessment, this approach will be more likely to lead to the conclusion that a risk reduction measure should be implemented.

Assessments should adequately justify that the selected scenarios conservatively represent the spectrum of scenarios that could occur.

4.5.7.2 Cost of the Risk Reduction Measure

The cost of the measure, against which the risk reduction is being compared, should be restricted to those costs that are solely required for the measure. Realistic costs should be used so that, for example, the measure is not over engineered to derive a large cost, distorting the comparison to conclude that it would be grossly disproportionate to implement.

If the cost of implementing a risk reduction measure is primarily lost or deferred production, the ALARP assessment should be undertaken for the two cases where lost or deferred production is and is not accounted for. If the decision is dependent on the additional cost of the lost or deferred production (i.e. the risk reduction measure would be installed without considering this cost), a highly robust and thorough argument as to why the measure could not be installed while losing less production (e.g. at a shutdown) will be required if the measure is to be rejected.

If the lost production is actually deferred production (i.e. the life of the equipment is based on operating rather than calendar time), then the lost production should only take account of lost monetary interest on the lost production plus allowance for operational costs during the implementation time, or potential increase in operational costs at the end of life.

If shortly after a design is frozen, or constructed, a risk reduction measure is identified that normally would have been implemented as part of a good design process, but has not been, it would normally be expected that the measure, or one that provides a similar risk reduction, is implemented. An argument of grossly disproportionate correction costs cannot be used to justify an incorrect design.

4.5.7.3 Remaining Lifetime

In determining whether it is reasonably practicable to implement a particular risk reduction measure, the remaining lifetime of the petroleum infrastructure is relevant in the analysis. This is immediately apparent in a cost benefit analysis if the cost of the risk reduction measure is mainly a capital cost since the aggregate risk reduction will rise as the remaining lifetime increases whilst the costs remain roughly constant. Thus a risk reduction measure will generally increase in reasonable practicability as the petroleum infrastructure lifetime increases.

If the cost of a risk reduction measure is assessed to be in gross disproportion to the safety benefit it provides and it is not implemented because of a short remaining lifetime, it is expected that supporting analysis will be carried out for a number of different remaining lifetimes due to the inherent uncertainty in such a figure. The justification for a non-implementation decision that is dependent on a short lifetime assumption would have to be extremely robust.

Over the lifecycle, improvements in Good Practice may occur that address safety critical deficiencies and, if implemented, would give reduced risks. It is recognised that the cost of modifying an existing activity or design may be grossly disproportionate to the safety benefit gained and so an ALARP assessment is appropriate to inform the decision on whether to implement the new risk reduction measures that are required to address the safety critical deficiencies. In this assessment, it is appropriate to consider the remaining life of the petroleum infrastructure, although any ALARP assessment where a risk reduction measure is not implemented due to a short remaining life will have to be robust and also subject to sensitivity analysis around the remaining life.

4.5.7.4 Differing Results

The situation where a petroleum undertaking is evaluating the results of one assessment tool (of those described above) against the opposing results of another should not be allowed to arise. In an example where the use of qualitative risk analysis concludes that a risk reduction measure is not required, but a quantitative risk assessment concludes that it is, if the techniques had been applied correctly, the conclusion should have been that the qualitative risk analysis was not a sophisticated enough technique to assess the risk reduction measure in question. The relative results and merits of the two approaches should not be balanced against each other – the petroleum undertaking should assess which approach gives a result with sufficient certainty on which to base a conclusion.

4.5.7.5 Avoidance of Reverse ALARP

An argument could be constructed that, for a reason such as the short remaining lifetime, the re-instatement cost of a previously functioning risk reduction measure is grossly disproportionate to the safety benefit that it achieves. This is commonly called *reverse ALARP*. In this case, the test of Good Practice must still be met and, since the risk reduction measure was initially installed, it is Good Practice to reinstall or repair it. Reverse ALARP arguments will not be accepted in an ALARP demonstration.

This does not prevent a suitably justified decision not to re-instate a risk reduction measure if the original reason for having the risk reduction measure has changed due to, for example, a hazard having been eliminated.

4.5.8 The Precautionary Principle

While there can be an element of uncertainty in the assessment of the risk of a petroleum activity, the approach adopted should be such that there is sufficient certainty that the results are at least representative, if not conservative, for the activities being considered. It is for the petroleum undertaking to demonstrate this in their analysis. Where there is reason to believe that serious danger could exist, but the scientific evidence is insufficient, inconclusive or uncertain regarding the risk, then the petroleum undertaking is expected to apply the precautionary principle. In applying the precautionary principle, it is expected that a cautious approach is adopted to hazard management, commensurate with the level of uncertainty in the assessment and the level of danger believed to be possible.

If there is a high degree of uncertainty and reason to believe that potentially serious negative consequences may arise, the petroleum undertaking is expected to conduct a structured scientific evaluation of the risk to safety that is as complete as possible, in order to select the most appropriate course of action to manage the risks generated by their proposed activities. The analysis needs to include an assessment of the scientific uncertainties and a description of the hypotheses used to compensate for the lack of scientific or statistical data and, where appropriate, proposals for advancing the scientific understanding such that the risk can be better understood. Assumptions made in the risk assessment about the frequencies and consequences are expected to err on the side of caution and so seek to avoid harmful effects. While the approach adopted is expected to be proportionate and consistent, under the precautionary principle, safety is expected to take precedence over economic considerations.

The hazards that are assessed in this process should not be hypothetical hazards with no evidence that they may occur. However, the hazards considered should at least include the worst-case scenario that can be realised.

The onus is on the petroleum undertaking to provide a robust case to demonstrate an acceptable level of safety in the face of significant uncertainty. Where risks presented by petroleum activities are well understood, and the supporting scientific evidence is robust, recourse to the precautionary principle is not necessary.

It is possible that the application of the precautionary principle will result in the implementation of control measures for which the cost may appear to be grossly disproportionate to the risk benefit gained. However, in the circumstances in which the precautionary principle is invoked, the uncertainty associated with the risk assessment means that it cannot be proven with sufficient certainty that the cost of the measure is grossly disproportionate to the safety benefit it brings.

4.6 Risk Reduction Measure Implementation and Lifecycle

All measures which have been assessed as being required to reduce risks to a level that is ALARP should be implemented.

There is a General Duty on petroleum undertakings to carry out their activities in a manner that makes any risk to safety ALARP and that any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in a manner that reduces risk to be ALARP. This requirement reinforces the need for the undertaking to consider ALARP at all stages of the lifecycle of petroleum infrastructure.

The need to ensure that the risk is ALARP must be considered at the beginning of the design process for an activity, namely during the concept selection stage. This requirement is important because, early in the design process, design decisions can fundamentally influence the risks. The concept and early design stages offer an opportunity to eliminate hazards and to make the petroleum infrastructure inherently safer. It is therefore important that the ALARP demonstration is considered at the concept stage of any petroleum infrastructure and throughout design and operations.

Figure 5 illustrates the impact that different risk reduction techniques can have at different stages of the lifecycle. The diagram is split into three bands. In each band the width of each risk reduction measure is a qualitative representation of the impact it can have on the overall risk.

The left-hand band shows that elimination and substitution are the most important risk reduction measures at the concept stage and that they apply more to this stage of the lifecycle than any other. Eliminating hazards and ensuring inherent safety principles are applied is vital at the concept and design stages. During the operational stage, the emphasis on further risk reduction measures is towards control, mitigation and emergency response measures, as the fundamentals of the design cannot usually be changed meaning that hazards cannot usually be eliminated.

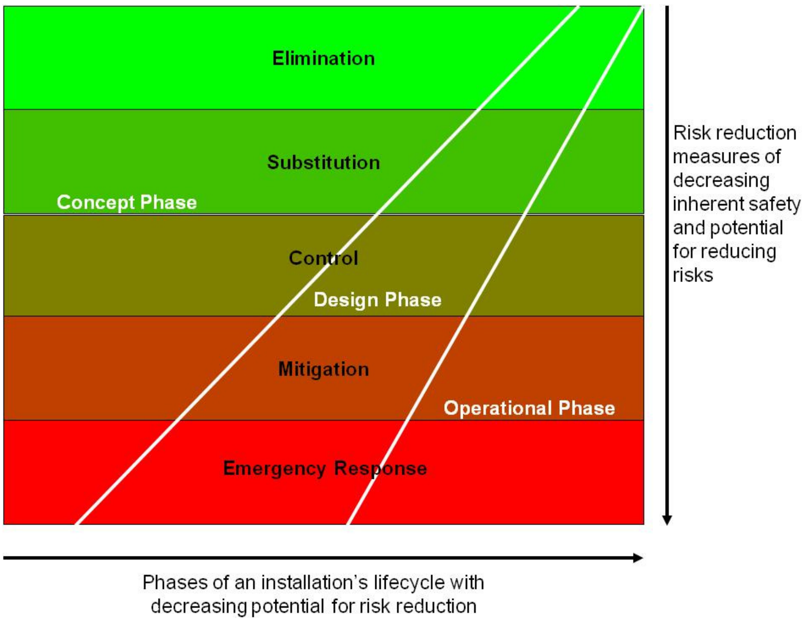

Figure 5: Risk reduction measures at different stages of the lifecycle.

As an activity progresses there is no guarantee that the risks will remain ALARP due to a number of factors including:

- Changes to the definition of Good Practice;
- Changes that may make the activity more hazardous;
- Changes in technology that allow for better hazard assessment or control of the hazard;
- Learning from mistakes or incidents;
- Learning from other operations.

Reducing risks to ALARP must be considered and re-considered throughout the lifecycle from early in the design stage through to the operational stage. It is incumbent on petroleum undertaking to continually review whether the risk remains ALARP.

5 Risk Tolerability Limits

5.1 Introduction

The ALARP principle requires that Risk Tolerability Limits are defined. This section provides guidance on these limits for both workers and members of the public as follows:

- Individual risk per annum (for workers and members of the public); and
- Societal risk per annum (in the form of an FN curve for members of the public – excluding workers).

The Risk Tolerability Limits are consistent with current practices in Ireland and internationally. While the limits provide guidance, petroleum undertakings are expected to abide by them.

5.2 Individual Risk

Individual risk is the risk to a single person. In order for any hazardous activity to be permitted, society must allow people to be exposed to some individual risk. Persons at work benefit directly from the activity and are aware of the associated hazards, whereas this generally does not apply to the public. Therefore, different individual risk limits are set for workers and the general public as set out in Table 1. A justification on why these figures are advised is given in Appendix D.

	Upper Tolerability Limit (Fatalities per year)	Lower Tolerability Limit (Fatalities per year)
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 1: Individual risk limits for workers and the general public

The limits apply to an individual risk metric that takes account of occupancy level of persons. For workers, individual risk should be calculated taking into account their normal work pattern, although a risk that is below the Upper Tolerability Limit solely because of a particular work pattern compared to a different, commonly used pattern will not be accepted.

Individual risk for the general public should be calculated on the basis of a hypothetical person occupying the nearest normally occupied building to an onshore site that is carrying out designated activities or pipeline and with means of escape. The likelihood of this hypothetical person spending time inside the building compared to time spent outside should be taken in the ratio 9:1 (also termed the occupancy level).

In addition, individual risk calculations for persons affected by the designated petroleum activities should include any Major Accident Hazard risk presented to those persons by other designated petroleum activities, as the tolerability levels apply to the cumulative risk, not just the risk from the hazard or site being considered.

5.3 Societal Risk

Major Accident Hazards have the potential to affect large numbers of people and there is a societal aversion to events that cause a large number of fatalities. Therefore, societal risk limits are defined to express a limit for the risk to groups of people who might be affected by a hazard.

Societal risk is commonly represented by a *frequency number (FN) curve,* which is a plot of cumulative frequency (likelihood) of all events with N or more fatalities. FN curves are typically plotted on a log-log scale since the frequency and number of fatalities can range over several orders of magnitude.

The FN curves that define the Tolerability Limits are shown in Figure 6 and with defining points shown in Table 2, where the risk terms have the same interpretation as in Figure 1. The FN curve that defines the upper tolerability limit has a slope of -1 and has a frequency of $2x10^{-5}$ for 50 fatalities or more. The FN curve that defines the Lower Tolerability Limit is two orders of magnitude below the Upper Tolerability Limit.

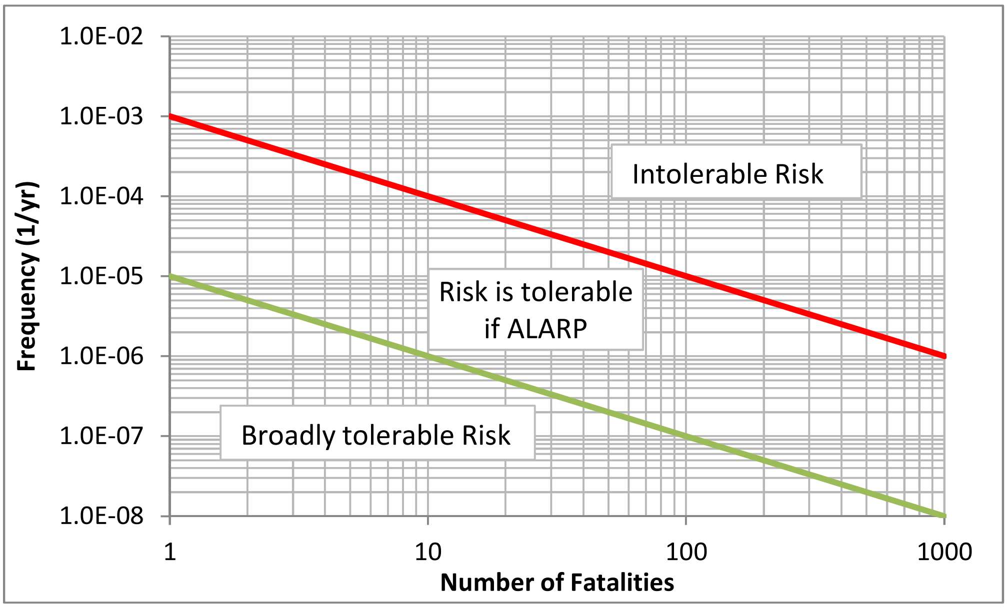

Figure 6: FN curve showing the tolerability limits for the public (excluding workers)

No. of Fatalities (≥)	Upper Tolerability Limit (per year)	Lower Tolerability Limit (per year)
1	1×10^{-3}	1×10^{-5}
10	1×10^{-4}	1×10^{-6}
50	2×10^{-5}	2×10^{-7}
100	1×10^{-5}	1×10^{-7}
1000	1×10^{-6}	1×10^{-8}

Table 2: Societal risk tolerability limits for members of the public (excluding the workforce)

The societal Risk Tolerability Levels only apply to members of the public and the workforce should not be included in this assessment. A justification on why these figures are advised is given in Appendix D.

Appendix A References

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Appendix B Defined ICAF

To assess of reasonable practicability using CBA, there is a need to set a Defined Implied Cost of Averting a Fatality (ICAF). This is compared to the calculated ICAF, which is defined as:

ICAF = Cost of measure / Reduction in Potential Loss of Life,

where the Reduction in Potential Loss of Life is the reduction in product of the frequency of events and the consequences in terms of loss of life over the lifetime of the risk reduction measure

For the purposes of this *ALARP Demonstration Guidance Document,* the CER advises that a Defined ICAF of at least **€2,400,000** at 2013 prices and index-linked.

This value is based on an existing determination made by the National Roads Authority (NRA) which is the only comparable figure which the CER found employed by another statutory agency in Ireland. The NRA has calculated accident costs and at resource costs (2009 prices and values) the cost per fatality was calculated at €2,060,099[13] which is €2,4000,000 in 2013 prices.

For example, this means that a risk reduction measure that saves a life over the lifetime of the risk reduction measure and for which the cost is not grossly disproportionate to €2,400,000 is reasonably practicable.

By way of comparison with other jurisdictions, in the UK the HSE[14] set the value of a life at £1,336,800 in 2003, which is approximately €2.25M in 2013 (assuming £1 = €1.25 and the value is increased by 3% each year for 10 years).

It is noted that the Central Expenditure Evaluation Unit (CEEU) within the Department of Public Expenditure and Reform (DPER) is in the process of developing best practice in the evaluation and implementation of programme and project expenditure within the Irish public sector within a Public Spending Code[15]. Once complete, this Public Spending Code will specify parameter values needed for the quantification of costs and conducting CBAs and it may include a value equivalent to the ICAF. If and when the CEEU specify such a figure, the CER will review the Defined ICAF figure in this guidance.

[13] See Reference [2].
[14] See Reference [3].
[15] See http://publicspendingcode.per.gov.ie/

Appendix C Gross Disproportion Factor

In CBA, the gross disproportion factor is the minimum factor between a calculated ICAF and the defined ICAF (see Appendix B) such that the CER will consider there to be gross disproportion between the cost of a risk reduction measure and the risk benefit it provides.
A figure of at least two for the Gross Disproportion Factor is required, with a robust justification required for any factor used that is less than ten.

In comparison, the UK HSE advises a gross disproportion factor of between 2 and 10, with the former applying to members of the public in a low risk situation and the latter to high risk situation[16].

A robust justification is required for values below ten because if a quantitative risk assessment is being used for the decision on whether a risk reduction measure should be implemented, as opposed to a less sophisticated type of assessment, it is clear that the decision on whether to implement cannot be easily made and, given the inherent uncertainty in any risk assessment, a larger factor is more prudent. In addition, the maximum cost of a risk reduction measure for lower risk numbers is extremely small. For example, for a risk reduction measure that reduces an individual risk of 10^{-5} per year by 10% for 10 people[17] over 10 years, the maximum cost of the risk reduction measure before it becomes grossly disproportionate to the risk reduction is €2,400 for a gross disproportion factor of 10. Therefore, the CER expect a robust justification if any value less than 10 is used.

For petroleum undertakings, the number of persons that may be exposed to any hazard is likely to be very low, far lower than say for the effects of a nuclear incident where a low risk may affect a very large number of people. Original work on the Gross Disproportion Factor in the UK was in relation to the nuclear industry and because of the large numbers of people involved, even a low individual risk may have led to a significant potential loss of life and therefore significant spend even with a relatively low disproportion factor. The CER wish to avoid a low disproportion factor being used to justify the non-implementation of a relatively low cost measure that has some risk benefit, but only to a small number of people whose individual risk is low. This supports the requirement for, a robust justification of a Gross Disproportion Factor below 10. In addition, there are safety critical systems, which are required in order to meet Good Practice, where the factor between the cost and the risk benefits is well in excess of ten, indicating that consideration of well-known hazards and associated risk reduction measures has, in some cases, used disproportion factors well in excess of those proposed here. In some cases, addition of a spare lifeboat on an offshore platform is such an example.

[16] See http://www.hse.gov.uk/risk/theory/alarpcba.htm
[17] Note that this argument does not follow if a very large number of people may be affected by the hazard as may be the case for a nuclear accident. Nuclear power is outlawed in Ireland, but forms the basis of the some of the UK risk regime, which explains some of the differences in the approaches.

Appendix D Justification of Risk Limits

D.1 Individual Risk

D.1.1 Risk Limits

Individual risk expresses the risk to a single person. The risk limits advised are shown in Table 3.

	Upper Tolerability Limit (Fatalities per year)	Lower Tolerability Limit (Fatalities per year)
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 3: Individual risk limits for workers and the general public

D.1.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH land use planning in Ireland[18] uses a risk-based methodology. For new establishments, a QRA is required to be submitted to the HSA, who will evaluate it before advising the planning authority. It must be demonstrated that the risk of fatality to an individual is less than 5×10^{-6} per year to current non-residential neighbours and less than 10^{-6} per year to the nearest residential neighbours, otherwise the HSA "advises against" the proposed development.

D.1.3 International Comparison

For land use planning criteria in the UK, the HSE propose a broadly acceptable individual risk level of one in a million (10^{-6}) per year. Similarly for land use planning in the Netherlands, safety distances have been defined in the regulations based on a 10^{-6} fatality per year individual risk criterion. Risk tolerability criteria, developed with public consultation in Western Australia, specified that a risk of 10^{-6} fatalities per year for residential areas was a risk so small as to be acceptable. An individual risk of one in a million (10^{-6}) per year is therefore seen as an acceptable level of everyday risk for the general public.

The HSE policy document *Reducing Risks Protecting People*[19] states a limit of 10^{-4} per year of fatality for people off-site (public).

HSE Offshore Information Sheet No. 3/2006[20] and HSE policy document *Reducing Risks Protecting People*[21] quote an individual risk of fatality of 10^{-3} per year for workers within the offshore industry, or other high risk industries, as the maximum tolerable individual risk.

[18] See Reference [4].
[19] See Reference [6].
[20] See Reference [5].
[21] See Reference [6].

D.2 Societal Risk

D.2.1 Risk Limits

Major Accidents have the potential to affect large numbers of people. Societal risk expresses the cumulative risk to groups of people who might be affected by such events and are represented by FN curves. The slope of the FN curve represents the degree of risk aversion to multiple fatality events. The more negative the FN curve slope then the more risk aversion is being adopted. Figure 6 in section 5 of this document and Figure 7 below shows the FN curve advised in this guidance.

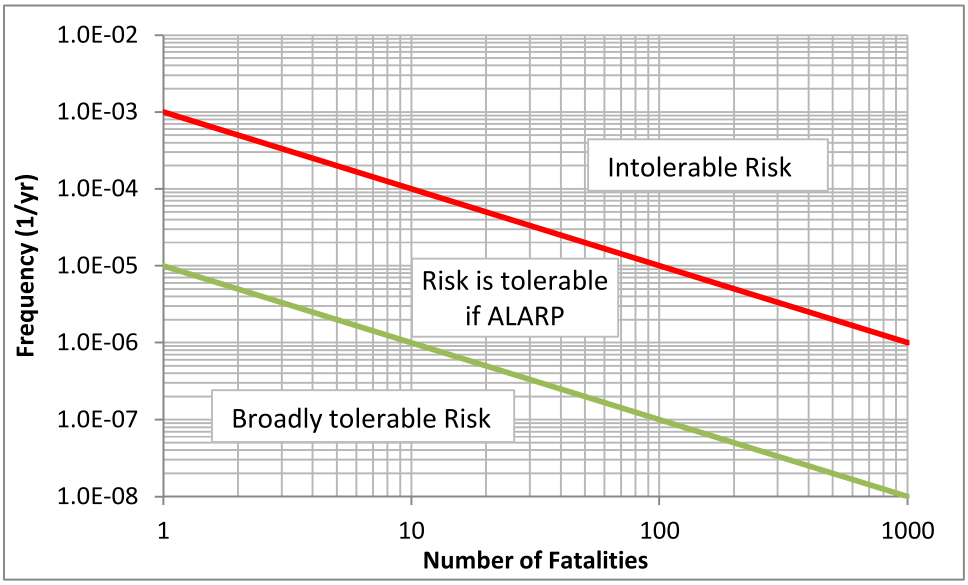

Figure 7: FN curve for the public (excluding workers)

The societal risk FN criterion presented in Figure 7 provides guidance on what CER considers to be an appropriate risk limit in relation to petroleum infrastructure in Ireland in all but exceptional circumstances. Instances where any part of the FN curve representing the societal risk to the public from a petroleum undertaking crosses the criterion for Intolerable Risk will be considered on a case-by-case basis. CER would expect the FN results to lie wholly within the criterion envelope for Intolerable Risk, but recognise the possibility that exceptional circumstances may arise where this is not the case, but where it is justified by other benefits (e.g. over-riding national interest). The limits will be reviewed and, if necessary, revised in future in the light of experience (Section 1.2) or to take account of changes in national or international practice.

D.2.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH Risk-based Land Use Planning in Ireland[22] gives a value for intolerable societal risk that would lead the HSA to advise against planning approval of 1 in 5,000 years for 50 fatalities. A value of 1 in 100,000 years for 10 fatalities represents the upper limit of what is considered to be broadly acceptable. In the "significant risk region" between these two values, the planning authority is advised of that fact in order to take it into account in their planning decision.

The HSA values are higher than implied by the FN criteria presented in Figure 7. However, the CER and HSA criteria serve different purposes. The HSA criteria are applied using a screening approach for proposed developments in the vicinity of all top tier COMAH sites (not only petroleum infrastructure), and determine the advice given by the HSA in individual cases. The role of the HSA in land use planning is to advise local authorities on proposed developments and takes the form of "advises against" or "does not advise against". The CER on the other hand is an approving authority and, based on the safety case and ALARP demonstration submitted, will determine whether or not a petroleum undertaking should be granted a permit. The CER criteria provide guidance on what CER considers to be an appropriate limit for installations in Ireland, in all but exceptional circumstances.

D.2.3 International Comparison

The UK HSE document *Reducing Risks Protecting People*[23] defines a FN curve with a slope of –1 passing through 50 fatalities with a frequency of 2×10^{-4} for maximum tolerable societal risk. In the UK, this figure includes workers at a hazardous site, whereas the CER criteria in Ireland is for members of the public only.

A range of different societal risk criteria are used worldwide. The limits proposed by the CER differ from those of the UK HSE, but are similar to those in use in some other countries. The FN criteria were specified following a process involving a review of international societal risk criteria[24] and an extensive comparison exercise to test the application of the proposed criteria to relevant examples of oil and gas installations, in the UK and other countries and also high level estimates of worldwide historical experience of incidents with large numbers of fatalities. As a result of this review, the selected FN criteria were considered appropriate and achievable for petroleum undertakings in Ireland within the regulatory remit of the CER; noting that the criteria apply to the public only and not to on-site workers (an important distinction that has a strong influence an FN curve for lower values of N).

[22] See Reference [4].
[23] See Reference [6].
[24] See Reference [8].